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BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 13482

Robotics — Safety requirements for service robots

Robotique — Exigences de sécurité pour les robots de service

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Contents

Page

Foreword	vii
Introduction	viii
1 Scope	1
2 Normative references	1
3 Terms and definitions	3
4 General safety requirements	9
4.1 General	9
4.2 Hazards due to energy storage and supply	10
4.2.1 Contact with hazardous energy parts	10
4.2.2 Hazards related to battery	11
4.2.3 Uncontrolled release of stored energy	13
4.2.4 Power failure or shutdown	14
4.3 Robot start-up and restart of regular operation	15
4.3.1 General	15
4.3.2 Inherently safe design	15
4.3.3 Safeguarding and complementary protective measures	15
4.3.4 Information for use	15
4.3.5 Verification and validation	15
4.4 Electrostatic potential	15
4.4.1 General	15
4.4.2 Inherently safe design	16
4.4.3 Safeguarding and complementary protective measures	16
4.4.4 Information for use	16
4.4.5 Verification and validation	16
4.5 Hazards due to robot shape	16
4.5.1 General	16
4.5.2 Inherently safe design	16
4.5.3 Safeguarding and complementary protective measures	17
4.5.4 Information for use	17
4.5.5 Verification and validation	17
4.6 Hazards due to power train components	17
4.6.1 General	17
4.6.2 Inherently safe design	17
4.6.3 Safeguarding and complementary protective measures	18
4.6.4 Information for use	18
4.6.5 Verification and validation	18
4.7 Emissions	18
4.7.1 Noise	18
4.7.2 Substances and fluids	19
4.7.3 Extreme temperatures	20
4.7.4 Radiation	21
4.8 Electromagnetic interference	22
4.8.1 General	22
4.8.2 Inherently safe design	22
4.8.3 Safeguarding and complementary protective measures	22
4.8.4 Information for use	23
4.8.5 Verification and validation	23
4.9 Stress, posture and usage	23
4.9.1 General	23
4.9.2 Physical stress and posture	23
4.9.3 Mental stress	24
4.10 Robot motion	25
4.10.1 General	25
4.10.2 Mechanical stability	25

4.10.3	Instability during travel	26
4.10.4	Instability while carrying loads	28
4.10.5	Instability in case of collision	29
4.10.6	Collisions	30
4.10.7	Physical contact during human-robot interaction	32
4.11	Durability	33
4.11.1	General	33
4.11.2	Inherently safe design	33
4.11.3	Safeguarding and complementary protective measures	33
4.11.4	Information for use	33
4.11.5	Verification and validation	34
4.12	Autonomous decisions and actions	34
4.12.1	General	34
4.12.2	Inherently safe design	34
4.12.3	Safeguarding and complementary protective measures	34
4.12.4	Information for use	35
4.12.5	Verification and validation	35
4.13	Awareness of robots by humans	35
4.13.1	General	35
4.13.2	Inherently safe design	35
4.13.3	Safeguarding and complementary protective measures	35
4.13.4	Information for use	36
4.13.5	Verification and validation	36
4.14	Environmental conditions	36
4.14.1	General	36
4.14.2	Inherently safe design	36
4.14.3	Safeguarding and complementary protective measures	37
4.14.4	Information for use	37
4.14.5	Verification and validation	37
4.15	Localization and navigation	38
4.15.1	General	38
4.15.2	Inherently safe design	38
4.15.3	Safeguarding and complementary protective measures	38
4.15.4	Information for use	38
4.15.5	Verification and validation	38
5	Wearable robots	39
5.1	General	39
5.2	Hazards due to loss of power supply or shutdown	39
5.2.1	General	39
5.2.2	Inherent safe design	39
5.3	Robot start-up and restart of regular operation	40
5.3.1	General	40
5.3.2	Inherently safe design	40
5.3.3	Safeguarding and complementary protective measures	40
5.3.4	Information for use	40
5.4	Hazards due to physical stress	40
5.4.1	General	40
5.4.2	Inherently safe design	40
5.4.3	Safeguarding and complementary protective measures	40
5.4.4	Information for use	41
5.5	Hazardous vibrations	41
5.5.1	General	41
5.5.2	Inherently safe design	41
5.5.3	Safeguarding and complementary protective measures	41
5.5.4	Information for use	42
5.5.5	Verification and validation	42
5.6	Mechanical instability	42
5.6.1	General	42

5.6.2	Inherently safe design	42
5.6.3	Safeguarding and complementary protective measures	42
5.6.4	Information for use	42
5.7	Instability in case of collision or intended contact	43
5.7.1	General	43
5.7.2	Inherently safe design	43
5.7.3	Safeguarding and complementary protective measures	43
5.7.4	Information for use	43
5.8	Hazards during donning or doffing	43
5.8.1	General	43
5.8.2	Inherently safe design	43
5.8.3	Safeguarding and complementary protective measures	43
5.8.4	Information for use	44
5.9	Hazards due to insufficient durability caused by cleaning and disinfection	44
5.9.1	General	44
5.9.2	Inherently safe design	44
5.9.3	Information for use	44
5.10	Hazards caused by assistive forces	44
5.10.1	General	44
5.10.2	Inherently safe design	45
5.10.3	Safeguarding and complementary protective measures	45
5.10.4	Information for use	46
5.10.5	Verification and validation	46
5.11	Joint injuries due to assistance that exceeds the range of motion	47
5.11.1	General	47
5.11.2	Inherently safe design	47
5.11.3	Safeguarding and complementary protective measures	47
5.11.4	Information for use	48
5.11.5	Verification and validation	48
5.12	Hazards due to unharmonized and uncoordinated motion	49
5.12.1	General	49
5.12.2	Inherently safe design	49
5.12.3	Safeguarding and complementary protective measures	49
5.12.4	Information for use	49
5.12.5	Verification and validation	49
6	Safety-related control system requirements	49
6.1	Required control system performance	49
6.1.1	General	49
6.1.2	Required control system performance	49
6.1.3	Determining severity	50
6.1.4	Determining probability of occurrence	50
6.1.5	Determining possibility of avoidance	50
6.2	Robot stopping	50
6.2.1	General	50
6.2.2	Robot stopping functions	51
6.2.3	Braking	52
6.3	Start and restart interlocking	53
6.3.1	Start interlock	53
6.3.2	Restart interlock	53
6.4	Limits to operational spaces	53
6.5	Speed control	54
6.6	Environmental sensing	55
6.6.1	General	55
6.6.2	Object sensing	55
6.6.3	Travel surface sensing	56
6.7	Stability control	57
6.8	Force control	57
6.9	Singularity protection	57

6.10	Moving robot in emergency situations	57
6.11	Interworking with a lift (an elevator)	58
6.12	Design of user interface	58
6.12.1	General	58
6.12.2	Status indication	59
6.12.3	Connection and disconnection	60
6.12.4	Single command device for multiple robots	60
6.12.5	Multiple command devices	60
6.12.6	Cableless or detachable command device	61
6.12.7	Protection against unauthorized use	61
6.13	Manual control devices	61
6.13.1	General	61
6.13.2	Labelling	61
6.13.3	Protection from unintended operation	61
6.14	Operational modes	62
6.14.1	General	62
6.14.2	Autonomous mode	63
6.14.3	Manual mode	63
6.14.4	Semi-autonomous mode	63
6.14.5	Maintenance mode	64
6.15	Cyber security and data privacy	64
6.15.1	General	64
6.15.2	Measures for data privacy and data security	65
6.15.3	Measures for cyber security managing access privilege and stability of operation	65
7	Verification and Validation	65
8	Information for use	66
8.1	General	66
8.2	Markings or indications	67
8.3	User manual	69
8.4	Service manual	70
	Annex A (informative) List of significant hazards for service robots	71
	Annex B (informative) Examples of operational spaces for service robots	78
	Annex C (normative) Safety function performance requirements	81
	Annex D (informative) Example of determination of the PLr or required SIL from risk estimation parameters of Annex C, C.2	98
	Annex E (informative) Example of the implementation of a safeguarded space	101
	Annex F (informative) Examples of service robots	104
	Annex G (informative) Information for lifting load	112
	Annex H (informative) Example of safety evaluation methods for lift boarding robots	114
	Annex I (informative) Example of safety evaluation method for braking distance	116
	Annex ZA (informative) Relationship between this European Standard and the essential requirements of Directive 2006/42/EC aimed to be covered	117
	Annex ZB (informative) Relationship between this European Standard and the essential requirements of Regulation (EU) 2023/1230 aimed to be covered	119
	Bibliography	122

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 documents should be noted. This standard was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the standard will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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.

This second edition cancels and replaces the first edition (ISO 13482:2014), which has been technically revised.

The main changes compared to the previous edition are as follows:

- The document has been re-structured from safety requirements to specific robot types
- The clauses on personal carrier robots have been removed.
- New clauses on cyber-security and data protection, and robots inter-working with lifts (elevators), with associated informative [annex H](#), are included in the document.
- Detailed coverage of wearable robots, previously referred to as personal assistant robots, is provided in [clause 5](#) with an informative [Annex G](#).

This document has been prepared under a standardisation request addressed to [the relevant ESO] 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 Z, which is an integral part of this document.

