
**Machine tools safety — Machining
centres, Milling machines, Transfer
machines —**

**Part 1:
Safety requirements**

*Sécurité des machines-outils — Centres d'usinage, fraiseuses,
machines transfert —*

Partie 1: Exigences de sécurité

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Foreword

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

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

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 document 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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 39, *Machine tools*, Subcommittee SC 10, *Safety*.

Introduction

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

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

- machine manufacturers (small, medium and large enterprises);
- health and safety bodies (regulators, accident prevention organisations, market surveillance, etc.).

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

- machine users/employers (small, medium and large enterprises);
- machine users/employees (e.g. trade unions, organizations for people with special needs);
- service providers, e.g. for maintenance (small, medium and large enterprises);
- consumers (in case of machinery intended for use by consumers).

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

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

When requirements of this type-C standard are different from those stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Milling machines present a wide range of hazards. Protection of operators and other persons from contact with moving cutting tools, especially when being rapidly rotated in the spindle or being swung from a tool magazine to the spindle during power-operated tool changing, or from contact with fast-moving workpieces, is of great importance.

When power-operated mechanisms are provided for workpiece transfer, they can also create hazardous situations during loading/unloading and workpiece alignment, clamping or releasing of the workpiece.

The significant hazards covered by this document are those listed in [Clause 4](#). The safety requirements and/or protective measures to prevent or minimize those hazards identified in [Table 2](#) and procedures for verification of these requirements or measures are found in [5.17](#).

The figures in [Annex D](#) are examples only and are not intended to illustrate the only interpretation of the text.

Machine tools safety — Machining centres, Milling machines, Transfer machines —

Part 1: Safety requirements

1 Scope

This document specifies the technical safety requirements and protective measures for the design, construction and supply (including installation and dismantling, with arrangements for transport and maintenance) of stationary milling machines (see 3.1.1), including machines capable of performing boring operations (see 3.1.2), machining centres and transfer machines which are intended to cut cold metal, and other non-combustible cold materials except for wood or materials with physical characteristics similar to those of wood as defined in ISO 19085-1, and for glass, stone and engineered/agglomerated materials as defined in EN 14618.

This document covers the following machines:

- a) manually, without numerical control, operated boring and milling machines (see 3.2.1, Group 1), e.g. knee and column type milling machines (see Figures C.1 and C.2);
- b) manually, with limited numerical control, operated boring and milling machines (see 3.2.2, Group 2), e.g. profile and contouring milling machines (see Figures C.3 and C.4);
- c) numerically controlled milling machines and machining centres (see 3.2.3, Group 3), e.g. automatic milling machines and milling centres, e.g. multi-spindle milling machines, gear-milling machines (see Figures C.5, C.6 and C.7);
- d) transfer and special-purpose machines (see 3.2.4, Group 4), which are designed to process only pre-specified workpieces or limited range of similar workpieces by means of a predetermined sequence of machining operations and process parameters (see Figures C.8, C.9, C.10, C.11, C.12 and C.13).

This document also applies to machines fitted with the following devices/facilities:

- tool magazine(s);
- tool changer(s);
- workpiece handling mechanism(s);
- powered workpiece clamping mechanism(s);
- swarf/chip conveyor(s);
- power-operated door(s);
- additional equipment for turning;
- additional equipment for grinding.

When in this document the sole word “machine” or “machines” is being used, it is referred to all above-mentioned groups and types of machines.

This document deals with all significant hazards, hazardous situations and events relevant to this type of machinery which may occur during transportation, assembly and installation, setting, operation, cleaning and maintenance, troubleshooting, dismantling or disabling according to ISO 12100, when the

machinery is used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer (see [Clause 4](#)).

This document presumes accessibility to the machine from all directions and specifies access conditions to operator positions. It also applies to workpiece transfer devices including transport devices for loading/unloading when they form an integral part of the machine.

