BS EN ISO 10218-2:2025

BSI Standards Publication

Robotics — Safety requirements

Part 2: Industrial robot applications and robot cells

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National foreword

This British Standard is the UK implementation of EN ISO 10218-2:2025. It is identical to ISO 10218-2:2025. It supersedes BS EN ISO 10218-2:2011, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AMT/10, Robotics.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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March 2025

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Robotik - Sicherheitsanforderungen für Robotersysteme in industrieller Umgebung - Teil 2: Robotersysteme, Roboteranwendungen und Integration von Roboterzellen (ISO 10218-2:2025)

This European Standard was approved by CEN on 3 January 2025.

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European foreword

This document (EN ISO 10218-2:2025) has been prepared by Technical Committee ISO/TC 299 "Robotics" in collaboration with Technical Committee CEN/TC 310 “Advanced automation technologies and their applications” the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2025, and conflicting national standards shall be withdrawn at the latest by March 2027.

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This document supersedes EN ISO 10218-2:2011.

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

For the relationship with EU Legislation, see informative Annex ZA, which is an integral part of this document.

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Annex ZA
(informative)

Relationship between this European Standard and the essential requirements of Directive2006/42/EC aimed to be covered

This European Standard has been prepared under a Commission's standardization request "M/396 Mandate to CEN and CENELEC for Standardisation in the field of machinery" to provide one voluntary means of conforming to essential requirements of Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast).

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding essential requirements of that Directive, and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Annex I of Directive 2006/42/EC

The relevant Essential Requirements of Directive 2006/42/EC	Clause(s)/sub-clause(s) of this EN
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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 second edition cancels and replaces the first edition (ISO 10218-2:2011), which has been technically revised.

The main changes are as follows:

— emphasising robot application and not robot system, as the robot application includes the workpieces, task program, and the machinery and equipment to support the application and intended tasks;

— incorporating safety requirements for collaborative applications (formerly, the content of ISO/TS 15066);

— clarifying requirements for functional safety;

— adding requirements for cybersecurity to the extent that it applies.

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.

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Introduction

This document has been created in recognition of the hazards that are presented by robots when they are integrated and installed with end-effectors into robot applications and robot cells. ISO 10218-1 addresses robots as partly completed machinery, while this document addresses robots integrated into completed machinery for specific robot applications.

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 safety of robot applications and robot cells:

— 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 at the drafting process of this document.

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

When provisions of a type-C standard are different from those which 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.

Hazards associated with robot applications are well recognized, but the sources of the hazards are frequently unique to each robot application. The number and type(s) of hazard(s) are directly related to the nature of the automation process and the complexity of the application. The risks associated with these hazards vary with the robot used, its safety functions, and the integration, installed, programs, use, and maintenance. This document provides requirements for safety in the integration of robots into robot applications and robot cells. The requirements include safeguarding of operators during integration, commissioning, functional testing, programming, operation, maintenance and repair. Requirements for the robot can be found in ISO 10218-1.

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

There are a broad range of robot applications and robot cell(s). Therefore, it is not possible to provide a list of all significant hazards, hazardous situations or events into which a robot application can be integrated. Moreover, the same kind of applications can have different levels of risk, resulting from different designs which correspond to the intended application (e.g. paint spraying on large or small parts, handling of a small harmful payload like a hot metal bolt or a large harmless payload like a box of paper tissues).

Other standards can be applicable to associated machinery and equipment in robot applications and robot cells.

For ease of reading this document, the words “robot”, “robot system” and “robot application” refer to “industrial robot”, “industrial robot system” and “industrial robot application” as defined in ISO 10218-1 and this document.

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This document has been updated based on experience gained since the release of the first edition of ISO 10218-2 in 2011. This document remains aligned with minimum requirements of a harmonized type-C standard for robot applications and robot cells in an industrial environment. Providing for a safe robot application and a safe robot cell depends on the cooperation of a variety of “stakeholders”. Stakeholders can include designers, manufacturers, suppliers and integrators. Users are the entity responsible for using robot applications and robot cells. Users can also be any of the other stakeholder roles.

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 this document. Safety functions that enable a collaborative application can be part of the robot (e.g. PFL), or can be provided by a protective device, or a combination.

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

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Robotics — Safety requirements —

Part 2: Industrial robot applications and robot cells

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document specifies requirements for the integration of industrial robot applications and industrial robot cells. The following are addressed:

— the design, integration, commissioning, operation, maintenance, decommissioning and disposal;

— integration of machines and components;

— information for use for the design, integration, commissioning, operation, maintenance, decommissioning and disposal.

This document is not applicable to the following uses and applications of industrial robots:

— underwater;

— law enforcement;

— military (defence);

— airborne and space, including outer space;

— medical;

— healthcare of a person;

— prosthetics and other aids for the physically impaired;

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

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

— lifting or transporting people;

— multi-purpose lifting devices or machinery, e.g. cranes, forklift trucks.

NOTE Applications for the automation of laboratories are not considered as medical or healthcare of a person.

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 integrator.

This document provides basic requirements for industrial robot applications, but does not cover the hazards related to the following:

— emission of airborne noise;

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

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— underground use;

— use that has hygienic requirements;

— processing of any material (e.g. food, cosmetics, pharmaceutical, metal);

— use in nuclear environments;

— use in potentially explosive environments;

— mobility when robots or manipulators are integrated with driverless industrial trucks;

— mobility when robots or manipulators are integrated with mobile platforms;

— use in environments with hazardous ionizing and non-ionizing radiation levels;

— hazardous ionizing and non-ionizing radiation;

— handling loads the nature of which could lead to dangerous situations (e.g. molten metals, acids/bases, radiating materials);

— when the public or non-working adults have access.

Emission of acoustic noise could be identified to be a significant hazard, but emission of noise is not covered in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of 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 8995-1:2002, *Lighting of work places — Part 1: Indoor*

ISO/CIE 8995-3:2018, *Lighting of work places — Part 3: Lighting requirements for safety and security of outdoor work places*

ISO 10218-1:2025, *Robotics – Safety requirements – Part 1: Industrial robots*

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*

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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 13854:2017, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body*

ISO 13855:2010, *Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body*

ISO 13856:2013, *Safety of machinery — Pressure-sensitive protective devices*

ISO 13857:2019, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs*

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 14122:2016, *Safety of machinery — Permanent means of access to machinery*

ISO 14738:2002, *Safety of machinery — Anthropometric requirements for the design of workstations at machinery*

ISO 15534-1:2000, *Ergonomic design for the safety of machinery — Part 1: Principles for determining the dimensions required for openings for whole-body access into machinery*

ISO 15534-2:2000, *Ergonomic design for the safety of machinery — Part 2: Principles for determining the dimensions required for access openings*

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, *+ AMD1:2021, 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 60825-1:2014, *Safety of laser products — Part 1: Equipment classification and 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 61000-6-7:2014, *Electromagnetic compatibility (EMC) — Part 6-7: Generic standards — Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*

IEC 61310:2007, *Safety of machinery — Indication, marking and actuation*

IEC 61496-1:2020, *Safety of machinery — Electro-sensitive protective equipment — Part 1: General requirements and tests*

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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 62046:2018, *Safety of machinery — Application of protective equipment to detect the presence of persons*

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

3 Terms, definitions, symbols 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, robot cell - related

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)* (3.1.2.7), programmable in three or more *axes* (3.1.2.1), which can be either fixed in place or fixed to a *mobile platform* (3.1.2.10) 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* (3.1.2.7), including *robot actuators* (3.1.2.12) 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* (3.1.2.10) with an integrated *manipulator* (3.1.2.7) or robot.

3.1.1.3
industrial robot system
robot system
industrial robot (3.1.1.2), an *end-effector(s)* (3.1.2.3), 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* (3.1.4.1), and machinery and equipment to support the *application* (3.1.1.5) and the intended task(s)

Note 1 to entry: The *application* (3.1.1.5) can be a *collaborative application* (3.1.1.6).

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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
application (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)* (3.1.7.3) are within the same *safeguarded space* (3.1.9.6)

3.1.1.8
robot cell
industrial robot cell
one or more *robot applications* (3.1.1.4), any obstacle or object that has influence on the risk assessment of the intended use and associated *safeguarded space(s)* (3.1.9.6) and *safeguards* (3.1.10.2)

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
additional axis
axis (3.1.2.1) that is not part of the *manipulator* (3.1.2.7)

Note 1 to entry: Additional axis includes any auxiliary axis as described in ISO 10218-1:2025, 5.1.9.