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

Introduction

This document has been developed in recognition of the particular hazards presented by robots and robotic devices for applications in non-industrial environments for providing services rather than manufacturing applications in industrial applications. This document focuses on the safety requirements for service robots in non-medical applications.

This document includes information in line with ISO 12100:2010 and adopts the functional safety approach proposed in ISO 13849 and IEC 62061:2024. This safety document considers the conditions for physical human-robot contact to formulate a safety standard for service robots.

This document is a type-C standard, as stated in ISO 12100:2010.

When a type-C standard deviates from one or more technical provisions dealt with by type-A or by type-B standards, the type-C standard takes precedence.

It is recognized that robots and robotic devices in service applications require close human-robot interaction and collaborations, as well as physical human-robot contact.

The service robots concerned, and the extent to which hazards, hazardous situations or hazardous events are covered, are indicated in the scope of this document.

Hazards are well recognized, and the sources of the hazards are frequently unique to particular robot systems. The number and types of hazards are directly related to the nature of the robot application, the complexity of the installation, and the level of human-robot interaction incorporated.

The risks associated with these hazards vary with the type of robot used and its purpose, and the way in which it is installed, programmed, operated, and maintained.

Not all of the hazards identified by this document apply to every service robot, nor will the level of risk associated with a given hazardous situation be the same from robot to robot. Consequently, the safety requirements, and/or protective measures can vary from what is specified in this document. A risk assessment is conducted to determine the protective measures needed when they do not meet safety requirements and/or protective measures specified in this document, and for the particular application being considered.

In this document, the following verbal forms are used:

- “shall” indicates a requirement;
- “should” indicates a recommendation;
- “may” indicates a permission;
- “can” indicates a possibility or a capability.

In recognition of the variable nature of hazards with service robot applications, this document provides guidance for the assurance of safety in the design and construction of the non-medical service robot, as well as the integration, installation, and use of the robots during their full life cycle. Since safety in the use of service robots is influenced by the design of the particular robot system, a supplementary, though equally important, purpose is to provide guidelines for the information for use of service robots and robotic devices.

The safety requirements of this document have to be met by the manufacturer and the supplier of the service robot.

ISO/TR 23482-2 provides guidance on robot applications covered by this document and gaps and overlaps with standards of similar products.

Robotics — Safety requirements for service robots

1 Scope

This document specifies safety requirements for service robots in *personal service* (3.22) and *professional service* (3.24) applications.

This document provides safety requirements for stationary, mobile, and wearable service robots.

This document describes significant hazards associated with the use of these robots, and provides requirements to eliminate, or reduce, the risks associated with these hazards to an acceptable level.

This document does not apply to:

- robots travelling faster than 20 km/h;
- robot toys;
- water-borne robots and flying robots;
- industrial robots and industrial robot applications covered in ISO 10218-1 and ISO 10218-2;
- cleaning robots and lawn mowers covered in IEC 63327, IEC 60335-2-2 or IEC 60335-2-107;
- robots as medical devices;
- military or public force application robots;
- driverless industrial trucks (AGVs) covered by ISO 3691-4:2023;
- autonomous driving Cargo e-Transporters (ACeTs) covered by IEC 63281-2-2. This document is applicable to robots with multiple intended uses where one of the intended uses falls within the scope of this document.

The scope of this document is limited primarily to human safety.

This document is not applicable to robots manufactured prior to its publication date.

This document deals with all significant hazards, hazardous situations or hazardous events as described in [Annex A](#).

This document does not provide any requirements for participation of service robots in road traffic environments.

This document does not provide any requirements for transportation of persons with service robots.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2631-1:1997, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 3746:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

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 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 4871:1996, *Acoustics — Declaration and verification of noise emission values of machinery and equipment*

ISO 7000:2019, *Graphical symbols for use on equipment — Registered symbols*

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

ISO 8373:2021, *Robotics — Vocabulary*

ISO 9227:2022, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 11202:2010, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions applying approximate environmental corrections*

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

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

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

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

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

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

ISO 13855:2010¹⁾, *Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body*

ISO 13856:2013, *(all parts), 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 14119:2013, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

ISO 15534:2000, *(all parts), Ergonomic design for the safety of machinery*¹⁾

ISO 21227-3:2007, *Paints and varnishes — Evaluation of defects on coated surfaces using optical imaging — Part 3: Evaluation of delamination and corrosion around a scribe*

ISO/TS 8100-21:2018, *Lifts for the transport of persons and goods — Part 21: Global safety parameters (GSPs) meeting the global essential safety requirements (GESRs)*

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

1) If used, consideration shall be given as to the relevance and applicability of the quantitative data to the intended users of the robot, especially for elderly people and children.

IEC 60335-1:2020, *Household and similar electrical appliances — Safety — Part 1: General requirements*

IEC 60335-2-29:2019, *Household and similar electrical appliances — Safety — Part 2-29: Particular requirements for battery chargers*

IEC 60417:2024, *Graphical symbols for use on equipment*

IEC 60529:2019, *Degrees of protection provided by enclosures (IP Code)*

IEC 60825-1:2014, *Safety of laser products — Part 1: Equipment classification and requirements*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use — Part 1: General requirements*

IEC 61140:2016, *Protection against electric shock — Common aspects for installation and equipment*

IEC 61326-3-1:2017, *Electrical equipment for measurement, control and laboratory use — EMC requirements — Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) — General industrial applications*

IEC 61496 (all parts), *Safety of machinery — Electro-sensitive protective equipment*

IEC 61508-1, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General requirements*

IEC 62061:2024, *Safety of machinery — Functional safety of safety-related control systems*

IEC 62133-2:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications — Part 2: Lithium systems*

IEC 62368-1:2023, *Audio/video, information and communication technology equipment — Part 1: Safety requirements*

IEC 62471:2006, *Photobiological safety of lamps and lamp systems*

IEC 62619:2022, *Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for secondary lithium cells and batteries, for use in industrial applications*

IEC/TS 62998-1:2019, *Safety of machinery — Safety-related sensors used for the protection of persons*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100:2010, ISO 8373:2021 and the following apply.

3.1

allowed contact

any *contact* (3.4) with the *service robot* (3.36) that is permitted by the manufacturer

3.2

autonomous mode

operational mode in which the robot function accomplishes its assigned mission without direct human intervention

EXAMPLE A *service robot* (3.36) waiting for an interaction (a command).

[SOURCE: ISO 8373:2021, 6.13.4]

3.3

command device

device that enables the *operator* (3.21) or a *user* (3.43) to control the robot

3.4

contact

zero distance between robot and an object (including human) in its external environment

3.5

contact sensing

detection or measurement capability that requires *contact* (3.4) with objects (including humans) in the environment

3.6

electro-sensitive protective equipment

ESPE

assembly of devices and/or components working together for protective tripping or presence-sensing purposes, and comprising as 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.

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: ..., or the ESPE itself, can further include ...]

3.7

hazard

potential source of harm

[SOURCE: ISO 12100:2010, 3.6, modified, notes 1, 2 and 3 to entry removed]

3.8

hazardous force

force of a point of a *service robot* (3.36) that creates an unacceptable *risk* (3.28)

3.9

hazardous obstacle

object, obstruction which can cause harm if it comes into contact or collision with the robot

3.10

hazardous speed

speed of a point (body location) of a *service robot* (3.36) that creates an unacceptable *risk* (3.28)

Note 1 to entry: In the definition, speed can be absolute or relative to the point of interest.

3.11

hazardous surface condition

adverse conditions of travel surface for a *mobile service robot* (3.17) that create an unacceptable *risk* (3.28)

EXAMPLE Surface conditions by which a *mobile service robot* (3.17) can roll over or slip causing injury or damage.

3.12

Low-power wearable robot

wearable robot (3.46) that a *user* (3.43) can overpower

3.13

manual control device

human operated device connected into the control circuit used for controlling the *service robot* (3.36)

Note 1 to entry: One or more manual control devices attached to a panel or housing form a *command device* (3.3).

3.14

manual mode

operational mode in which the robot is operated by direct human intervention via, for example, handguiding, pushbuttons or a joystick

Note 1 to entry: This mode is usually used for teaching, tele-operation, fault-finding, repair, cleaning, etc.

3.15

maximum space

volume which can be swept by the moving parts of the robot as defined by the manufacturer, plus the volume which can be swept by manipulators and payloads

Note 1 to entry: For mobile platforms, this volume can be defined by the physical boundaries through which the robot can move around.

Note 2 to entry: See [Figure E.2](#).

3.16

mobile platform

assembly of the components which enables locomotion.

Note 1 to entry: A mobile platform can include a chassis which can be used to support a load.

Note 2 to entry: A mobile platform can provide the structure by which to affix a manipulator.

Note 3 to entry: Mobile platform following a predetermined path indicated by markers or external guidance commands.

3.17

mobile service robot

MSR

service robot ([3.36](#)) able to travel under its own control

3.18

monitored space

space in which a person or object is detected by sensors that provide information to the robot.

Note 1 to entry: Monitored space can reach beyond the *maximum space* ([3.15](#)) and can be defined by a collection of sensors on the robot or outside the robot that provide information to the robot.

Note 2 to entry: This space can be static or dynamic depending on the service robot and its application.

Note 3 to entry: See [Figure E.2](#).