2 Normative references

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

ISO 230-5:2000, *Test code for machine tools — Part 5: Determination of the noise emission*

ISO 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

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

ISO 6385, *Ergonomics principles in the design of work systems*

ISO 9355-1, *Ergonomic requirements for the design of displays and control actuators — Part 1: Human interactions with displays and control actuators*

ISO 9355-2, *Ergonomic requirements for the design of displays and control actuators — Part 2: Displays*

ISO 9355-3:2006, *Ergonomic requirements for the design of displays and control actuators — Part 3: Control actuators*

ISO 11161:2007, *Safety of machinery — Integrated manufacturing systems — Basic requirements. Amended by ISO 11161:2007/Amd1:2010.*

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 11204:2010, *Acoustics — Noise emitted by machinery and equipment — Determination of emission sound pressure levels at a work station and at other specified positions applying accurate environmental corrections*

ISO 11228-1, *Ergonomics — Manual handling — Part 1: Lifting and carrying*

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

ISO 13849-1:2015, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

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

- ISO 13851:2002, *Safety of machinery — Two-hand control devices — Functional aspects and design principles*
- ISO 13854, *Safety of machinery - Minimum gaps to avoid crushing of parts of the human body*
- ISO 13855:2010, *Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body*
- ISO 13856-1, *Safety of machinery — Pressure-sensitive protective devices — Part 1: General principles for design and testing of pressure-sensitive mats and pressure-sensitive floors*
- ISO 13856-2, *Safety of machinery — Pressure-sensitive protective devices — Part 2: General principles for design and testing of pressure-sensitive edges and pressure-sensitive bars*
- ISO 13857:2008, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs*
- ISO 14118:2000, *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 14120:2015, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*
- ISO 14122-1, *Safety of machinery — Permanent means of access to machinery — Part 1: Choice of fixed means and general requirements of access*
- ISO 14122-2, *Safety of machinery — Permanent means of access to machinery — Part 2: Working platforms and walkways*
- ISO 14122-3, *Safety of machinery — Permanent means of access to machinery — Part 3: Stairs, stepladders and guard-rails*
- ISO 14122-4, *Safety of machinery — Permanent means of access to machinery — Part 4: Fixed ladders*
- ISO 14738, *Safety of machinery — Anthropometric requirements for the design of workstations at machinery*
- ISO 15534-1, *Ergonomic design for the safety of machinery — Part 1: Principles for determining the dimensions required for openings for whole-body access into machinery*
- ISO 15534-2, *Ergonomic design for the safety of machinery — Part 2: Principles for determining the dimensions required for access openings*
- ISO 15641, *Milling cutters for high speed machining — Safety requirements*
- ISO 16156:2004, *Machine-tools safety — Safety requirements for the design and construction of work holding chucks*
- ISO 19085-1, *Woodworking machines - Safety - Part 1: Common requirements*
- ISO 19353, *Safety of machinery — Fire prevention and fire protection*
- ISO 23125:2015, *Machine tools — Safety — Turning machines*
- IEC 60204-1:2009, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*
- IEC 60529, *Degrees of protection provided by enclosures (IP code); Corrigendum 2*
- IEC 60825-1, *Safety of laser products — Part 1: Equipment classification and requirements*
- IEC 61000-6-2, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments*

ISO 16090-1:2017(E)

IEC 61000-6-3, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments*

IEC 61800-5-2:2016, *Adjustable speed electrical power drive systems — Part 5-2: Safety requirements — Functional*

IEC 62061:2005+AMD1:2012+AMD2:2015, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

IEC/TS 62046, *Safety of machinery — Application of protective equipment to detect the presence of persons*

EN 1005-1+A1, *Safety of machinery — Human physical performance — Part 1: Terms and definitions*

EN 1005-2+A1, *Safety of machinery — Human physical performance — Part 2: Manual handling of machinery and component parts of machinery*

EN 1005-4+A1, *Safety of machinery — Human physical performance — Part 4: Evaluation of working postures and movements in relation to machinery*