3.1.2.3
end-effector
device specifically designed for attachment to the *mechanical interface* (3.1.2.9) 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
fixture
device used to hold in position an item as part of the handling or assembling process in a *robot application* (3.1.1.4), but not as an *end-effector* (3.1.2.3)

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3.1.2.6
manual load/unload station
part of the *robot application* (3.1.1.4) designed for the direct manual intervention for the placement and removal of parts or workpieces for processing by the *robot application* (3.1.1.4)

3.1.2.7
manipulator
mechanism consisting of an arrangement of segments, jointed or sliding relative to one another

Note 1 to entry: *Robot actuators* (3.1.2.12) can constitute parts of a *manipulator*.

3.1.2.8
mass per manipulator
M
mass of all moving parts of the *manipulator* (3.1.2.7)

3.1.2.9
mechanical interface
mounting surface at the end of the *manipulator* (3.1.2.7) to which the *end-effector* (3.1.2.3) is attached

3.1.2.10
mobile platform
assembly of the components which enables locomotion and provides the structure by which to affix or integrate a *manipulator* (3.1.2.7) or *robot* (3.1.1.2)

3.1.2.11
payload
mass of all that is attached to the *manipulator* (3.1.2.7), 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* (3.1.2.9) of the *robot* (3.1.1.2).

3.1.2.12
robot actuator
powered mechanism that converts energy to effect motion

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

3.1.2.13
tool centre point
TCP
point defined for a given *application* (3.1.1.5) relative to the *mechanical interface* (3.1.2.9) coordinate system

Note 1 to entry: The TCP setting defines the location of the TCP relative to the *mechanical interface* (3.1.2.9).

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 is referred to as a portable control station].

Note 2 to entry: The portable or hand-held control station for a *robot* (3.1.1.2) is referred to as a *teach pendant* (3.1.3.3).

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

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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.

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
local control
state of the system or portions of the system in which operation is effected from a *control station* (3.1.3.1) or *teach pendant* (3.1.3.3) of the individual machine(s) or portions of the machine(s)

Note 1 to entry: An *operator* (3.1.7.3) using the local control(s) usually has a direct view of the *robot cell* (3.1.1.8).

3.1.3.5
span-of-control
predetermined portion of the *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).

3.1.3.6
simultaneous motion
motion, of two or more *robots* (3.1.1.2) at the same time under the control of a single robot control, which can be coordinated or can be synchronous

3.1.3.7
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* (3.1.7.3).

[SOURCE: ISO 10218-1:2025, 3.1.3.6]

3.1.3.8
mode
operating mode
characterization of the way and the extent to which the *operator* (3.1.7.3) interacts with the control equipment

Note 1 to entry: Mode refers to the control state, e.g. *manual mode* (3.1.3.9), *automatic mode* (3.1.3.10).

3.1.3.9
manual mode
control state that allows control directly by an *operator* (3.1.7.3)

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

3.1.3.10
automatic mode
control state that allows executing programmed tasks

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3.1.4 Program-related

3.1.4.1
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 by the *integration* (3.1.7.1) or use.

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

3.1.4.2
teach
programming of the task manually by positioning of the *manipulator* (3.1.2.7), or by using a *teach pendant* (3.1.3.3) to move the *robot* (3.1.1.2) through the desired 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).

3.1.4.3
program verification
execution of a *task program* (3.1.4.1) for confirming the robot path and process performance

Note 1 to entry: Program verification can include the total path traced by the *tool centre point* during the execution of a *task program* (3.1.4.1) 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 of existing *applications* (3.1.1.5).

3.1.5 Power-, energy-related

3.1.5.1
drive power
energy enabling the *robot actuators* (3.1.2.12) 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, modified — Note 3 has been deleted.]

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

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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 the *application* (3.1.1.5).

3.1.7.2
integrator
entity that designs, provides, manufactures, or assembles *robot applications* (3.1.1.4) or *robot cells* (3.1.1.8) and oversees the safety strategy, including the *protective measures* (3.1.10.1), control interfaces and interconnections of the control system(s)

Note 1 to entry: The integrator can be referred to as the "manufacturer" of the supplied *robot application* (3.1.1.4) or *robot cell* (3.1.1.8). The role of the integrator can be provided by the manufacturer, assembler, engineering company or the *user* (3.1.7.4).

3.1.7.3
operator
person using, operating, adjusting, maintaining, cleaning, repairing, troubleshooting, transporting, commissioning and disassembling

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

3.1.7.4
user
entity that uses *robot applications* (3.1.1.4) and *robot cells* (3.1.1.8) and is responsible for the *operator(s)* (3.1.7.3) 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)

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

3.1.8.2
emergency stop
emergency stop function
function which 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

[SOURCE: ISO 12100:2010, 3.40]

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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
space
three-dimensional volume

Note 1 to entry: See Annex B for illustrations of *spaces*.

3.1.9.2
maximum space
space (3.1.9.1) 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* refers to the *robot application* (3.1.1.4) which includes the *space* (3.1.9.1) reached by the *end-effector* (3.1.2.3) and workpiece(s).

Note 2 to entry: In the context of *mobile platforms* (3.1.2.10), *maximum space* is indeterminate.

3.1.9.3
operating space
portion of the *restricted space* (3.1.9.4) that is used while performing all motions commanded by the *task program* (3.1.4.1)

Note 1 to entry: In the context of this document, *operating space* refers to the *robot application* (3.1.1.4) which includes the *space* (3.1.9.1) reached by the *end-effector* (3.1.2.3) and workpiece(s).

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3.1.9.4
restricted space
portion of the *maximum space* (3.1.9.2) restricted by *limiting devices* (3.1.9.5)

Note 1 to entry: When the *restricted space* refers to the *robot system* (3.1.1.3), this includes the *space* (3.1.9.1) reached by the *end-effector* (3.1.2.3).

Note 2 to entry: When the *restricted space* refers to the *robot application* (3.1.1.4), this includes the *space* (3.1.9.1) reached by the *end-effector* (3.1.2.3) and workpiece(s).

3.1.9.5
limiting device
limiting function
means that reduces the range of motion to a portion of the *maximum space* (3.1.9.2), resulting in the *restricted space* (3.1.9.4)

Note 1 to entry: The ISO 12100:2010 definition of a *limiting device* is broader, encompassing more than motion. In ISO 12100, it is a device that prevents a machine or hazardous machine condition(s) from exceeding a designed limit (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* (3.1.10.2).

3.1.9.6
safeguarded space
space (3.1.9.1) where *safeguards* (3.1.10.2) are active or where the *perimeter safeguard* (3.1.10.3) 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.

3.1.9.7
hazard zone
any *space* (3.1.9.1) within and/or around machinery in which a person can be exposed to a *hazard* (3.1.6.1)

[SOURCE: ISO 12100:2010, 3.11]

3.1.9.8
task zone
any predetermined *space* (3.1.9.1) within and/or around the *robot application* (3.1.1.4) in which *operators* (3.1.7.3) can perform a specified activity

3.1.9.9
detection zone
zone within which a specified test piece will be detected by the *sensitive protective equipment* (3.1.10.6)

Note 1 to entry: The *detection zone* can also be a point, line or plane.

[SOURCE: IEC 61496-1:2020, 3.4, modified — addition of the note to entry and deletion of “electro-” before “sensitive”]

3.1.9.10
separation distance
shortest permissible distance between any moving hazardous part of the *robot application* (3.1.1.4) and any *operator* (3.1.7.3)

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

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3.1.10 Risk reduction measures

3.1.10.1
protective measure
measure intended to achieve risk reduction, implemented

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

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

[SOURCE: ISO 12100:2010, 3.19]

3.1.10.2
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 by which to reduce or control risks, for example:

— interlocking devices for guards,

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

— *safety functions* (3.1.8.1) that replace a *protective device* (3.1.10.5),

— *limiting devices* (3.1.9.5),

— limited movement control device.

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

3.1.10.3
perimeter safeguard
safeguard (3.1.10.2) that surrounds one or more *safeguarded space(s)* (3.1.9.6)

Note 1 to entry: A perimeter safeguard can encompass portion(s) of or an entire *robot application* (3.1.1.4), *robot cell* (3.1.1.8) or machine, and can consist of guards and *protective devices* (3.1.10.5).

3.1.10.4
impeding device
any physical obstacle (low barrier, rail, fixture, etc.) which, without totally preventing access to a *hazard zone* (3.1.9.7), reduces the probability of access to this zone by offering an obstruction to free access

[SOURCE: ISO 12100:2010, 3.29, modified — “fixture” has been added.]