3.19

non-contact sensing

detection or measurement capability that does not require *contact* ([3.4](#)) with objects (including humans) in the environment

3.20

operational mode

characterization of the way and the extent to which the *operator* ([3.21](#)) or user intervenes with the service robot control devices

[SOURCE: ISO 8373:2021, 6.13, modified; intervenes in the control equipment changed to or user intervenes with the service robot in the control devices and note 1 to entry removed]

3.21

operator

person designated and trained to make parameter and program changes, and to start, monitor, and stop the *service robot* ([3.36](#)) for the benefit of users.

[SOURCE: ISO 8373:2021, 3.11, modified; and trained to make parameter and program changes, and *service robot* ([3.36](#)) for the benefit of users added]

3.22**personal service**

means of satisfying an individual's needs where the robot is used for and potentially operated by the beneficiary.

Note 1 to entry: In case of personal service the robot is not used for financial gain.

EXAMPLE Personal services include handling and transportation of goods, providing information including cognitive support, providing companionship or entertainment, grooming, cooking and food handling, and physical assistance.

3.23**pressure-sensitive protective equipment****PSPE**

sensitive protective equipment of the “mechanically activated trip” type intended to detect the touch of a person or body part of a person and which can also act as impeding device.

Note 1 to entry: Examples of PSPE are pressure sensitive mats and floors, bumpers, pressure sensitive edges and bars.

Note 2 to entry: PSPE generate a stopping signal by the use of different techniques, e.g. mechanical contacts, fibre-optic sensors, pneumatic sensors.

[SOURCE: ISO 13856-3:2013, 3.1, modified: replaced note 1 to entry and note 2 to entry]

3.24**professional service**

means of satisfying one or multiple individuals' needs or business organisation's needs where the operator of the robot is either the service provider or organisation's personnel.

Note 1 to entry: In case of professional service the robot can be used for financial gain.

EXAMPLE Professional services include handling and transportation of goods, building inspection, surveillance, cooking and food handling, lifting and transporting of objects with support of an exoskeleton.

3.25**protective stop space**

space in which the *service robot* (3.36) will perform a protective stop if a person or object enters it

EXAMPLE Examples of operational spaces for some different service robots are presented in [Annex B](#).

Note 1 to entry: Space can be static or dynamic, depending on the service robot, its application and its (dynamic) shape.

Note 2 to entry: See [Figure E.2](#).

3.26**relative speed**

magnitude of the difference between the velocity vectors of the robot and an object (including a human) nearby

Note 1 to entry: The robot velocity is the vector sum of velocities of the robot body and its moving parts.

3.27**restricted space**

portion of the *maximum space* (3.15) defined by the robot manufacturer and/or user within which the robot is intended (or allowed) to be used (or operated)

Note 1 to entry: For *mobile service robots* (3.17), this volume can be limited by special markers on floors and walls, or by *software limits* (3.38) defined in the internal map of the robot or facility (maximum space).

Note 2 to entry: See [Figure E.2](#).

[SOURCE: ISO 8373:2021, 5.12, modified; restricted by limiting devices (6.21) that establish limits which will not be exceeded changed to defined by the robot manufacturer and/or user within which the robot is intended (or allowed) to be used (or operated) and note 2 to entry added]

3.28

risk

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

[SOURCE: ISO 12100:2010, 3.12]

3.29

risk assessment

overall process comprising a risk analysis and a risk estimation

[SOURCE: ISO 12100:2010, 3.17, modified; evaluation changed to estimation]

3.30

safeguarded space

space in which the *service robot* (3.36) initiates a safety-related function if a person or object is detected within it

Note 1 to entry: Examples of safety-related functions include trajectory changes, safety-related speed control, protective stop, safety-related force control.

Note 2 to entry: [Annex E](#) provides more details on possible implementations of algorithms for the speed reduction.

Note 3 to entry: Space can be static or dynamic, depending on the service robot, its application and its (dynamic) shape.

Note 4 to entry: See [Figure E.2](#).

3.31

safe state

condition of a *service robot* (3.36) where it does not present an impending *hazard* (3.7)

[SOURCE: ISO 10218-2:2023, 3.11, modified; machine or piece of equipment changed to service robot]

3.32

safety-related force control

function in safety-related control system that prevents the robot from reaching *hazardous force* (3.8).

3.33

safety-related part of a control system

part of a control system that performs a safety function, starting from a safety-related input(s) to generating a safety-related output(s)

[SOURCE: ISO 13489-1:2023, 3.1.1, modified; notes 1 to entry removed]

3.34

safety-related speed control

function in safety-related control system that prevents the robot from reaching *hazardous speed* (3.10).

3.35

semi-autonomous mode

operational mode in which motions of the *service robot* (3.36) are determined by combination of the autonomous task program and partial user intervention

EXAMPLE *Wearable robot* (3.46) that tries to correct the human-chosen path to avoid collisions.

[SOURCE: ISO 8373:2021, 6.13.3, modified; operation changed to operational, motions of service robot included and manual user inputs given at the same time changed to partial user intervention and note 1 to entry removed]

3.36

service robot

robot in personal use or professional use that performs useful tasks for humans or equipment

[SOURCE: ISO 8373:2021, 2.10, modified, notes 1 and 2 to entry removed]

3.37

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 which can lead to hazardous situations.

Note 2 to entry: The Jacobian matrix is typically defined as a matrix of the first order partial derivatives of the robot's degrees of freedom.

[SOURCE: ISO 10218-1:2011, 3.22, modified; note 2 to entry added]

3.38

software limits

restrictions to one or more operational parameters of the robot defined in the control system

Note 1 to entry: Software limit can restrict operating spaces, speed, force, etc.

3.39

span-of-control

predetermined portion of a *service robot* (3.36) application that is under control of a specific device for a safety function.

3.40

stationary service robot

service robot (3.36) fixed to a surface or transportable

3.41

third party

a person or persons not the *user* (3.43) (or beneficiary); or *operator* (3.21) in proximity to or present in the defined operating area of the robot.

3.42

unintended contact

unplanned *contact* (3.42) between *service robot* (3.36) and object (including human) while performing the intended task

3.43

user

Person designated to start, monitor and stop the robot for their own use or the beneficiary of the service provided by the *service robot* (3.36).

Note 1 to entry: In some applications, a user could be both the operator and the beneficiary.

Note 2 to entry: A user can be a layperson or trained for the use of the robot.

Note 3 to entry: A user can be a person who owns or has management responsibility for the robot.

3.44

validation

confirmation, through the provision of objective evidence, that the requirements for specific intended use or application of the *service robot* (3.36) have been fulfilled

[SOURCE: ISO 9000:2015, 3.8.13 modified; application of the service robot added and notes 1 and 2 to entry removed]

3.45**verification**

confirmation, through the provision of objective evidence, that specified requirements of the *service robot* (3.36) have been fulfilled

[SOURCE: ISO 9000:2015, 3.8.12, modified; requirements of the service robot added and notes 1 and 2 to entry removed]

3.46**wearable robot**

service robot (3.36) that is fastened to a *user's* (3.43) body during use and physically assists the *user* (3.43) to perform required tasks by providing supplementation or augmentation of personal capabilities

4 General safety requirements**4.1 General**

Service robots shall conform to the safety requirements of this clause. In addition, the service robot shall be designed according to the requirements of ISO 12100:2010.

For each service robot a risk assessment according to ISO 12100:2010 shall be performed.

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 service robot(s).

For risk assessment, the limits of the service robot may be divided into several sets of limits, each referring to a certain environment, user group and/or task. If such an approach is used, appropriate measures for risk reduction shall be determined for each set of limits. In addition, risks shall be considered that can occur, if the robot is operated outside its current set of limits.

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 Annex [C.2](#) for risk estimation.

NOTE 4 A robot can for example have two sets of limits, one for use in environments limited only to operators and one for use in environments which are open to the public, with the latter having lower speed limits.

Measures shall be taken to reduce risk to an acceptable level for exposed persons.

NOTE 5 Clause 7 of ISO/TR 23482-2:2019 includes examples of risk assessment process that lead to acceptable levels of risk for several types of service robots.

The applicability and appropriateness of the risk reduction measures listed in the standard can be determined by the risk assessment (e.g. requirements in the standard indicated as where appropriate)

If risks can be eliminated or reduced by measures that are not described in this standard, these measures shall achieve at least the same level of risk reduction as the measures described in this standard.

Service robots can adhere to additional standards and regulations if the robot is also intended to be used in environments or applications not within the scope of this standard.

The safety requirements for mobile service robots differ depending on whether they are equipped with manipulators or not.

Attachments to service robot, for example such as those used for cleaning or disinfection shall be considered during risk assessment and suitable measures for risk reduction shall be identified. The structure of the following sub-clauses reflects the three-step-method stated in ISO 12100:2010 in the following way:

- Requirements for inherently safe design measures are provided in subclauses 4.x.2 or 4.x.x.2 of each subclause 4.x or 4.x.x respectively.

- Requirements for safeguards and complementary protective measures are provided in subclause 4.x.3 and 4.x.x.3.
- Requirements for information for use are provided in subclauses 4.x.4 and 4.x.x.4.

When risk reduction is achieved by the use of safety-related control functions, the requirements of [Clause 6](#) apply.

Recommended methods of verification and validation of various requirements for the significant hazards are shown in subclause 4.x.5 or 4.x.x.5 of each subclause 4.x or 4.x.x (respectively). A description of the verification and validation methods is given in [Clause 8](#).