EN 1127-1:2011, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

IEC 61000-4-2, *Electrostatic discharge immunity test*

IEC 61000-4-4, *Electrical fast transient / burst immunity test*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and ISO 13849-1 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 General terms

3.1.1

milling machine

machine tool using geometrically defined rotary cutters to remove material in order to produce plane or formed surfaces on a workpiece while advancing (i.e. feeding) the tool or the workpiece in a certain direction (axis movement) or certain directions (axes movements)

3.1.2

boring machine

machine tool for boring holes in which the principal motion is a rotating cutter against a non-rotating workpiece along a feed axis and the diameter of the hole is adjusted by a different axis which is usually perpendicular to the feed axis

Note 1 to entry: This definition does not include machines exclusively for drilling.

3.1.3

stationary machine

machine which is assembled, installed and intended to be used permanently at a predefined location

3.1.4**boring operation**

machining process of enlarging a hole that has already been produced (e.g. drilled or cast), by means of a single-point cutting tool or a boring head which contains several such tools

3.1.5**numerical control**

NC

automatic control of a process performed by a device that makes use of numeric data introduced while operation is in progress

[SOURCE: ISO 2806:1994, 2.1.1]

3.1.6**computerized numerical control**

CNC

realization of *NC* (3.1.5) using a computer to control the machine functions in which the part program is generated by inputting data manually at the machine

[SOURCE: ISO 2806:1994, 2.1.2, modified — Manual data input]

3.1.7**manual data input**

MDI

mode of operation of a CNC system in which the part program is generated by inputting data manually at the machine

3.1.8**electro-sensitive protective-equipment**

ESPE

assembly of devices and/or components working together for protective tripping or presence-sensing purposes comprising a sensing device, controlling monitoring devices, output devices and all interconnecting wiring

[SOURCE: IEC 61496-1:2012, 3.5]

3.1.9**active opto-electronic protective device**

AOPD

device whose sensing function is performed by opto-electronic emitting and receiving elements detecting the interruption of optical radiation, generated within the device, by an opaque object present in the specified detection zone

Note 1 to entry: IEC 61496-2 gives detailed provisions on AOPD. For applications, see IEC/TS 62046.

3.1.10**pressure sensitive protective device**

PSPD

sensor(s) that responds to the application of pressure, a control unit and one or more output signal switching device(s) and equipment for detecting persons or parts of persons which generates an appropriate signal to the control system to reduce risk to the persons detected

Note 1 to entry: ISO 13856-1, ISO 13856-2 and ISO 13856-3 give detailed provisions.

Note 2 to entry: Safety-related control system associated with the PSPD or the PSPD itself can further include a secondary switching device, start interlock, re-start interlock, etc.

3.1.11

operational stop

stop of the machine movements in the production process

Note 1 to entry: Control functions between control system and machine drives are maintained (torque, speed of rotation, position).

3.1.12

safe operating stop

SOS

operational stop with additional control system measures for monitoring standstill, preventing hazardous machine movements due to control system faults

Note 1 to entry: The SOS function prevents the motor from deviating from the stop position by more than a specified value. The power drive system supplies the motor with energy so that it can withstand external forces; see also IEC 61800-5-2.

3.1.13

safe stop 1

SS1

function which either

- a) initiates and controls the motor deceleration rate within set limits to stop the motor and initiates the STO function when the motor speed is below a specified limit, or
- b) initiates and monitors the motor deceleration rate within set limits to stop the motor and initiates the STO function when the motor speed is below a specified limit, or
- c) initiates the motor deceleration and initiates the STO function after an application specific time delay

Note 1 to entry: This safety function corresponds to a controlled stop in accordance with stop category 1 of IEC 60204-1.