3.1.10.5
protective device
safeguard (3.1.10.2) 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 which generates an appropriate signal to the control system to reduce risk to the persons detected

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

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3.1.10.7
presence-sensing device
PSD
sensitive protective equipment (3.1.10.6) that creates a sensing field, area or plane for detecting the presence of a body part or the whole of a person

Note 1 to entry: *Pressure-sensitive protective devices* (3.1.10.9) can be used as tripping devices as well as presence-sensing devices, as mentioned in ISO 12100:2010, 3.28.5 NOTE to entry.

[SOURCE: ISO 13856-3:2013, 3.2]

3.1.10.8
electro-sensitive protective equipment
ESPE
assembly of devices and/or components working together for protective tripping or presence-sensing purposes and comprising at a minimum:

— a sensing device;

— controlling/monitoring devices;

— output signal switching devices and/or a safety-related data interface

Note 1 to entry: The safety-related control system associated with the ESPE, or the ESPE itself, can further include a secondary switching device, muting functions, stopping performance monitor, etc. (see Annex A).

Note 2 to entry: A safety-related communication interface can be integrated in the same enclosure as the ESPE.

[SOURCE: IEC 61496-1:2020, 3.5 modified — “may” changed to “can” in Note 1 to entry.]

3.1.10.9
pressure-sensitive protective device
PSPD
sensitive protective equipment (3.1.10.6) of the “mechanically activated trip” type intended to detect the touch of a person or body part of a person

Note 1 to entry: A *pressure-sensitive protective device* consists of a sensor or sensors, which generates a signal when pressure is applied to part of its outer surface, and a control unit, which responds to the signal from the sensor and generates an output signal(s) to the control system of a machine.

Note 2 to entry: *Pressure-sensitive protective devices* can be used as tripping devices as well as *presence-sensing devices* (3.1.10.7), as mentioned in ISO 12100:2010, NOTE in 3.28.5.

Note 3 to entry: For the definitions of *sensitive protective equipment* (3.1.10.6) and *impeding device* (3.1.10.4), see ISO 12100:2010, 3.28.5 and 3.29, respectively.

[SOURCE: ISO 13856-3:2013, 3.1]

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 — Notes 1, 2, 3 to entry have been deleted and a new Note 1 to entry has been added.]

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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 — Note 1 to entry has been added.]

3.1.12 Contact-related

3.1.12.1
body model
representation of the human body consisting of individual body segments characterized by biomechanical properties

3.1.12.2
compliant
exhibiting deformation of material or mechanism when subjected to a force

Note 1 to entry: The reciprocal of stiff (e.g. compliant linkage, compliant surface).

3.1.12.3
quasi-static contact
contact to an *operator* (3.1.7.3) from moving part(s) of a *robot application* (3.1.1.4), where the body part can be clamped between a moving part of the *robot application* (3.1.1.4) and another fixed or moving part of the *application* (3.1.1.5)

Note 1 to entry: This includes contact from the *manipulator* (3.1.2.7), moving parts attached to the *manipulator* (e.g. cables, hoses), *end-effector* (3.1.2.3), and workpiece.

3.1.12.4
transient contact
brief contact to an *operator* (3.1.7.3) from moving part(s) of a *robot application* (3.1.1.4) where the body part is not clamped and can recoil or retract from the moving part of the *robot application* (3.1.1.4)

Note 1 to entry: This includes contact from the *manipulator* (3.1.2.7), moving parts attached to the *manipulator* (3.1.2.7) (e.g. cables, hoses), *end-effector* (3.1.2.3), and workpiece.

3.2 Abbreviated terms and symbols

Abbreviated term or symbol	Term	Occurrence
2D/ 3D	Two-dimensional / three-dimensional	4.2
3P	Three-position [enabling device]	5.7.6, 5.7.7
A	Surface area (2-dimensional) of contact	Annex M, M.1, M.2, M.3.4, Figure M.2, Formulae M.1, M.5, M.6
A	Ampere, unit of electrical current	Annex C, Table C.2
A1	Avoidable	Annex C, C.2.1.4.1, Annex E, Tables C.7, E.1, E.2, E.5
A2	Reasonably avoidable	Annex C, C.2.1.4.1, Annex E, Tables C.7, E.1, E.2, E.5
A3	Not avoidable	Annex C, C.2.1.4.1, Annex E, Tables C.7, E.1, E.2, E.5
AIS	Abbreviated Injury Scale	Annex M, M.3.1, Table M.2, footnote b
AIS 1	Abbreviated Injury Scale 1	Annex M, M.3.1, Table M.2, footnote b

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Abbreviated term or symbol	Term	Occurrence
AOPD	Active Opto-electronic Protective Device	5.8.6.1, 5.8.10, Annex J, J.2.3, J.2.9, Annex K, K.2.3, Figures J.4, J.5, J.6, K.3,
AOPDDR	Active Opto-electronic Protective Devices Responsive to Diffuse Reflection	5.8.6.1, Annex J, J.2.9, Annex K, K.2.3, Figures J.7, K.4,
AP	Possibility of avoidance	Annex C, C.2.1.4.1, C.2.1.4.2, Tables C.6, C.7
Av	Probability of avoiding or limiting harm, denoted as Av1, Av3 or Av5	Annex E, E.2.2; Tables E.1, E.3, E.4; Formula E.1
C	Intrusion distance	5.8.9.1, Annex L, Formula L.1, Figure L.1
°C	Degrees in Celsius, unit of temperature	Annex C, Table C.2
cm	Centimetre, unit of distance	Annex N, Figure N.6,
Cat.	Category, as in stop category or functional safety architecture, denoted as B, 1, 2, 3, or 4	5.5.3, Annex C, C.1, Annex D, Annex E, E.2.1, Tables D.1, E.2
CL	Claim Limit (of a SIL)	Annex E, E.2.2, Table E.4
CNC	Computer numerical control machine	Annex D, Table D.1
D	Distance	Annex L, Figure L.1
D	Dominant body side	Annex M, Table M.1
D	Duration of a single exposure in minutes	Annex C, C.2.1.3.4, Formula C.1
DCavg	Average diagnostic coverage	5.5.3
DL	[Harm/] Damage likelihood	Annex C, C.2.1.3.5.4, Table C.5
E	Transfer energy	Annex M, Table M.5, Formulae M.1, M.2
E	Exposure (to a hazard)	Annex C, C.2.1.3.4, Formula C.1
E0	Exposure prevented	Annex E, E.2.3, Tables E.1, E.5
E1	Low exposure to hazard	Annex C, C.2.1.3.2, Annex E, Tables E.1, E.2, E.5
E2	High exposure to hazard	Annex C, C.2.1.3.2, Annex E, Tables E.1, E.2, E.5
EMC	Electromagnetic compatibility	5.5.10
EOAT	End-of-arm tooling	3.1.2.3
ESPE	Electro-sensitive protective equipment	3.1.10.8, 5.8.1, 5.8.6.1, 5.8.9.1, Annex J, J.2.6, Annex K, K.1, K.2.3, Annex L, Figure L.2
F	Frequency, denoted as F1 or F2	Annex C, C.2.1.3.4, Formula C.1, Annex E, Formula E.1
Fr	Frequency and duration of exposure, denoted as Fr3 or Fr5	Annex E, E.2.2, Tables E.3, E.4, Formula E.1
F_{max}	Threshold force, quasi-static contact	Annex M, Table M.2, Annex N, N.2.4.6, Figure N.7, Formulae M.1, M.6
F_T	Threshold force, transient contact *(multiplier of quasi-static force)*	Annex M, Annex N, N.2.4.6, Table M.3, Figure N.7, Formulae M.2, M.5
F_{SA}	Actual maximum force, quasi-static contact	Annex N, N.2.4.6, Figure N.7
F_{TA}	Actual maximum force, transient contact	Annex N, N.2.4.6, Figure N.7
F_{Trig}	Trigger force	Annex N, N.2.4.6
h	Hour	5.5.2, 5.5.3, Annex C, Table C.1, Table C.3
H	1 000 mm minimum height of impeding device	Annex J, Figure J.6
HFT	Hardware fault tolerance	5.5.2, 5.5.3, Annex D, Table D.1