NOTE ISO/TR 23482-2 includes further information on structured approach of risk reduction of ISO 13482.

Additional safety requirements applicable to mobile service robots are in [Clause 6](#). Additional safety requirements applicable to wearable robots are in [Clause 5](#).

4.2 Hazards due to energy storage and supply

4.2.1 Contact with hazardous energy parts

4.2.1.1 General

A service robot shall be designed and constructed so that all hazards related with its energy are prevented.

Service robot's electrical equipment shall be designed and constructed in compliance with one or more of the following standards, relevant for its design and application:

IEC 60204-1:2021 for electrical equipment,

IEC 60335-1:2020 for appliances,

IEC 61140:2016 for electrical equipment,

ISO 4414:2010 for pneumatic equipment,

ISO 4413:2010 for hydraulic equipment,

IEC 62368-1:2023 for AV/ICT equipment,

IEC 61010-1:2010 for inspection, measurement, and process equipment

Any exposed person shall be protected from harm caused by direct or indirect contact with live electrical parts on the robot.

A means of isolating any hazardous energy sources (e.g. electrical, mechanical, hydraulic, pneumatic, chemical and thermal) shall be provided, if the limits specified in [4.2.1.2](#) are exceeded. Such hazardous energy sources shall be clearly identified, and the isolators shall be capable of being locked if accidental reconnection during maintenance can lead to a hazard.

4.2.1.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) use of safe extra-low voltage (SELV) sources for accessible circuits and parts according to the applicable standards such as IEC 60204-1:2021 or IEC 60335-1:2020 or IEC 62368-1:2023 or IEC 61010-1:2010.

NOTE 1 In IEC 61140:2016, SELV is defined as less than 25 V AC rms and 60 V DC

- b) use of low pressures for pneumatic/hydraulic equipment such that the resulting forces do not exceed the limits specified in ISO 4414:2010 and ISO 4413:2010, and the stress exerted upon the components used does not lead to hazardous situation.

NOTE 2 For more guidance see ISO 4413:2010, ISO 4414:2010.

Other types of stored energy shall be kept to a level as low as reasonably practicable, to minimize the hazard.

4.2.1.3 Safeguarding and complementary protective measures

Where guards or enclosures are used to protect from hazardous energy parts, their design shall conform to appropriate IP class as defined in IEC 60529:2019 for electrical hazards and safety distances of ISO 13857:2019 for other hazards as determined by risk assessment.

Where excessive heat is present, heat dissipation measures shall be applied (e.g. heat sinks, air flow). If fans are used, fan control devices are recommended.

4.2.1.4 Information for use

Warning markings indicating the form of hazardous energy (e.g. IEC 60417-6042 electric shock) should be put on the service robot. They shall comply with IEC 60417:2024, ISO 3864-2:2016, ISO 7000:2019, or ISO 7010:2019, and their meaning shall be explained in the information for use.

4.2.1.5 Verification and validation

Appropriate test method(s) shall be chosen from the following: A, B, C, E, H.

NOTE An applicable test method can be found in Clause 6.1 of ISO/TR 23482-1:2020.

4.2.2 Hazards related to battery

4.2.2.1 General

Persons shall be protected against hazards related to batteries in intended use and reasonably foreseeable misuse. Charging or discharging batteries shall not result in fire, explosion, electrolyte leakage, venting, burns, rupture, or other hazards.

Lithium batteries shall comply with IEC 62133-2:2017 or IEC 62619:2022. Batteries of other chemistries shall comply with an appropriate battery standard.

NOTE 1 IEC 62368-1:2023 Annex M includes a list of battery standards.

Hazards associated with internal (non-replaceable) batteries, or detachable (replaceable) batteries shall be considered.

Hazards associated with the method(s) employed to charge batteries shall be considered, including:

- through direct connection to an external docking station;
- connection by cordset to an external charger; or
- mains-connected cordset plugged into an internal charger;
- through inductive charging from a wireless power transmitter.

NOTE 2 External charging of a detachable (replaceable) battery when removed from the robot is not covered by this standard.

NOTE 3 Guidance for inductive charging from a wireless power transmitter can be found in IEC 62368-1:2023, ISO 15118-1, SAE J2954, ETSI EN 303 417.

If a service robot has a battery that can be charged while embedded inside the robot, persons shall be protected against hazards due to accidental contact with the charging connections on the robot and its charging systems.

When robots are intended to be automatically supplied with power when the power cable is connected to the robot, hazards that can occur due to the connection shall be considered.

If the robot is not intended to operate while charging, the robot's operation shall be prevented while charging.

If the remaining power of battery is insufficient to operate safely, the robot shall give status warning in order to avoid the situation where the user is brought to the level of unacceptable risk.

Chargers shall comply with IEC 60335-2-29:2019 or IEC 62368-1:2023 as appropriate and should be in compliance with IEC 60529:2019.

4.2.2.2 Inherently safe design

Batteries shall be suitable for intended use and reasonably foreseeable misuse. Batteries shall be operated within their specific ratings.

For robots with replaceable batteries, the design of the robot and/or the battery shall prevent reverse polarity installation or short circuit.

Charging contacts and plugs shall be designed in a way that accidentally touching live parts is prevented (e.g. caps for plugs and outlets).

The battery charging voltage shall conform to appropriate standard according to the application and/or environment of the charging systems, such as IEC 61010:2010, IEC 61140:2016, IEC 60335-2-29:2019, IEC 62368-1:2023 and IEC 61851-1.

4.2.2.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) sufficient ventilation shall be provided to batteries to prevent overheating or accumulation of hazardous gases;
- b) if there are battery hazards not fully addressed within the battery, the battery management system or the charger, they shall be prevented by the robot's control system. Examples include protection against over-discharge, excessively high or low temperatures, or overload conditions;
- c) the robot's control system shall respond appropriately to fault/error messages from the battery;
- d) charging connections shall be designed in such a way that they are only energised when the service robot is connected to a charging system;
- e) any in-built charging system shall automatically supervise the correct charging of the battery.

If each protective measure is to be achieved by functional safety, it shall be assured by an appropriate performance level according to the results of the risk assessment or according to [Annex C](#).

4.2.2.4 Information for use

Information for use shall contain instructions for battery charging, in particular:

- the procedure for charging the service robot;
- the environmental conditions (e.g., outdoor or indoor charging);
- requirement to switch the service robot off, or into a certain operational mode;
- appropriate warnings.

The battery charging status should be displayed.

Robots with replaceable batteries shall include the following markings (or equivalent):

- “WARNING: Risk of explosion if battery is replaced by an incorrect type. Replace battery only with the same type of battery. Dispose of used batteries according to instructions”;
- “WARNING: Risk of explosion. See manual for battery replacement.”

The manual shall state the types of battery that are suitable for replacement and instructions for disposal. In addition, the correct procedure for replacing the battery shall be described.

4.2.2.5 Verification and validation

Appropriate method(s) shall be chosen from B, C, D, E in [Clause 8](#).

4.2.3 Uncontrolled release of stored energy

4.2.3.1 General

Uncontrolled release of stored energy shall not lead to any hazard, including fire. This applies while the robot is operating as well as when the robot is switched off.

A means to remove hazards due to uncontrolled release or removal of stored hazardous energy shall be provided. This shall not lead to any additional hazard.

NOTE Stored energy can occur in pneumatic and hydraulic pressure accumulators, capacitors, batteries, springs, counter balances, flywheels, etc.

4.2.3.2 Inherently safe design

Stored energy shall be kept to a level as low as reasonably practicable. Energy storage shall be designed to prevent uncontrolled release of energy.

NOTE Uncontrolled release of stored energy can be prevented with e.g. high gear reduction ratio, electric fuse and pneumatic choke.

4.2.3.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) guards/covers shall be applied to minimize the risk during any release of energy;
- b) the robot shall be provided with the means to regulate its energy supply so as to prevent over-heating or over-currents caused by overloads, short circuits, clothes which encompass the heat source of the robot, or device malfunction.

4.2.3.4 Information for use

Labels shall be affixed to identify all the stored energy hazards and their locations. Information for use shall contain the description of the means, and the procedures for the removal of stored energy or hazards due to uncontrolled release of stored energy.

4.2.3.5 Verification and validation

Appropriate method(s) shall be chosen from the following: B, D, E, H.

4.2.4 Power failure or shutdown

4.2.4.1 General

Power failure or unintended shutdown, including low-power condition, of a service robot and subsequent re-application of power shall not lead to unacceptable risk. Special consideration shall be taken to ensure the following.

- a) Service robots shall be designed in a way that risks due to movement of the robot and robot components, instability (hazard from falling over due to loss of power, e.g. for robots with self-balancing functions), and dropping of loads in the event of failure or full or temporary shutdown of power are acceptable. This shall be achieved regardless of the type(s) of power supply (e.g. electrical, hydraulic, pneumatic, vacuum).
- b) Service robots equipped with mobile platforms shall be designed to ensure that the risks due to robot travel following failure or shutdown of power (e.g. loss of braking system function) are acceptable. This shall be achieved regardless of the robot locomotion mechanisms (e.g. wheels, tracks, legs).
- c) If a moving part of a service robot locks as a result power failure or shutdown and poses hazard, e.g., trapping a user, it shall be possible to move the part without drive power by a single person. This shall consider the full range of potential users to allow their escape or rescue, as determined by risk assessment. If this is not practicable, a complementary safe guarding measure shall be applied.