3.1.14

safe stop 2

SS2

function which either

- a) initiates and controls the motor deceleration rate within set limits to stop the motor and initiates the safe operating stop function when the motor speed is below a specified limit, or
- b) initiates and monitors the motor deceleration rate within set limits to stop the motor and initiates the safe operating stop function when the motor speed is below a specified limit, or
- c) initiates the motor deceleration and initiates the safe operating stop function after an application specific time delay

Note 1 to entry: This safety function corresponds to a controlled stop in accordance with stop category 2 of IEC 60204-1.

3.1.15

safe torque off

STO

function which ensures that no energy is applied to the motor that can cause rotation or motion (in the case of a linear motor)

Note 1 to entry: The Power Drive System (PSD) will not provide energy to the motor which can generate torque or force (in the case of a linear motor).

Note 2 to entry: This safety function corresponds to an uncontrolled stop in accordance to stop category 0 of IEC 60204-1.

Note 3 to entry: This safety function may be used where power removal is required to prevent an unexpected start-up.

Note 4 to entry: In circumstances where external influences (e.g. falling of suspended loads) are present, additional measures (e.g. mechanical brakes) may be necessary to prevent any hazardous situation.

Note 5 to entry: Electronic means and electric contactors are not adequate for protection against electric shock and additional measures for isolation may be necessary.

**3.1.16
direction control**

positive actuation device to select and maintain a movement

Note 1 to entry: A direction control can be a soft key, touch key, push button control or a rotary type button, e.g. for opening or closing a door or for a movement for clockwise or counter clockwise.

**3.1.17
non-combustible materials**

materials, excluding wood, with $PCS \leq 3,0 \text{ MJ/kg}$ (ISO 1716) or $\Delta T \leq 50 \text{ }^\circ\text{C}$ and $\Delta m \leq 50 \%$ and $t_f \leq 20 \text{ s}$ (ISO 1182), which withstand surface flame attacks and edge flame attacks with 30 s exposure time without flame spread in excess of 150 mm vertically from the point of application of the test flame within 60 s from the time of application (ISO 11925-2)

**3.1.18
short presence**

dwelling time of a person staying in the hazard zone less than an accumulated time of one hour, but never more than 10 min per single exposition, during an 8 h shift

Note 1 to entry: See also IEC 62061:2005, Table A.2.

3.2 Groups of machines

With regard to the applications and the relevant hazards, machines are subdivided into four different groups. See the overview in [Table 1](#).

Table 1 — Overview of groups of machines

Group No.	Group name	Subclause in which group is defined
Group 1	Manually controlled boring and milling machines without numerical control	3.2.1
Group 2	Manually controlled boring and milling machines with limited numerical controlled capability	3.2.2
Group 3	Numerical controlled milling machines, milling and machining centres	3.2.3
Group 4	Transfer and special purpose machines	3.2.4

3.2.1

Group 1: Manually controlled boring and milling machine without numerical control

machine where axis motion is controlled by actuation of a mechanical handwheel or where powered single-axis motion is controlled by mechanical, electrical or other means but without the capability for programmed multiple axes movement

Note 1 to entry: For illustration, see [Figures C.1](#) and [C.2](#).

3.2.2

Group 2: Manually controlled boring and milling machine with limited numerical controlled capability

machine that can be operated like a Group 1 machine by the use of mechanical or electronic handwheels or as a machine with limited NC control by operating controls on the NC panel

Note 1 to entry: For illustration, see [Figures C.3](#) and [C.4](#).

Note 2 to entry: This group of machines may be equipped with some or all of the features of Group 1 machines (manual machines without NC) and the following:

- a limited numeric control system (NC) providing;
- constant service speed (CSS);
- axis interpolation (i.e. copying/predefined profiling);
- thread cutting cycles.

However, the following features shall not be provided:

- automatic program start;
- automatic initiated tool change;
- unlimited rapid axis movements;
- automatic workpiece change or bar feed system.

3.2.3

Group 3: Numerical controlled milling machine, milling and machining centre

numerically controlled machine capable of performing programmed multiple axis movements

Note 1 to entry: For illustration, see [Figures C.5](#), [C.6](#), and [C.7](#).