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Abbreviated term or symbol	Term	Occurrence
HGC	Hand-guided control	4.3.1, 5.5.7.1, 5.14.3, 5.14.4, 5.14.4.1, 5.14.4.2, Annex C, Annex I, I.3.1, Table C.1, Figure I.1
HP	Hazard perception	Annex C, C.2.1.4.2, C.2.1.4.3, C.2.1.4.4; Tables C.6, C.7
Hz	Hertz, unit of alternating current or electromagnetic wave frequency	Annex N, N.1.4
I/O	Input(s)/Output(s)	Annex F, Table F.1
IH	Incident history	Annex C, C.2.1.3.5.4, Table C.5
IMS	Integrated manufacturing system	5.3.1, 5.3.5
J	Joule, unit of energy	Annex M, Table M.4
K	Effective spring constant (stiffness) for a specific body region	Annex M, Table M.3 Formulae M.1, M.2, M.5, M.6, Annex N, N.1.1, N.1.5, N.5.2, Table N.1, Figure N.1
kg	Kilogram, unit of mass	Annex M, Table M.3, Annex N, Table N.1
kHz	Kilohertz, unit of alternating current or electromagnetic wave frequency	Annex N, N.1.4
kPa	Kilopascal, unit of pressure and stress	Annex C, Table C.2
lx	Lux, unit of light intensity per unit of area	5.15.4, Annex H
M	Mass per manipulator	3.1.2.8, Annex M, Figure: M.3, Formula: M.4
m	Metre, unit of distance	7.5.19, Annex L, L.2
m_H	Effective mass of the human body region and the effects of that body region being connected to other body regions	Annex M, Annex N, M.3.4, M.3.4.1, N.2.4.1.2, Tables : M.3, N.1 Figure: M.2, Formula: M.3
m_L	Effective mass of the payload for the robot application (specified maximum payload of the application)	Annex M, M.3.4, Figures: M.2, M.3, Formula M.4
m_R	Effective mass of the moving parts of the robot as a function of robot posture and motion	Annex M, M.3.4, M.3.4.1, Table M.2, Figures: M.4, Formulae: M.3, M.4
mA	Milliampere, unit of electrical current	Annex C, Table C.2
mm	Millimetre, unit of distance	3.1.8.6, 5.5.6.1, 5.5.6.2, 5.7.2.3.2, 5.7.7.2, 5.8.5.1, 5.12.2.1, 5.12.2.2, Annex M, Annex N, Table M.5, Table N.1
$MTTF_D$	Mean time to failure dangerous	5.5.3
N	Newton, unit of force	Annex C, Table C.2, Annex M, Annex N, Figure N.6, N.7, N.8
ND	Non-dominant body side	Annex M, Table M.1
n_{op}	Mean number of annual operations	Annex D, Table D.1
Nr	Factor for the number of persons exposed	Annex C, C.2.1.3.4, Formula C.1
O1	Probability of occurrence – low	Annex C, C.2.1.3.5.1, Annex E, E.2.1, Tables: C.5, E.1, E.2
O2	Probability of occurrence – medium	Annex C, C.2.1.3.5.1, Annex E, E.2.1, Tables: C.5, E.1, E.2
O3	Probability of occurrence – high	Annex C, C.2.1.3.5.1, C.2.1.3.5.2, Annex E, E.2.1, Tables: C.5, E.1, E.2
OS	Operator skill / information	Annex C, C.2.1.4.2, Tables: C.6, C.7
P_{max}	Threshold pressure, quasi-static contact	Annex M, Annex N, M.3.4.1, N.2.4.6, Table M.2, Figure N.7, Formulae: M.1, M.6

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Abbreviated term or symbol	Term	Occurrence
P_T	Threshold pressure, transient contact, a multiplier of quasi-static pressure	Annex M, Annex N, N.2.4.6, Table M.2, Figure N.7, Formula M.5
P_{SA}	Actual maximum pressure, quasi-static contact	Annex N, N.2.4.6, Figure N.7
P_{TA}	Actual maximum pressure, transient contact	Annex N, N.2.4.6, Figure N.7
P_{Trig}	Trigger pressure	Annex N, N.2.4.6
PFH	Average frequency of a dangerous failure per hour	5.5.2, 5.5.3, Annex D, Table D.1
PFL	Power and force limiting	4.3.1, 5.5.6.1, 5.7.7, 5.9.4, 5.14.3, 5.14.4.1, 5.14.5.1, 5.14.6, 5.14.6.1, 5.14.6.3, Annex B, Figure B.6, Annex C, Annex I, Annex J, Annex M, Annex N, I.3.2, J.2.1, M.1, M.2, M.3.2, N.1.1, N.2.1, N.4, N.4.3, Table C.1, Figure I.2,
PFMD	Pressure and/or Force Measuring Device	Annex M, Annex N, M.3.4, N.1.1, N.1.2, N.2.3, N.2.4, N.2.4.1.1, N.2.4.1.2, N.2.4.2, N.2.4.3, N.2.4.4, N.4.2, N.5, N.5.2, N.5.3, N.5.4, Figures: N.1, N.2, N.3, N.4
PL	Performance Level, denoted as PL a, PL b, PL c, PL d or PL e	4.1, 5.5.2, 5.5.3, Annex C, C.1, Annex D, Annex E, E.1, E.2, Tables: C.1, D.1, E.1 (footnote), E.2, E.5
PL_r	Required Performance Level	4.1, 5.5.3, Annex C, Annex E, Annex I, C.1, E.1, E.2.1, E.2.3, I.3.2, Tables: C.1, E.1 (footnote), E.2, E.5
PLC	Programmable logic controller	Annex D, Table D.1
PPE	Personal protective equipment	Annex I, I.2.3
Pr	Probability of occurrence of hazardous event, denoted as Pr1, Pr2 or Pr3	Annex E, E.1, E.2.2, Tables: E.1, E.3, E.4, Formula E.1
PSD	Presence-sensing device	3.1.10.7,
psi	Pounds per square inch, unit of pressure and stress	Annex C, Table C.2
PSPD	Pressure-sensitive protective device	3.1.10.9
PTFE	Polytetrafluoroethylene	Annex N
s	Second, unit of time	3.1.8.6, 5.5.6.2, 5.5.6.2, 5.7.2.3.2, 7.5.19, Annex C, Table C.2, Annex M, Annex N, Table M.5, Figure N.6, N.7, N.8
S1	Severity parameter – minor	Annex C, C.2.1.2.1, Annex E, E.1, E.2.1, Tables: C.2, E.1, E.2, E.5
S2	Severity parameter – moderate	Annex C, C.2.1.2.1, Annex E, E.1, E.2.1, Tables: C.2, E.1, E.2, E.5
S3	Severity parameter – serious	Annex C, Annex E C.2.1.2.1, E.1, E.2.1; Tables: C.2, E.1, E.2, E.5
S4	Severity parameter – catastrophic	Annex C, C.2.1.2.1, Annex E, E.1, E.2.1, Tables: C.2, E.1, E.2
Se	Severity, denoted as Se1, Se2, Se3 or Se4	Annex E, Tables: E.1, E.4
S_h	Contribution to the separation distance attributable to the operator's change in location until the robot application has stopped	Annex L, Figure L.1, Formulae: L.1, L.2, L.3
S_p	Separation distance	Annex L, Figure L.1, Formula L.1, Figure L.1
S_r	Contribution to the separation distance attributable to the robot application reaction time	Annex L, Figure L.1, Formulae: L.1, L.4, L.5
S_s	Contribution to the separation distance that occurs while the robot application is stopping until it stops	Annex L, Figure L.1, Formulae: L.1, L.6