NOTE For unexpected start-up from power failure, see [4.3](#)

4.2.4.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) braking mechanisms shall take effect when they are de-energised;
- b) internal storage of sufficient energy (e.g. due to spring compression or electric capacitor) to allow recovery to a safe state following power failure/shutdown.

4.2.4.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) provision of an uninterruptable power source;
- b) service robots able to trap humans in isolated locations shall be provided with a means of summoning assistance powered independently;
- c) in case the available internal energy or stored power (e.g. battery power) falls below a certain threshold, the robot shall notify its status to the user and/or operator by means such as audio, light, vibration indications, and shall come into a safe state automatically.

4.2.4.4 Information for use

The information for use shall describe the residual risks relevant to power failure or shutdown. Maintenance procedures can be required following such power failures or shutdowns, if deemed necessary by risk assessment (see [8.4](#)).

4.2.4.5 Verification and validation

Appropriate method(s) shall be chosen from the following: B, D, E, H.

4.3 Robot start-up and restart of regular operation

4.3.1 General

Service robots shall not perform any hazardous action upon start up. The robot shall comply with ISO 14118:2017.

If self-testing during initialisation requires robot motion, the robot's axes may be moved by the necessary minimum to conduct the test. The risks associated with this motion shall be kept as low as reasonably practicable.

4.3.2 Inherently safe design

The following measures shall be applied where appropriate.

- a) The service robot shall start up in a state of restricted speed, force, etc. (see [6.5](#) and [6.8](#)) and shall only return to normal levels of control by means of a mode change (see [6.14](#)).
- b) The service robot shall always start up in manual mode, and shall only continue operation in autonomous mode by means of a mode change as specified in [6.14.1](#).

4.3.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate

- a) during start-up the service robot shall perform internal control tests, and start up the robot within safe limits (e.g. speed, force, etc.) to ensure that all safety-related functions are available before starting any hazardous operation;
- b) if the service robot's safety-related functions cannot be performed correctly after start up, then it shall immediately perform a protective stop;
- c) manipulators, mobile platforms and other moving parts shall be de-activated by safety-related functions at start-up (to prevent any unintended actions). Application functions shall only be enabled if it can be positively established, via sensors, that no hazardous situation exists. This measure shall be applied if the robot is intended to enter autonomous mode immediately after start-up.
- d) the service robot shall always start up in a stationary condition and shall only return to normal operation by means of an operator action.

4.3.4 Information for use

Necessary start-up and restarting instructions shall be provided in the robot's information for use according to the measures which have been applied.

4.3.5 Verification and validation

Appropriate method(s) shall be chosen from the following: B, D, F.

4.4 Electrostatic potential

4.4.1 General

The service robot shall be designed to avoid harm to humans caused by electrostatic potential and discharge.

Electrostatic discharge (ESD) protection shall be sufficient so that no personal protective equipment is required by users.

Any build-up of harmful electrostatic potential shall be discharged.

The service robot shall be designed to avoid harmful malfunction due to electrostatic potential discharge.

NOTE IEC 61000-4-2 gives additional guidance.

4.4.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) use of conductive materials;
- b) discharging of outer surfaces by earthing;
- c) other techniques to prevent build-up of electrostatic charge on surfaces or parts that can be touched.

4.4.3 Safeguarding and complementary protective measures

To avoid contact with live parts, electrical equipment enclosures and covers shall comply with the application Standard(s) per [subclause 4.2.1.1](#) (e.g., IEC 60204-1:2021, IEC 60335-1:2020, IEC 62368-1:2023, IEC 61010-1:2010).

4.4.4 Information for use

If necessary, relevant warning signs for ESD from ISO 7010:2019 shall be provided together with the information for use.

4.4.5 Verification and validation

Appropriate method(s) shall be chosen from the following: B, C, E.

NOTE IEC 61000-4-2 and ISO 7176-21 contain applicable test methods.

4.5 Hazards due to robot shape

4.5.1 General

Intended use case scenarios to perform intended tasks by the service robot shall be considered in the design of the overall shape of the robot, and of its external parts, to avoid the potential for accidents that could cause, for example, crushing, cutting, or severing injuries.

The age of persons (e.g., children) intended to be in the robot's operating area shall be considered in the design of the robot

The service robot shall be designed in a way, that protective equipment is not necessary to be worn during use and handling of the robot, except when required as part of a tool or maintenance task.

Risk assessment shall also consider the shape of load being carried by the service robot.

EXAMPLE Exoskeleton straps should be designed not to cause injuries, e.g. cutting or scratching or laceration.

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

4.5.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) Accessible components and parts of service robots shall ensure the radius of chamfer is at least 0,3 mm (radius or chamfer of more than 0,5 mm is preferred) according to IEC 63281-2-1.

- b) To prevent crushing of fingers the distance separating accessible moving parts from other moving parts or from fixed parts of the service robot shall, either be less than 5 mm, or greater than 18 mm in any position or in compliance with ISO 13854:2017 and ISO 15534:2000.
- c) The robot's joints (e.g., manipulator joints) shall be designed in a way that they have sufficient gaps to prevent the human body parts from being crushed when the joints are moved as intended by the manufacturer. This can be done by choosing the robot geometry as well as by restricting the joint limits inherently.

4.5.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) cushioning on sharp edges and points shall be provided to eliminate shearing, stabbing, cutting hazards and reduce impact hazards;

NOTE ISO/TR 23482-1:2020 Annex A provides quantitative criteria on hazards due to contact between human and robot (component).

- b) adjustment of the robot speed and behaviour, if hazardous loads (e.g. sharp or pointed objects) are being carried.

4.5.4 Information for use

Warnings and instructions mitigating shape-related risks shall conform to ISO 12100:2010, ISO 7010:2019, and/or IEC 60417:2024.

The information for use shall contain instructions for protective equipment (e.g. gloves) needed for handling, using, or operating, etc., the service robot.

Where the shape of load being carried can lead to additional hazards, appropriate instructions to deal with these risks shall be given.

Information on limiting the load being carried to objects which are not sharp or pointed shall be provided.

4.5.5 Verification and validation

Appropriate method(s) shall be chosen from the following: A, C, G, H.

4.6 Hazards due to power train components

4.6.1 General

Service robots shall be designed so that the risk of hazards caused by exposure to power train components such as motor shafts, gears, drive belts, wheels and tracks is acceptable.

NOTE Hazards due to collision of manipulators and mobile platforms with humans are covered in clause 4.9.6.

Service robots shall be designed in compliance with ISO 13857:2019 in order to prevent hazard zones being reached by parts of the body.

4.6.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) the service robot should be designed with the minimum number of accessible powertrain components;
- b) the service robot should be designed with moving parts in which components such as motor shafts, gears, drive belts, wheels and tracks are not exposed.

4.6.3 Safeguarding and complementary protective measures

Hazards due to moving parts shall be prevented either by fixed guards or by movable guards, depending on the foreseeable frequency of access, in accordance with ISO 14120 and the risk assessment..

Appropriate method(s) shall be chosen from the following.

- a) Where fixed guards are used, that can be removed e.g. for maintenance, the following measures shall apply:
 - 1) fixed guards shall be installed so that they can be opened or removed only with tools;
 - 2) their fixing system shall remain attached to the guards or to the service robot when the guards are removed, if deemed necessary by risk assessment;
 - 3) where applicable, guards shall be incapable of remaining in place without their fixings.
- b) Where movable guards are used, the following measures shall apply:
 - 1) movable guards shall be designed so that once opened, they remain attached to the service robot;
 - 2) movable guards shall be interlocked with the hazardous movements in such a way that hazardous movements come to a stop; the control system performing this function shall conform to [Clause 6](#) in accordance with the service robot's risk assessment; the guard shall remain closed and locked until the risk due to the hazardous machine functions covered by the guard has disappeared, in accordance with ISO 14119:2013;
- c) Enclosures shall be used to provide protection against hazardous rotating components in accordance with ISO 13857:2019.

4.6.4 Information for use

Where fixed or movable guards are incorporated into a service robot design, information for use shall include all instructions necessary for their correct installation, adjustment and removal.

4.6.5 Verification and validation

Appropriate method(s) shall be chosen from the following: A, B, H.

4.7 Emissions

4.7.1 Noise

4.7.1.1 General

Any human near the service robot shall be protected from hazardous noise (including ultrasonic noise) that could directly cause discomfort, stress, hearing loss, loss of balance or consciousness of the user, or similar disorders arising from the robot's operation.

The level of acoustic noise emitted by the service robot shall be sufficiently low that no special protective equipment needs to be worn.

Where a service robot communicates through loudspeaker the operator should be able to adjust the volume of the loudspeaker. The manufacturer should consider suitable measures for assessing loudspeaker sound in context of noise.

The service robot shall conform to noise emission standards appropriate to its intended purpose (e.g. see ISO 1996, ISO 3740, ISO 11200, ISO/TS 15666, ISO 15667).

NOTE 1 Acoustic environmental noise assessment can be found in ISO 1996-1 and ISO 1996-2.

NOTE 2 Noise validation test can be found in ISO/TR 23482-1:2020 clause 6.2.

NOTE 3 ISO 1999 provides recommendations for noise limits.