Note 2 to entry: Such machines may incorporate facilities for manual control in varying degrees.

Note 3 to entry: It is possible to have different machining processes within Group 3 machinery. For these kind of processes, e.g. turning, grinding, etc., see relevant standard.

3.2.4

Group 4: Transfer and special purpose machine

machine designed to process only a pre-specified workpiece or family of workpieces, by means of a predetermined sequence of machining operations and process parameters

Note 1 to entry: For illustration, see [Annex C](#), [Figures C.8](#) to [C.13](#) and [Figures D.7](#) to [D.8](#).

3.3 Parts of machines

3.3.1

station of a transfer machine

zone which is processing in each operation of the transfer machine working cycle including also the fixtures, units, spindle heads and other mechanisms associated with the process performed at a particular station

Note 1 to entry: See [Figures C.11](#), [C.12](#) and [C.13](#).

Note 2 to entry: Stations are normally identified by sequential numbering, e.g.:

- station 1: Load station
- station 2: Machining station
- station 3: Gauging station
- station 4: Idle station
- station xx: Unload station

3.3.2

electronic handwheel

manual pulse generator

MPG

manually operated control device which initiates and maintains an axis movement by pulse generation input to the *numerical control* (3.1.5) during its rotation

3.3.3

workpiece setting station

machine area in which the workpiece is loaded/unloaded

3.3.4

workpiece transfer device

device incorporated in the machine (e.g. pallet changer) to load/unload the workpiece

3.3.5

workpiece load/unload mechanism

mechanism that delivers workpieces to, or removes them from, the machine

3.3.6

feed axis

axis for feeding a cutting tool or a workpiece

Note 1 to entry: "Feed axis" may be driven by one or more feed drives.

3.3.7

work zone

zone where the cutting process is taking place

3.3.8

accessible work zone

zone of a machine where a stationary standing position is required within the work zone for use in accordance with its intended purpose

3.3.9

spindle

drive system for rotating a cutting tool (tool spindle)

3.3.10

workholding spindle

drive system for rotating a workpiece in case of turning and grinding operation

3.3.11

counter spindle

spindle which is constructed of two workholding spindles facing each other and those spindles can be rotated synchronously

3.4 Mode of safe operations

3.4.1

mode of safe operation

MSO

mode of operation to supply a defined amount of machine functions under predefined safety measures

Note 1 to entry: Mode of safe operation is not a function itself. The functions summarized under the term mode of safe operation can only be used when that particular mode of safe operation has been activated.

Note 2 to entry: See [Clause 5](#) for safety requirements and measures relating to modes of safety operations.

3.4.2

MSO selection system

facility for manual selection of the machine mode of safe operation, to which only an authorized group of persons have access

3.4.2.1

MSO access device

facility which limits access to an authorized group of persons and prevents accidental or abusive actuation of the selection system

3.4.2.2

MSO selection device

facility which allows changing the mode of safe operation of a machine

Note 1 to entry: The selection device can be integrated into the access device, e.g. in a key switch (mode of safe operation selector switch).

3.4.2.3

MSO activation device

device that activates a selected mode of safe operation

3.4.3

mode of safe operation 0

MSO 0

operation of the machine by the operator with non-automatic mode of the machine axes, where the operator has control over the machining process without the use of pre-programmed operations

Note 1 to entry: MSO 0 is also be referred to as manual mode.

Note 2 to entry: The motion of axes can be controlled by means of a hold-to-run control device, direction control, electronic handwheels or joysticks.

3.4.4

mode of safe operation 1

MSO 1

automatic, programmed, sequential operation mode of the machine with the facility for manual or automatic loading/unloading of workpieces and tools, until stopped by program or operator

Note 1 to entry: MSO 1 is also be referred to as automatic mode.

Note 2 to entry: The automatic mode can include an operational interruption for loading/unloading of workpieces and tools.