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Abbreviated term or symbol	Term	Occurrence
Shore A	Shore A, unit of measurement of the hardness of a material, i.e., resistance to indentation, obtained by use of a shore durometer	Annex N, Table N.1
SIL	Safety Integrity Level, denoted as SIL 1, SIL 2, or SIL 3	4.1, 5.5.2, 5.5.3, Annex C, C.1, Annex D, Annex E, E.1, E.2.2, Tables: C.1, D.1, E.1 (footnote), E.3, E.4
SPE	Sensitive protective equipment	3.1.10.6, 5.8.4, 5.8.6.2, 5.8.6.3, 5.8.8, 5.12.2.3, Annex B, Figure B.5, Annex J, J.2.3, J.2.8, J.2.9, Figure J.3, J.4, J.5
SR	System robustness	Annex C, C.2.1.3.5.4, Table C.5
SRP/CS or SCS	Safety-related part of the control system	5.5.1, 5.5.2, 5.5.3, Annex F, Table F.1, Annex J, Figure J.4
SSM	Speed and Separation Monitoring	4.3.1, 5.14.3, 5.14.4.1, 5.14.5, 5.14.5.1, 5.14.5.2, Annex C, Annex F, Annex L, L.2, L.3, Tables: C.1, F.1, Figure L.1, L.2
t* or *T	Time	Annex C, Annex L, Table C.3, Figure L.1
T*, *dt	Time (T) and the differential for the integration variable (dt)	Annex L, Figure L.1, Formulae: L.2, L.3, L.4, L.5, L.6
t_0	Present or current time	Annex L, Figure L.1, Formulae: L.2, L.4, L.5, L.6
T_r	Reaction time of the robot application, excluding the time for the robot application to come to a stop	Annex L, Figure L.1, Formulae: L.2, L.3, L.4, L.5, L.6
T_s	Stopping time of the robot application, from the activation of the stop command until the robot application has stopped	Annex L, Figure L.2, Formulae: L.2, L.3, L.6
T_{trig}	Trigger time	Annex N, N.2.4.6
TCP	Tool centre point	3.1.2.13, 5.2.14, 5.9.6, 7.5.8, Annex L, L.2
TCP/UDP	Transmission control protocol/ user datagram protocol, describing types of ports for transmission or receipt of data	5.2.16
μ	Reduced mass of the two-body system	Annex M, Formulae: M.2, M.3, M.5, M.6
V	Volt, unit of electric potential or electromotive force	Annex A, Table A.1
V	Velocity	Annex L, Figure L.1, Formulae: L.2, L.4, L.5, L.6
v_h	Directed speed of an operator in the safeguarded space in the direction of the moving part of the robot application	Annex L, Figure L.1, Formula L.2
v_r	Directed speed of the robot application in the direction of an operator in the safeguarded space	Annex L, Figure L.1, Formulae: L.4, L.5
v_s	Speed of the robot application during stopping, from the activation of the stop command until the robot application has stopped	Annex L, Figure L.1, Formula L.6
v_{rel}	Relative speed between moving parts of the robot application and human body region	Annex M, Figure M.2, Formula M.2
$v_{rel,max}$	Maximum relative speed between moving parts of the robot application and human body region	Annex M, Figure M.4, Formula M.6
VBPD	Vision-Based Protective Devices	5.8.6.1
ω	Rotational speed	Annex M, Figure M.3
Z_d	Position uncertainty of the operator as measured by the PSD, resulting from the accuracy of the sensing system measurement	Annex L, Figure L.1, Formula L.1

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Abbreviated term or symbol	Term	Occurrence
Z_r	Position uncertainty of the robot application, resulting from the accuracy of the robot application position measurement system	Annex L, Figure L.1, Formula L.1

4 Risk assessment

4.1 General

A risk assessment in accordance with ISO 12100:2010 shall be performed for the robot application(s) and if applicable, the robot cell(s).

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 robot applications and robot cells, including end-effectors and manual load/ unload stations.

NOTE 3 Annex C contains safety function performance requirements with a choice of using the listed performance or performing a risk assessment using the parameters and thresholds of C.2 for risk estimation.

NOTE 4 Annex E contains examples for determining the PL_r or required SIL when the risk estimation parameters of C.2 are used. See 5.3.

NOTE 5 See IEC 60812:2018 for information about failure mode and effects analysis.

NOTE 6 For practical guidance on conducting risk assessment for machinery in accordance with ISO 12100:2010 including descriptions of various methods and tools, see ISO/TR 14121-2:2012.

The integrator should seek participation of the user when conducting the risk assessment.

4.2 Characteristics of robot applications and robot cells

The characteristics of robot applications and robot cells can be significantly different from those of other machines and equipment. The risk assessment shall include the following aspects, if relevant:

a) robot applications and their workpieces are capable of high energy movements through a large space;

b) the initiation of movement and the path of the robot application are difficult to predict and can vary;

   EXAMPLE Changes and variations can be due to handling of various size parts, changing motion paths based on conditions that are not obvious, and running different program.

c) the operating space of the robot application and its workpiece(s) can overlap

   — a portion of other robot applications' operating space(s) and their workpiece(s);

   — the task zones for other machines and related equipment;

   — task zones of operators.

d) end-effector selection and design can be used to reduce risks due to hazards of the end-effector and of workpiece(s).

   — end-effectors interact with workpieces and other parts of the robot application;

   — cleaning and maintenance can require frequent interactions, e.g. extended operator interaction with an adaptive fixture for variable presentation of workpiece or assembly;

   — troubleshooting is also a consideration;

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NOTE See 5.9 and Annex I.

e) robot applications can vary greatly, as will the tasks associated with these uses, where the tasks can include:

1) commissioning;

2) process control and monitoring;

3) workpiece loading;

4) performing operations on the workpiece(s);

5) teaching, programming and verifying;

6) operator intervention not requiring disassembly;

7) entering and/or leaving the safeguarded space;

8) starting and stopping the robot application;

9) tasks involving more than one operator;

10) tasks involving more than one robot;

11) setting-up (e.g. fixture changes, end-effector exchange, process equipment refresh or adjustment);

12) troubleshooting;

13) correcting malfunction(s) (e.g. equipment jams, dropped parts, event recovery);

14) control of hazardous energy (including fixtures, clamps, turntables, and other equipment);

15) integrating hardware and software with local cell control systems or wider enterprise systems;

16) integrating local 2D/ 3D vision systems;

17) maintenance and repairing;

18) equipment cleaning;

19) application changes;

20) re-deploying of the robot application or robot cell;

21) decommissioning;

22) disposal.

f) operator tasks not associated with the collaborative application could have travel path(s) through a collaborative application's safeguarded space, requiring this additional consideration when determining the collaborative application layout and access requirements.

4.3 Characteristics of collaborative applications

4.3.1 General

In addition to 4.2, the risk assessment of collaborative applications shall include the following aspects, if relevant:

a) operators can work near the robot application while power to the robot actuators and end-effector(s) are available;

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b) collaborative applications can use one or more of the following safety functions:

— hand-guided controls (HGC) (5.14.4);

— speed and separation monitoring (SSM) (5.14.5);

— power and force limiting (PFL) (5.14.6).

c) there is the potential for intended or reasonably foreseeable unintended contact situations from the moving parts of the robot application to operator(s);

d) collaborative applications can have additional tasks to those listed in 4.2 e); these collaborative tasks can include the following:

1) during production or normal operation, there can be greater frequency and duration of:

— operator presence in the safeguarded space with a moving robot application (e.g. collaborative assembly with external fixtures);

— contact (e.g. hand guiding, physical interaction with tool or workpiece);

— operator interaction with the robot application.

2) transitioning between non-collaborative and collaborative use;

3) automatic or manual restart of motion after the collaborative application has been completed;

4) tasks involving more than one operator.

NOTE See 5.4 for the layout. See Annex B for illustrations of spaces, Annex M for collaborative application biomechanical limits, and Annex N for pressure and force measurement.

4.3.2 Risk assessment for contacts between moving parts of the robot application and operator(s)

Risk assessment shall consider hazardous situations in which possible contact could result in harm to the operator. Risk assessment shall consider means of reducing the possible contact where practicable and where not practicable, the contact situations shall not result in harm to the operator. This shall be achieved by:

— identifying conditions in which such contact would occur;

— evaluating the risk potential for such contacts;

— designing the robot application and safeguarded space so that such contact is infrequent and avoidable;

— applying risk reduction measures to keep the contact situations below pressure and force threshold limit values.

This identification shall consider the following criteria for potential contact events:

a) exposed operator body regions;

b) origin of contact events, i.e. intentional action as part of intended use versus unintentional contact or reasonably foreseeable misuse;

c) probability or frequency of occurrence;

d) type of contact event, i.e. quasi-static or transient (see 5.14.6.2);

e) contact surface areas, speeds, forces, pressures, momentum, mechanical power, transfer energy, and other quantities characterizing the physical contact event.

NOTE For information about ergonomic design principles related to mental workload, see ISO 10075-2:2024.

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5 Safety requirements and risk reduction measures

5.1 General

Robot applications and robot cells shall be designed according to ISO 12100:2010 for relevant but not significant hazards which are not dealt with by this document. Robots applied in robot applications shall conform with the requirements of ISO 10218-1:2025.

Figure 1 shows the organization of Clause 5.