4.7.1.2 Inherently safe design

ISO/TR 11688-1 gives general technical information and guidance for the design of low-noise machines. Special care shall be taken in the acoustical design of the robot. The following measures shall be applied where appropriate:

- a) low-noise component: the service robot shall be constructed with components which are inherently silent in their operation;
- b) appropriate operational behaviour: robot actions and/or motions shall be designed to be as quiet as practicable, given the required tasks of the service robot;
- c) sound-damping materials: the service robot shall be constructed with materials that limit acoustic noise and reduce its emission to the outside environment.

NOTE ISO/TR 11688-2 gives useful information on noise generation mechanisms in machinery.

4.7.1.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) additional sound absorbing materials, e.g. foam, baffles, curtains, coatings;
- b) use of active noise cancellation (anti-noise) mechanisms.

4.7.1.4 Information for use

Information for use shall list safeguards and protective measures used for noise reduction, and shall give appropriate instructions for maintenance. Where necessary, instructions for regular checks of the emitted noise shall be provided.

4.7.1.5 Verification and validation

Appropriate test method(s) shall be chosen from the following: C, D.

NOTE An applicable test method can be found in Clause 6.2 of ISO/TR 23482-1:2020.

The dual-number declaration according to ISO 4871:1996 shall be applied, and the measurement, declaration and verification of noise emission values shall be made according to ISO 3746:2010 or ISO 11202:2010, as appropriate.

4.7.2 Substances and fluids

4.7.2.1 General

A service robot user shall be protected from emissions of any poisonous or noxious materials, or from solvents from the robot body surface or from even within its body if the solvent is highly volatile, which can cause burns or any kind of irritation (e.g. see ISO 14123-1).

The service robot shall be designed so that no hazardous substances and fluids are emitted. The robot shall be designed such that during normal operation no protective equipment needs to be worn by the user.

No material that can cause allergies should be used at a surface which comes into contact with human skin during normal use of the service robot.

NOTE Nickel, chromium and some types of rubber can cause allergic reactions.

4.7.2.2 Inherently safe design

The following measures shall be applied where applicable:

- a) elimination or avoidance of potentially hazardous substances and fluids, e.g. oil, cooling fluid, and dust arising from brake abrasion within the service robot;
- b) substitution of potentially hazardous substances and fluids, e.g. oil, cooling fluid, and brake materials by those which are less harmful or non-hazardous;
- c) design of the service robot to contain substances internally so that they are not leaked into the external environment.

4.7.2.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) measures to detect loss of hazardous substances and fluids (e.g. oil) if hazardous substances or fluids are needed for operation;
- b) shut-off valves or fuses to seal leaking fluid pipes;
- c) measures to prevent humans from touching in case of leakage (e.g. covers).

4.7.2.4 Information for use

Information for use shall be provided about any hazardous substances inside the service robot. If necessary, instructions for taking precautions during use, handling, maintenance, and disassembly of the robot shall be given.

If allergenic materials are used in exposed parts of the robot, the information about the materials shall be provided.

4.7.2.5 Verification and validation

Appropriate method(s) shall be chosen from the following: E, G, H.

4.7.3 Extreme temperatures**4.7.3.1 General**

A service robot user shall be protected from extreme temperatures (either high or low temperatures) of the robot or its components that can cause burns, chilblains, stress, discomfort, or similar disorders of any kind. To achieve this requirement, the service robot shall conform to ISO 13732-1:2006 (Clause 4), ISO 13732-3:2005 (Clause 6.2), or other relevant standard listed in [Clause 4.2.1.1](#).

NOTE Surface temperatures between 10 °C and 43 °C are normally not considered to be extreme (ISO 13732-1:2006, ISO 13732-3:2005).

4.7.3.2 Inherently safe design

The following measures shall be applied where applicable:

- a) elimination or avoidance of extreme high/low temperature sources within the service robot;
- b) choosing materials and their textures with appropriate thermal conductivities.

4.7.3.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) reducing (or increasing) the surface temperature with an appropriate cooling (or heating) system;
- b) isolation or the application of guards (see ISO 13732-1:2006 (clause 4) for high temperature and ISO 13732-3:2005 (clause 5) for low temperature);
- c) where necessary, temperatures inside the service robot, especially near heat sources shall be monitored: the robot shall react in an appropriate way (e.g. shutting itself off in a safe manner), if temperature limits are exceeded.

NOTE ISO/TR 23842-1 clause 9 provides temperature test methods.

4.7.3.4 Information for use

Information for use shall contain warnings and markings on the hot/cold parts having extreme temperatures in compliance with ISO 3864-1:2011. If necessary, instructions for taking precautions during use, handling, maintenance and disassembly of the service robot shall be given.

4.7.3.5 Verification and validation

Appropriate test method(s) shall be chosen from the following: C, D.

NOTE An applicable test method can be found in Clause 6.3 of ISO/TR 23482-1:2020.

4.7.4 Radiation

4.7.4.1 General

Emissions by hazardous radiation including incoherent broadband radiation shall be prevented. Light sources other than lasers shall be designed not to exceed Risk Group 2, in accordance with IEC 62471:2006.

NOTE 20 W/m² for eyes and 100 W/m² for skin surface, both at 0,1 m or more away from the source, are standardized in the case of radio wave ranging from 30 GHz to 100 GHz.

If the robot employs a laser, it shall comply with IEC 60825-1:2014. A Class 3B or Class 4 laser as classified by IEC 60825-1:2014 that is incorporated into a service robot shall not be exposed to humans. The lowest possible laser class required by the application shall be used.

Service robot users and third parties shall be protected from ionising radiation emitted by the robot or its components. Exposure to such radiation shall be minimized to avoid any harmful physical injuries or disorders.

Mechanisms producing ionising radiation should not normally be used in any service robot. If such a mechanism is essential for the robot's application (i.e. where there is no alternative method of achieving the application objectives) then special protection requirements shall be developed. Special safety protection measures shall be developed in accordance with appropriate standards (e.g. ISO 2919, ISO 3925 and ISO 14152).

4.7.4.2 Inherently safe design

Whenever possible, use of lasers shall be limited to Class 1 per IEC 60825-1:2014.

NOTE National and regional legislation regarding occupational safety and health (OSH) and regarding the general public, for example for consumer products, can contain additional or different requirements.

4.7.4.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) protective shutters;
- b) interlocking movable guards;
- c) direction control of laser beams, e.g. avoiding directions where eyes are likely to be according to the requirements in [clause 5.1](#);
- d) controlling laser-power (e.g. pulse duration, intensity) in compliance with [clause 5.1](#);
- e) for lasers of class 2 and higher, the protective measures of IEC 60825-1:2014 shall be met.

4.7.4.4 Information for use

Information for use shall provide details of potentially hazardous emissions likely to be encountered by persons and, where appropriate, property in the operational environments of the service robot. If appropriate, the information for use shall advise not to look directly into light, shall give information for personal protective devices and other special behaviour. If appropriate, markings on the robot shall be attached, and their meaning shall be described in the information for use.

4.7.4.5 Verification and validation

Appropriate method(s) shall be chosen from the following: C, D, G.

4.8 Electromagnetic interference

4.8.1 General

For all reasonably foreseeable electromagnetic disturbances, hazardous robot motion and unsafe system states shall be prevented.

The service robot shall conform to EMC standards relevant for their designated use environment, e.g.

- IEC 61000-6-1 for immunity in residential, commercial and light-industrial environments;
- IEC 61000-6-2 for immunity in industrial environments;
- IEC 61000-6-3 for emissions in residential environments;
- IEC 61000-6-4 for emissions in industrial environments.

NOTE IEC 61000-1-2 provides a methodology for the achievement of functional safety of electrical and electronic systems, including equipment, with regard to electromagnetic phenomena.

4.8.2 Inherently safe design

The functions of the control system described in [6.1](#) shall be designed to meet the electromagnetic immunity requirements of IEC 61326-3-1:2017.

Other function(s) of the service robot should meet IEC 61000-6-1 or IEC 61000-6-2, according to the intended operating environment.

4.8.3 Safeguarding and complementary protective measures

The risk shall be reduced to an acceptable level by electromagnetic shielding against incoming radiation.

4.8.4 Information for use

Information for use shall provide necessary information of the property of the radiating electromagnetic waves as well as the property of the electromagnetic waves which can potentially cause interference.

4.8.5 Verification and validation

Appropriate test method(s) shall be chosen from the following: B, C, D.

NOTE An applicable test method can be found in Clause 14.3 of ISO/TR 23482-1:2020.

4.9 Stress, posture and usage

4.9.1 General

Hazards can arise from both physical and mental aspects of using the service robot. In addition to reducing the individual effects as described in [4.9.2](#) and [4.9.3](#), the combined effects shall also be considered in the risk assessment.

4.9.2 Physical stress and posture

4.9.2.1 General

Risk assessment shall identify hazards due to physical stress and posture, and the service robot's design shall ensure that any such risk is minimized. This can be achieved by, but not be limited to, the following requirements:

- a) A service robot shall be designed to minimize or reduce physical stress or strain to its user due to continuous use, including but not limited to uncomfortable posture, operational environments that would directly cause physical discomfort, e.g. pressure ulcer and/or blister, fatigue and tendon inflammation.
- b) The design of the service robot shall take into account typical body sizes of the intended user population in order to avoid physically demanding body postures or to ensure easy operation. ISO 14738 and ISO 6385 describe how principles of ergonomic factors, by construction of workstations and machinery, can be applied. This should be considered when building a service robot, where somebody sits on or stands in front of the robot.