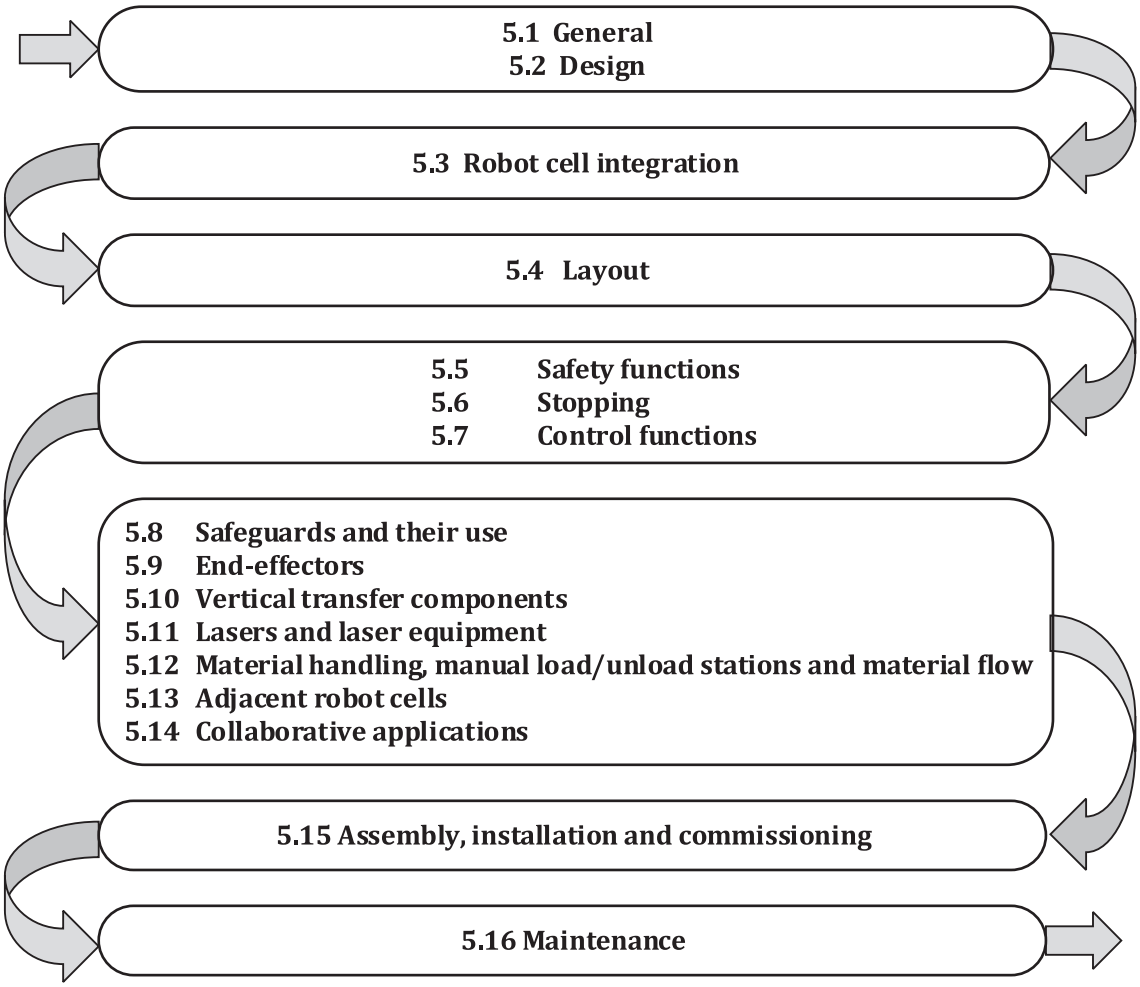

Figure 1 — Clause 5 structure

NOTE Methods of verification and validation of the requirements in this clause are in Clause 6 and Annex H.

5.2 Design

5.2.1 General

The design shall be based on the information for use provided with the robot, end-effector and the associated machinery and equipment. The design shall conform with the requirements as described in 5.2.2 through 5.2.16.

NOTE Suitable housings and covers can be used to mitigate potential hazards.

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5.2.2 Materials, mechanical strength and mechanical design

5.2.2.1 General

Robot applications and robot cells shall be designed and constructed to prevent hazardous situation(s) which result from failure due to fatigue and wear. Design and manufacturing shall take into account the lifecycle of the intended use (e.g. transportation, installation, operating conditions and maintenance in accordance with Clause 7, information for use).

Robot applications and robot cells shall be designed and constructed to take account of the constraints (e.g. protective gloves and control device push button dimensions) to which the operator is subject as a result of the use of personal protective equipment for the intended application.

5.2.2.2 Materials

Materials used shall:

a) be selected to be appropriate for the intended use (e.g. resistance to corrosion, abrasion, impacts, fatigue, deformation, aging);

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, the design and construction shall address risks due to filling, use, recovery or draining.

5.2.2.3 Mechanical strength

The parts of the robot application shall be designed and constructed to withstand the loads expected for the intended application and the expected operating conditions.

The parts of the robot application involved in lifting operations (e.g. lifting workpieces or tools) 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 payload multiplied by the dynamic test coefficient, where the dynamic test coefficient shall be at least 1,1.

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

Where complete ropes are used for lifting functions, the ropes and their endings shall have a minimum working coefficient of 5. Where chains are used for lifting functions, they shall have a minimum working coefficient of 4.

NOTE Complete ropes are finished assemblies which are designed to meet the requirements for use in lifting.

5.2.2.4 Mechanical design

The parts of the robot application shall be designed and constructed such that

— exposed sharp edges and corners unnecessary for the robot application and accessible to operator(s) shall be eliminated;

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— hazardous projections and corners unnecessary for the robot application and accessible to operator(s) shall be eliminated;

— any exposed sharp edges, sharp corners and hazardous projections that are necessary for the robot application shall be reduced as far as reasonably practicable.

Hazardous mechanisms that enable motion shall be installed or mounted such they are normally inaccessible.

Exposure to hazards caused by components such as motor shafts, gears, drive belts, or linkages which are not protected by integral covers (e.g. panel over a gear box) shall be prevented either by fixed guards or movable guards according to ISO 14120:2015. The fixing systems of the fixed guards which are intended to be removed for routine service actions shall remain attached to the robot, machine or equipment or remain attached to 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.

Where a risk of rupture or disintegration remains despite the measures taken, the parts concerned shall be mounted, positioned and/or guarded in such a way that any fragments will be contained, preventing hazardous situations.

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

5.2.3 Provisions for lifting or moving

Instructions and provisions for lifting or moving parts of the robot application shall be provided when intended to be moved after initial installation. The provisions shall be capable of handling the anticipated load.

NOTE 1 For the lifting or moving of robot applications and its components, the information provided by the integrator can be sufficient, which could include a specific robot pose.

NOTE 2 The robot could be transported with parts mounted on the robot, e.g. end-effector, wiring, hoses.

5.2.4 Hazardous substances

Robot applications shall be designed and constructed in such a way that risks of inhalation, ingestion or contact of hazardous materials and substances shall be prevented.

Where the use of hazardous substances cannot be eliminated, the robot application shall be designed such that those substances can be contained, evacuated, precipitated by water spraying, filtered or treated by another effective method.

Where the application does not allow the total enclosure of the substances during normal operation, containment and/or evacuation shall be designed to be effective.

5.2.5 Stability

To prevent tipping and falling-over, components of robot applications shall be:

— affixed to be stable (e.g. to other components, rails, tracks, mobile platforms, the floor or parts of the building structure); or

— stable itself for installation, operation and use.

Where components are used that move on rails, they shall be provided with means to prevent derailment when practicable. If risk of derailment or overturning persists due to a failure of a rail or of a moving component, means shall be provided to prevent the components or workpiece from falling or overturning.

NOTE The component could be the robot or any part of the robot application.

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5.2.6 Temperature and fire risks

The design of the robot application shall be such that the temperatures of accessible surfaces are according to ISO 13732-1:2006 and ISO 13732-3:2005.

NOTE 1 ISO/TS 13732-2:2001 contains 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).

5.2.7 Special equipment

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

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

5.2.8 Position holding

Hazardous motion of the robot application shall be prevented by position holding when drive power is lost. Position holding shall conform with ISO 10218-1:2025, 5.1.8.

When the position holding means is provided as part of the robot, it shall be implemented in accordance with the robot's information for use.

Position holding can be achieved using mechanical devices (e.g. brakes, pins, or other technology).

Position holding can be provided by:

a) safety function(s) to prevent hazardous situations whereby operators are crushed or impacted by the robot, end-effector, workpiece(s), other machines and sub-assemblies; and/or

b) a means to maintain posture and/or position of the robot, end-effector and workpiece(s), other machines and sub-assemblies to prevent hazardous situation(s) and damage of the workpiece or robot application.

NOTE 1 When provided by a safety function, the capability of configurable monitored position(s) can be provided. See Annex O, O.7.1.

NOTE 2 See 5.5.4 for failure or fault detection.

NOTE 3 See 5.2.10 about power loss or change.

Position holding means shall be designed and constructed to withstand an overload during static testing according to 5.2.2.3.

5.2.9 Additional axis (axes)

Additional 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. 5.2.1, 5.2.2, 5.2.8, 5.5, 5.6, 5.7). When additional axis motion can affect the TCP speed in reduced-speed manual mode, the requirements of reduced-speed (5.5.6.1) shall be applied to the additional axes.

If the robot application has additional axis (axes) being operated in coordination with one another, each axis can move at different speeds. Safeguarding and/or safety functions shall be implemented to protect operators from the risks associated with the speed differences.

For calibration or other isolated movements of an additional axis,

— high-speed manual mode (5.7.2.3.3) may be used with the monitored-speed parameter set for this use;

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— it shall not be possible to actuate other axes when an additional axis operates at greater than reduced-speed.

5.2.10 Power loss or change

Loss or change of electrical, hydraulic, pneumatic or vacuum power shall not result in a hazardous situation.

Re-initiation of power shall not lead to any hazardous movements or a change of the safety-related parameters.

Unexpected start-up shall be prevented in accordance with ISO 14118:2017.

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

NOTE 2 See 5.9 for end-effectors.

5.2.11 Component malfunction

Robot application components shall be designed, constructed, secured, or contained in accordance with 5.2.2, so that risks caused by breaking or loosening, or releasing, including those related to stored energy, are prevented as far as practicable.

NOTE Robot application components can include robot, end-effectors, safeguarding, external controllers, other equipment and machinery, etc.

5.2.12 Hazardous energy

5.2.12.1 General

Release of 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, there shall be a means to secure it in a position which can be either the energized or de-energized position.

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

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

NOTE 1 Hazardous energy can take many forms: kinetic, gravity, electrical, pneumatic, hydraulic, thermal, chemical, etc. 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).

Where additional axes can sink, drop or drift, 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 (5.2.8) may be provided to prevent uncontrolled or hazardous release of stored energy.

NOTE 2 Axes that do not maintain position (e.g. axis or axes that hang, drop, sink, drift) can create a significant risk depending on the task and frequency or duration of exposure (e.g. standing below the axis [axes] during setting).

Figure 2 shows an example of stored energy in a spring balancer.

EXAMPLE A hazardous situation can occur when a motor is removed, even though the energy to the robot is isolated as shown in Figure 2. Upon release, the unexpected motion due to the energy in the spring balancer can cause crushing, entrapment and more.

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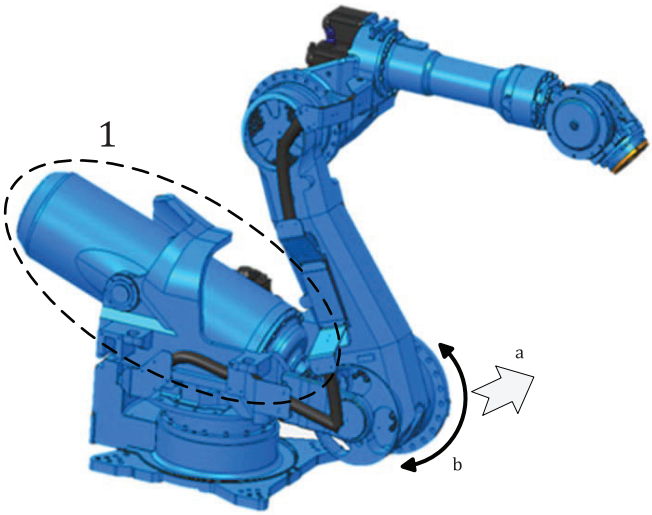

Key

1 spring balancer

a Motor removal (direction of motion removal).

b Motion direction.

Figure 2 — Example of stored energy in a spring balancer

5.2.12.2 Isolation of sources

Means of isolating the robot, end-effector, and robot application from any hazardous energy source shall be provided. This means shall be provided with capability of locking or otherwise securing only in the de-energized position.

The robot application should have a single supply disconnecting device for each type of energy source (e.g. electrical, pneumatic, hydraulic). For multiple robot applications and robot cells, multiple disconnecting devices for each type of energy can be necessary.

Each isolation device shall be readily identifiable as to what it isolates (e.g. by durable marking where necessary). The span-of-control for each of these devices shall be clearly marked near the disconnecting device (e.g. text or symbol).

For electrical supply disconnecting devices, IEC 60204-1:2016+AMD1:2021, 5.3.1 shall be applied.

For energy separation and dissipation requirements, ISO 14118:2017 shall be applied.

5.2.13 Electrical, pneumatic and hydraulic parts

Electrical parts shall be designed and implemented in accordance with the relevant requirements of IEC 60204-1:2016+AMD1:2021.

Pneumatic parts of the robot application shall be designed and implemented according to the relevant requirements of ISO 4414:2010.

Hydraulic parts of the robot application shall be designed and implemented according to the relevant requirements of ISO 4413:2010.

NOTE For requirements related to specific sub-assemblies, and components and machines, see relevant IEC or ISO standards (e.g. IEC 60269-1:2014, IEC 60745-1:2006, IEC 60947-1:2020, ISO 13850:2015).

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

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5.2.14 Tool centre point (TCP) setting

When the capability to enter tool centre point (TCP) settings has been provided in the robot (ISO 10218-1:2025, 5.1.14) and failure to enter these settings can create a hazard, the TCP setting shall be entered in accordance with the robot information for use.

NOTE For additional axis requirements, see 5.2.9.

5.2.15 Payload setting

Where the payload setting is provided in the robot (ISO 10218-1:2025, 5.1.15) and failure to enter these settings can create a hazard, the payload setting shall be entered in accordance with the robot information for use.

NOTE The payload setting can be determined by the robot application.

5.2.16 Cybersecurity

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

NOTE 1 The means to prevent unauthorized access can include providing 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 configurations (e.g. usernames, user passwords, IP addresses and safety authentication).

NOTE 2 For guidance about the 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 about industrial communication networks and system security, see IEC 62443-3-3:2013.

5.3 Robot cell integration

5.3.1 General

Other machinery and equipment can be associated with the robot application or robot cell. If the associated machinery and equipment have relevant type-C standards, these standards shall be applied.

When machines are integrated and not directly controlled by the robot application or robot cell controller, ISO 11161 can be applicable.

Any safety-related control interfaces between the robot application(s), robot cell(s) and other machines and, if applicable, an IMS (Integrated Manufacturing System) shall conform with the requirements of 5.5 and Annex C.

Safeguarding shall protect operators against access to the following hazards:

— from other machines;

— within each hazard zone of a robot application and robot cell; and

— at the interfaces to adjacent hazard zones (e.g. conveyors).

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5.3.2 Span-of-control

In the case of multiple robot applications, multiple robot cells or other machinery, different span-of-control may be applied. In such cases, the span-of-control shall be set according to the requirements of the task(s) to be performed or the characteristics of the system (e.g. process flow, equipment structure, entry locations through perimeter safeguarding, location of other protective devices, hazards inside the safeguarded space).

NOTE See ISO 11161 for information about span-of-control.

5.3.3 Span-of-control of emergency stop function

Actuation of an emergency stop function shall stop:

— all hazardous motion of the robot, end-effector, and workpiece; and

— other hazardous movements and hazardous functions:

  — in the robot application or robot cell; and

  — at the interface(s) between robots, end-effectors, robot applications and robot cells.

The span-of-control shall be in accordance with ISO 13850:2015, 4.1.2 and be either perspicuous or clearly marked (e.g. by text or symbol) near the emergency stop device. The emergency stop functions for the robot and its end-effector shall have the same span-of-control. All emergency stop devices for the same hazard zone shall have the same span-of-control. In the event of additional risks due to hazards in the remainder of the robot application, the risk assessment may be used to determine whether these risks share the same span-of-control.

NOTE See ISO 13850:2015 for more information about the emergency stop span-of-control.

5.3.4 Operational modes with multi-robot applications or robot cells

In a robot cell with more than one robot system or robot application, mode(s) may be selected:

— individually on each robot control; or

— for each robot application; or

— be common for all associated robot applications in the robot cell.

If a mode is selected individually for each robot, it is not necessary that all robots be switched to manual mode. Robot applications that are not operated manually shall remain in a safe state, independent of the operational mode selected, and shall not create a hazard.

5.3.5 Local control, remote control and single-point-of-control

The following shall be fulfilled:

— determining what is considered remote control shall be according to 5.7.6.1;

— local control shall be according to 5.7.6.2;

— remote control shall be according to 5.7.6.3;

— single-point-of-control shall be according to 5.7.5.