4.9.2.2 Inherently safe design

This may include, but not be limited to, the following measures:

- a) the design and location of manual control devices, so that they can be operated without physical stress or discomfort;
- b) the proper ergonomic design and location of the seat, so that good posture can be maintained during operation of the service robot;
- c) command devices that are detachable or hand-held instead of being permanently attached to the service robot in an inappropriate position.

4.9.2.3 Safeguarding and complementary protective measures

Safeguarding and complementary protective measures may include, but not be limited to, the following measures:

- a) use of shock absorbing (suspension) mechanisms;
- b) use of posture supports.

4.9.2.4 Information for use

The information for use shall contain instructions about the correct way to operate the manual control devices and how to use the service robot. The information for use shall include the need for proper training where necessary.

4.9.2.5 Verification and validation

Appropriate test method(s) shall be chosen from the following: A, C, D, H.

NOTE An applicable test method can be found in Clause 8 of ISO/TR 23482-1:2020.

4.9.3 Mental stress**4.9.3.1 General**

Risk assessment shall identify hazards due to mental stress and usage, and the service robot's design shall ensure that any such risk is minimized. This can be achieved by, but not be limited to, the following requirements:

- a) a service robot shall be designed to minimize or reduce mental stress to its user and third party due to continuous use (see ISO 10075-2:1996, clause 4.2);
- b) user interfaces such as controls, signalling or data display elements, shall be designed to be easily understood so that clear and unambiguous interaction between the user/third party and the service robot is possible (see ISO 6385:2016, clause 3.6.5);
- c) tactile and haptic interfaces shall be designed not to activate hazardous level of force (see ISO 9241-920:2009, clause 5.3).

NOTE Additional guidance can be found in other related standards appropriate to human-centred ergonomics design such as ISO 9241-100, ISO 9241-210, etc.

4.9.3.2 Inherently safe design

Inherently safe design may include, but not be limited to, the following measures:

- a) provision of adequate lighting;
- b) designing the service robot to avoid the need for sustained attention in order to detect critical signals as far as reasonably practicable or over long periods of time;
- c) adequate display design;
- d) reduction of signal uncertainty and improvement of detectability.

4.9.3.3 Safeguarding and complementary protective measures

There are no recommended measures for safeguarding with respect to this hazard.

4.9.3.4 Information for use

The information for use shall contain instructions about the correct way to operate the manual control devices and how to use the service robot. The information for use shall include the need for proper training where necessary.

4.9.3.5 Verification and validation

Appropriate method(s) shall be chosen from the following: A, C, D, H.

4.10 Robot motion

4.10.1 General

The risk of hazards due to any motion (intended or unintended) of the service robot shall be reduced to an acceptable level. Robot components shall be designed, constructed, secured, or contained so that the risks of hazards caused by breaking or loosening are reduced to acceptable levels.

Exposed persons shall be protected from hazardous movement of the service robot, e.g. rollovers, runaways and falls under normal usage and operation of the robot, curves, inclines, and similar operational conditions in its working environment.

4.10.2 Mechanical stability

4.10.2.1 General

Service robots shall be designed to have sufficient stability for any intended use during the robot lifecycle including transportation, installation, normal use, service/maintenance, decommissioning and dismantling. Special consideration shall be given to:

- Instability in case of failures;
- Static and dynamic forces from moving parts and loads.

The risk assessment shall also consider reasonable foreseeable misuse such as climbing on the robot or unintentional leaning on the robot.

The service robot shall conform to mechanical stability standards appropriate to its intended purpose.

The service robot shall be designed so that no extraordinary actions or procedures are required by the user in order to maintain its mechanical stability.

Specific stability requirements for wearable robot type in particular situations are specified in [clause 5.7.1](#).

NOTE If the robot's design is not inherently stable (e.g., self-balancing type), appropriate handling conditions should be given according to the structural characteristics of the robot in its unpowered state.

The service robot shall be designed to minimize mechanical instability (e.g. overturning, falling or excessive leaning when in motion) due to failure or reasonably foreseeable misuse.

Mechanical stability shall not be affected in any phase of the robot's life cycle (including handling, transportation, installation, use, de-commissioning, and dismantling).

Stability shall be maintained against static and dynamic forces from any moving parts and loads of the robot within the usage conditions specified by the manufacturer as the limits.

A service robot shall be protected from potential instability due to reasonably foreseeable external forces (e.g., climbing or mounting on the robot, unintentionally leaned on by human to the robot) from humans around the robot.

4.10.2.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) designing the ground support area to be as large as reasonably practicable;
- b) designing the centre of gravity of the service robot to be as low as reasonably practicable;
- c) designing the masses and inertia of moving parts, especially the manipulator, to be as low as reasonably practicable.

4.10.2.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) use of stability control such as tilts at an appropriate angle to counteract an applied external force;
- b) means to detect the onset of instability and act (or not) to reduce harm;
- c) means to limit the velocity or range of the manipulator;
- d) means to prevent overload.

EXAMPLE Tilt sensors, harnesses, roll-bars, feedback control, monitoring and controlling the zero moment point.

Any control systems performing the above functions shall comply with [6.1](#), in accordance with the robot's risk assessment.

4.10.2.4 Information for use

The information for use shall contain limits of use for the service robot concerning slope of travel surface, speed, payload, etc.

Where appropriate, a warning shall be given, either in the manual or on the robot itself, that the persons shall not lean against the robot.

4.10.2.5 Verification and validation

The robot shall be tested per appropriate verification and validation methods in the most unfavourable position based on the robot construction. All movable and adjustable robot parts and rated maximum load of the robot, shall be arranged in any combination that results in the least stability.

NOTE Applicable test methods can be found in ISO/TR 23482-1.

4.10.3 Instability during travel

4.10.3.1 General

A service robot capable of travel shall be designed to ensure that it does not cause any hazardous rollovers, runaways, or drops of its body parts or loads being carried during travel. This shall be achieved for all intended travel patterns (e.g. forward/backward travels, rotations, turns/U-turns, accelerations, and decelerations) in its specified operating environments, which is determined depending on its specific application type and design.

The robot shall be designed to be able to travel on slopes and thresholds of intended use environment specified by the manufacturer.

Robots tethered with an external supply connection shall be designed to account for hazards of robot's instability due to stepping, disconnection of supply. Examples of supply can be painting, compressed air, electrical power, water, etc.

For service robots whose stability vary depending on configurations and loads, maximum speeds and accelerations shall be determined for each intended situation as follows:

- a) The robot shall not tip over when performing a U-turn on a slope in its smallest possible turning radius, with a person in normal traveling posture and/or a manipulator grasping the maximum load and assuming the most unfavourable pose, as applicable.
- b) The robot shall not tip over when operating the manipulator to the maximum intended range of motion with the manipulator gripping the most adverse load to the extent intended by the manufacturer with the run stopped on the test slope.

Even under the conditions described above, the robot shall be designed to restore its posture and not to roll over; this requirement shall apply to instability that occurs within the scope described in the specifications of robot.

For service robots that travel autonomously, the control system should be designed, as far as reasonably practicable, to ensure travel stability under foreseeable conditions. In addition, factors like operational environment, failures and travel patterns shall be taken into consideration.

NOTE [Table 4.1](#) lists examples of operational environments and travel patterns that could be factors that cause instability while the robot is travelling and the instability events caused by such factors. The probability of occurrence increases especially when two or more of these factors are combined. Therefore, conditions combining these factors can be given due consideration in the design as well.

Table 4.1 — Example of instability events and its factors during travel of robots

Category	Examples of factors	Examples of instability events caused by the factors
Operational environment	Slopes	— The robot travels backward when travelling uphill or moves down after entering a stopped state. — The robot becomes uncontrollable when travelling downhill and becomes unable to restore its posture.
	Bumps on floor surfaces	— The robot stumbles over a bump and becomes unable to restore its posture
	Openings or grooves on travelling surfaces	— Dropping
	Continuous irregularities on traveling surfaces	— The robot becomes unable to restore its posture
	Wet ground surfaces	— Slipping, spinning, or overrun — The robot becomes unable to restore its posture
	Foreign objects caught in wheels	— The wheel becomes locked and the MSR becomes unable to restore its posture
	Stairs or large openings	— Falls down
Failures	Faulty drive wheel motors	— The wheel becomes locked and the MSR becomes unable to restore its posture
Travel patterns	Sudden acceleration or deceleration (sudden stops)	— The robot becomes unable to restore its posture
	Sharp turns or U-turns	— Slips, spinning, overrun, rollovers

4.10.3.2 Inherently safe design

The following measures shall be applied where appropriate:

- design of the mass distribution within the service robot to ensure that the robot cannot fall, rollover or overturn, even when travelling at maximum acceleration/deceleration or turning at maximum speed on the worst case travel surface gradient identified within the intended environment specified for the robot or when load or an extended manipulator is placed in the most critical position;
- design of the travel actuators (e.g. wheels, legs/feet) shall ensure that sufficient adhesion with the terrain is maintained over all terrain types, even on slippery surfaces, etc., as defined in the specification of intended environmental conditions for the service robot;
- design of the stability of the service robot to ensure that it does not fall, rollover or overturn when travelling over uneven terrain, up to the worst case limits defined within the intended environmental conditions specified for the robot.

4.10.3.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) the service robot shall be able to plan a travel path to perform its intended task based on environmental sensing technology;
- b) travel surface sensing, including means to protect the service robot from falling due to different elevations (e.g. stairways, holes), or from rolling over, shall be provided for the intended operational environments (see [6.6](#));
- c) restriction of the dynamics (e.g. speed, acceleration and centre of mass) of the service robot within limits that ensure the robot will not overturn, even when attempting to turn on a worst-case travel surface gradient identified within the intended environment specified for the robot;
- d) restriction of the workspace of a manipulator to prevent the center of gravity of the robot, including the maximum load, from exceeding the stability range under all expected travel conditions

Any control systems performing the above functions shall conform to [\(6.1\)](#) in accordance with the service robot's risk assessment.

4.10.3.4 Information for use

Information for use shall specify conditions of the environment under which the service robot can operate. For environmental conditions that can lead to hazardous situations but are likely to be found in situations where the robot performs its tasks, the information for use shall contain warnings.

Information for use of warning signals, e.g. audio, visual, vibrations, or any combination of signals shall be provided.

If necessary, proper training shall be provided to avoid abnormal and abrupt operations, e.g. sudden turns, accelerations/decelerations.

4.10.3.5 Verification and validation

Travel stability performance shall be evaluated under various safety-related surface conditions according to the results of risk assessment (surface conditions, e.g. carpets, metal tiles, plastic laminates and turfs).

Appropriate method(s) shall be chosen from the following: B, D, F.

NOTE An applicable test method can be found in Clause 13 of ISO/TR 23482-1:2020.

4.10.4 Instability while carrying loads

4.10.4.1 General

Changes in the kinematic properties of the service robot due to the load shall not cause any hazard.

Any human near the service robot shall be protected from falling objects when the robot performs tasks, as well as while carrying up to maximum loads. This shall include uneven loads and movable loads (e.g. fluids sloshing in storage containers).

Risk assessment shall consider the consequences of dropped loads and any actions required by the service robot in the aftermath of any such event. Also the loss of a fixture shall be considered by the risk assessment.

For emergency operation, the maximum deceleration rate shall be commensurate with emergency stop dynamic criteria including the requirements for load stability and retention.

4.10.4.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) the holders, placement areas, racks, etc., on the service robot, but especially end effectors (e.g. grippers or robotic hands), shall be designed to avoid the potential for accidents by lost loads;
- b) use of form fitting designs;
- c) use of passive means of securing loads (e.g. screws, elastic ties, spring-loaded clamp);

4.10.4.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) loads shall be tied or locked down by bolting or latching devices, or held by a gripping device;
- b) the maximum speed and acceleration shall be commensurate with requirements for load stability during normal operation;
- c) for normal operation, including a protective stop or an emergency stop, the deceleration rate shall be commensurate with requirements for load stability.
- d) detection of the weight and position of load placed on the robot, e.g. in a cargo bed in order to maintain a safe weight distribution under all expected travel patterns.

Any control systems performing the above functions shall conform to [6.1](#), in accordance with the service robot's risk assessment.

4.10.4.4 Information for use

Information for use shall contain information about maximum size and/or weight and type of loads (if appropriate), and their limits that can be carried. Where loads require fastening, instructions shall be provided. Where appropriate, load limits that depend on certain configurations of the manipulator shall be specified.

4.10.4.5 Verification and validation

The performance of hands, grippers, and fittings shall be determined by a series of extreme movements, e.g. acceleration, stops, and U-turns of the mobile service robot and fast manipulator movements. All tests shall be carried out with maximum load and with the maximum speed.

Appropriate method(s) shall be chosen from the following: B, D, F.

4.10.5 Instability in case of collision**4.10.5.1 General**

Persons shall be protected from hazardous movements related to collisions. A collision between a service robot and any hazardous obstacle should not cause instability of the robot.

A service robot shall be designed to ensure that it does not cause any hazardous rollovers, runaways, or detachment of robot body parts, even when it receives any collision forces or reacts to humans or hazardous obstacles during its motion, up to the limits specified for its intended operation.

4.10.5.2 Inherently safe design

The following measures shall be applied where appropriate:

- a) design of the mass distribution and shape of the service robot so that unintended collisions within the maximum expected limits do not result in overturning;

- b) use of soft materials to absorb forces which lead to hazardous instability.

4.10.5.3 Safeguarding and complementary protective measures

The following measures shall be applied where appropriate:

- a) design of braking performance of the mobile platform of the service robot to prevent runaway under a collision of the maximum expected force (see [6.2.3](#));
- b) design of the motion behaviour of the service robot to minimize impact forces (see [6.8](#));
- c) use of safety-related speed control (see [6.5](#)) to minimize instability and high impact forces during collisions.
- d) prevent shifting of loads due to a collision.

4.10.5.4 Information for use

Information for use shall specify all necessary precautions that need to be taken by the user of the robot, e.g. where and how loads can be fastened/located and how much can be loadable.

4.10.5.5 Verification and validation

Appropriate method(s) shall be chosen from the following: B, D, F, G.

4.10.6 Collisions

4.10.6.1 General

Service robots shall be designed such that unacceptable risks due to collision with humans or hazardous obstacles (see [3.9](#)) are avoided. A risk assessment shall be made including procedures of how to manage collisions. Risks related to collisions can be mitigated by the following approaches:

- Preventing a collision event by stopping or performing an evasion movement;
- Reducing the transfer of power, force or pressure to the human.

If one or more manipulators are used while a mobile service robot is travelling, risk assessment shall consider the additional risks originating from the combined motion. In particular, it shall be taken into account

- a) that the velocity of moving components combine, leading to higher impact forces;
- b) that in case of a protective stop the component of the robot with the longer stopping time and stopping distance will determine when all components come to a stop;
- c) that braking distances can add up, which can require larger sensing distances for person detection sensors;
- d) that the reaction forces from a stopping manipulator can lead to a change of orientation of the mobile platform;
- e) that a safety-related force control of a manipulator can fail as safeguard, if the mobile platform pushes the manipulator forward after it has stopped;
- f) that the stability of the robot is affected by the mass of an extended manipulator and mass of payload handled by the manipulator as well as reaction forces due to the moving mass.

If a manipulator handles load while traveling, the load shall remain stable under all travel conditions. An unexpected stop of the robot shall not lead to dropped loads.

NOTE ANSI-RIA R15.08-1-2020 "Industrial mobile robots" provides more detailed examples of how stability during travel is impacted.

If the MSR is intended to perform manipulator work during travel, then in addition to the specific requirements of this clause, it shall be required to comply with any additional safety requirements identified by the risk assessment results by the manufacturer.

4.10.6.2 Inherently safe design

Inherently safe design may include, but not be limited to, the following measures:

- a) physical limitation of the speed of all parts of the service robot to an inherently safe maximum (according to [clause 6.1](#));
- b) moving parts should be designed so that unacceptable impact energy, force or pressure are avoided;
- c) reduce impact forces and pressures to levels that do not cause harm (e.g. use of materials, structures, geometry).

4.10.6.3 Safeguarding and complementary protective measures

In order to reduce the probability of possible collisions, one or more of the following measures shall be applied:

- a) calculating a minimum distance between the service robot and a hazardous obstacle and stopping the robot or reducing speed that avoid unacceptable risk if this distance is not maintained: this can be achieved by position and speed control (see [6.5](#)) or by functions that avoid the hazardous obstacle, e.g. electro-sensitive protective equipment (ESPE)(see [6.6.2.1](#));

NOTE 1 ISO 13855:2010 provides default speed of human approach within the context of workers. The robot speed should be reduced to a speed that avoids un-acceptable risk. This speed is not necessarily zero. If collision energy is provided mostly/only by the human, risk reduction can be achieved by reducing projecting geometries, including sharp edges and corners.

NOTE 2 [Annex B](#) presents examples of operational spaces for service robots.

NOTE 3 [Annex E](#) presents an example application of a service mobile robot with collision avoidance capability. The speed of the robot can be controlled in the safeguarded space, where the relative velocity of humans is detected and can be used for reduced speed control.

- b) executing a protective stop (see [6.2.2.3](#)), when a human is in the service robot's protective stop space;
- c) hand-guiding or steering the service robot. In this case, the risk assessment shall consider if all collisions with the robot can be avoided.

NOTE 4 ISO 13855:2010 provides default speed of human approach within the context of workers. However, the ISO 13855:2010 is not intended for small children and infants. It is important that stronger or more demanding requirements for detection are considered (e.g. lower pressure for bumper actuation, smaller resolution of ESPE in order to detect the smaller limbs of children) when deemed necessary by risk assessment.

In order to reduce the effects of possible collisions, one or more of the following measures shall be applied:

- use of safety-related speed control (see [6.5](#));
- use of safety-related force control ([6.8](#));
- use of safety-related contact sensing ([6.6.2.2](#)).

4.10.6.4 Information for use

Information for use shall describe the collision avoidance behaviour of the robot. Where any degree of manual control is required for collision avoidance, information for use shall provide the user instructions required and the limits of the applied control measures.