When local control (5.7.6.2) is selected, other machines and their control systems shall be notified of this condition. Local control shall not be overridden by remote controls. The local control shall be located to be adjacent to and have a direct view of the robot cell.

The emergency and protective stop functions shall remain operational during both local control and remote control, in accordance with 5.6.1.

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5.3.6 Automatic workpiece feeding

Where workpieces are automatically fed, hazards caused by breakage shall be prevented or the risks shall be minimized by the design and integration.

5.4 Layout

5.4.1 General

The design shall be such that the operator can safely perform all intended and reasonably foreseeable tasks. The location of the robot application(s), equipment and machinery within the robot cell should not introduce additional hazards. If additional hazards are introduced, protective measures shall be applied to reduce the risks associated with these hazards, in accordance with Clauses 4 and 5.

Robot applications and cells shall be designed and constructed so that risks due to access of controls and equipment (e.g. weld controller, pneumatic valves) during automatic operation have been assessed and reduced.

The layout and anticipated tasks shall be reviewed to eliminate trapping and crushing possibilities within the robot application restricted space.

EXAMPLE The robot application can include fixtures, manual load/unload station (5.12.2), material handling equipment (5.10), end-effector changing systems (5.9) and process-related equipment.

The layout shall allow operator tasks to be performed from outside the safeguarded space. Where it is necessary to perform tasks within the safeguarded space(s), there shall be safe and adequate access to the task locations. Access paths and means shall not expose operators to hazards, including slipping, tripping, and falling hazards.

The design for access shall consider, for example:

— cable channels, places where operators could stumble;

— frequency of the required access for manual loading/unloading;

— physical characteristics of the load;

— abidance and observation zones;

— service positions (e.g. tip change);

— easily accessible maintenance locations.

Components which have to be changed frequently shall be capable of being removed and replaced easily and safely.

Permanent means of access shall be provided, considering the frequency and the ergonomic aspects of the task. Platforms, walkways, stairs, stepladders, and fixed ladders shall be in accordance with the relevant parts of the ISO 14122:2016 series.

Workstations shall be designed according to ISO 14738:2008. Access openings shall be designed according to ISO 15534-2:2000. Opening dimensions for the purpose of providing whole body access shall conform with ISO 15534-1:2000.

NOTE 1 See ISO/TR 22100-3:2016 for guidance on ergonomics standards.

NOTE 2 For whole body access requirements, see ISO 13857:2019, 4.4, where the whole body access is into hazardous areas or safeguarded spaces. See 5.5.7 and 5.8.

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5.4.2 Use and limits

The following shall be considered during the layout design process.

— use limits;

— operator task limits;

— space limits;

— time limits;

— end-effector limits;

— workpiece limits.

5.4.3 Design

Design considerations shall include:

a) the need for manual intervention(s);

b) allowing tasks requiring manual intervention to be performed from outside the safeguarded space;

EXAMPLE Loading and unloading the workpieces and the end-effector exchange system can be located outside the safeguarded space for ease of access.

c) ergonomics and human interface with equipment:

1) allowing for the variability of the operator's physical dimensions, strength and stamina;

2) providing enough space for movements of the parts of the operator's body;

3) visibility of the robot application and activities associated with the equipment;

4) clear association of controls with robot application(s) and robot cell(s);

5) local or user control design specifications;

6) position of workpiece relative to the operator;

7) consideration of avoiding a machine determined work rate;

8) avoiding tasks that requires lengthy concentration;

9) foreseeable misuse.

d) requirements for and location of emergency stop devices and possible spans-of-control (e.g. robot application or robot cell stops);

e) requirements for and location of additional enabling devices;

f) the intended use of all components;

g) specifications:

1) robot cell safety functions, including speed monitoring and limiting devices;

2) end-effector safety functions, if any;

3) robot(s) mass, payload, velocity, shape and dimensions;

4) mass, shape and dimensions of the end-effector and workpiece(s);

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5.4.4 Design for collaborative applications

Since collaborative applications can present unique risks, the following factors shall be addressed:

a) the spatial (three dimensional) limits of the safeguarded spaces;

NOTE Established limits can be static or dynamic.

b) access and clearance, and contacts:

1) influences on the safeguards (e.g. material storage, workflow requirements, obstacles);

2) the intended and reasonably foreseeable contact(s) from portions of the robot application to an operator, including pressure, force, and body location of contact;

3) object features (e.g. sharp edges, hot surfaces, etc.) around or in the space where trapping between the robot application and object could occur;

4) end-effectors, workpieces and protrusions shall not have exposed sharp edges where hazardous contact between robot application and person could occur.

c) ergonomics and human interface with equipment:

1) possible stress, fatigue, or lack of concentration arising from the collaborative applications;

2) ease of error or misuse (intentional or unintentional) by operator;

3) possible reflex behaviour of operator to movement of the robot, end-effector, workpiece and related equipment;

4) inability to predict potential motion of the robot application;

5) required training level and skills of the operator;

6) potential consequences of single or repetitive contacts from the robot application to operators.

d) transitions (time limits):

1) starting and ending of collaborative tasks;

2) transitions from collaborative tasks to other tasks.

5.4.5 Prevention of trapping within the safeguarded space

The robot application shall be designed and constructed such that it prevents a person from being trapped within the robot application or robot cell.

The safeguarded space shall be designed, constructed, or fitted with a means of preventing an operator from being trapped within the safeguarded space. For example, this may be fulfilled by providing for manual opening of movable guards from inside the safeguarded space, regardless of the state of the energy supply.

NOTE For information about escape release, see ISO 14119:2024, 6.9.1.

If this is not practicable, all the following shall be provided:

— a means by which to stop the robot application;

— a means to prevent the start/restart of the robot application (5.5.7 and 5.7.3);

— a means to summon help;

— a means to release a trapped operator.

When means to stop and means to prevent the start are provided, these means shall be readily accessible and located away from hazardous zone(s).

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5.4.6 Establishing restricted spaces

The restricted space shall be established by limiting motion of the robot, end-effector and workpiece in accordance with 5.4.7.

When the maximum space is required for the robot application, the maximum space shall be considered to be the restricted space.

5.4.7 Limiting motion

5.4.7.1 General

Robot applications shall be designed and integrated to reduce the potential exposure of operator(s) to hazards by implementing limiting devices. Limiting devices are used to reduce the space that a robot application uses, thereby establishing a restricted space (5.4.6). The restricted space can be made smaller than the maximum space by use of limiting devices. Limiting devices can be integral to the robot or by external means.

NOTE 1 See ISO 10218-1:2025, 5.7 for motion limiting requirements of robots.

NOTE 2 See space illustrations in Annex B.

Limiting the motion of the robot application may be fulfilled by a combination of the following:

a) means integral to the robot (e.g. safety functions, software-based limiting safety function(s));

b) mechanical limiting devices provided with the robot in accordance with ISO 10218-1:2025, 5.7;

c) mechanical limiting devices provided with the integration;

d) integrating external limiting devices;

e) installing limiting devices for machines and components of the robot application and robot cell.

Limiting devices shall

— prevent motion beyond the limiting device setting by either mechanical limiting devices (5.4.7.2) or safety functions that prevent reaching the limit (5.4.7.3 and Annex C); or

— initiate a protective stop by non-mechanical limiting devices (5.4.7.3) which can include software-based limiting safety functions.

NOTE 3 For robot applications using robots that compensate speed based on actual payload, it is possible for the speed to change when the robot carries less than the expected payload.

NOTE 4 The restricted space is defined where the motion stops, not by where the stop is initiated. The restricted space can be defined by the location of mechanical limiting devices (e.g. hard stops). Locating non-mechanical limiting devices, including software-based limiting (5.4.7.3), can require that activation time and stopping distance be considered.

Devices designed to protect the machine (e.g. collision sensors) may be used as limiting devices if they are specifically designed, tested, integrated and determined to be suitable as a safety function for limiting motion according to ISO 10218-1:2025, 5.7.

5.4.7.2 Mechanical limiting devices

If mechanical limiting devices are used, they shall conform with the requirements for limiting devices in ISO 10218-1:2025, 5.7.3 or 5.7.4 and this subclause. If mechanical limiting devices are selected as the means for limiting motion, the mechanical limiting devices shall be installed and adjusted for the robot application.

In cases where the perimeter guard is designed to be the limiting device, the results of the risk assessment and ISO 14120:2015 shall be used to determine the requirements for the design, strength, and deflection for that guard.

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