3.4.5**mode of safe operation 2**

MSO 2

operation mode in which adjustments and preparations for the following machining process are performed by the operator(setter) with the possibility that guards are open and/or protective devices suspended

Note 1 to entry: MSO 2 is also be referred to as setting mode.

Note 2 to entry: Assessments of tool or workpiece position (e.g. by touching the workpiece with a probe or tool in single step mode) are procedures of the setting mode (see [5.2.4.5](#)).

3.4.6**mode of safe operation 3**

MSO 3

limited automatic mode (fixed sequence of separate consecutive steps) started by the operator, which temporarily allows manual control or numerically controlled operation of the machine, with guards opened and/or protective devices suspended

Note 1 to entry: MSO 3 is also be referred to as optional special mode for manual intervention under restricted operating conditions.

3.4.7**mode of safe operation service**

MSO Service

operation mode for service and maintenance tasks while guards are open and/or protective devices suspended

Note 1 to entry: Examples for service and maintenance tasks are checking the accuracy of positioning of an axis by laser systems, circular interpolation testing, spindle error analysis, vibration analysis, etc.

3.5 Maximum permissible spindle speed and feed rate**3.5.1****maximum spindle speed**

maximum permissible rotational speed for a tool spindle specified and set as a machine parameter by the machine manufacturer

3.5.2**reduced spindle speed**

maximum permissible rotational speed (speed limit) of a spindle limited by control for safety purpose by the machine manufacturer

Note 1 to entry: The spindle speed for both, tool and workpiece, is reduced for safety reasons in MSO 2, MSO 3 and MSO Service.

3.5.3**maximum feed rate**

maximum permissible feed rate of the axes, specified and set as a machine parameter by the machine manufacturer

Note 1 to entry: The maximum permissible feed rate of the axes depends on constructional limits specified by the manufacturer of the machine.

3.5.4**reduced feed rate**

maximum permissible feed rate limited by control for safety purposes

Note 1 to entry: The feed rate is reduced for safety reasons in MSO 2, MSO 3, and MSO Service.

3.5.5 safely limited speed

SLS

function to prevent the motor from exceeding the specified speed limit

Note 1 to entry: The SLS function prevents the motor from exceeding the specified speed limit, see IEC 61800-5-2 and also safety functions in [Table J.17](#), 17.3 and 17.4.

3.5.6 minimum quantity lubrication

MQL

process of using a little quantity lubrication on cutting point by external spray or through-tool systems

Note 1 to entry: The amount to be used depends on the machining process and type of MQL delivery system.

4 List of significant hazards

4.1 General

This clause contains all the significant hazards, hazardous situations and events identified by risk assessment as significant for this type of machinery and which require action to eliminate or reduce the risk.

4.2 Main hazard zones

The main hazard zones are the following:

- a) working areas with moving spindle(s) and workpiece(s), clamping components for workpiece and tool clamping, tool changer, copying unit(s), setting places for workpiece(s) and tool(s), coolant under high pressure, special measuring devices (e.g. laser);
- b) handling devices for workpiece loading/unloading;
- c) tool magazines and tool changers;
- d) area surrounding the swarf and chip conveyor (if integrated);
- e) exposed gear box;
- f) exposed cam mechanisms;
- g) lead screw (Group 4: manual machines without NC functions);
- h) feed screw (Group 1: manual machines without NC functions);
- i) ball screw (Groups 2, Group 3 and Group 4 machines);
- j) linear and rotary drives.

4.3 Significant hazards and hazardous situations covered by this document

The significant hazards covered by this document are listed in [Table 2](#).

Table 2 — List of significant hazards and hazardous situations

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas at milling machines	Possible consequences	Relevant clause in this document
1	Mechanical hazards			
1.1	Approach of a moving element to a fixed part	Manual operations between the area of tool and parts of the machine, for milling application, especially the work piece support or between tool and workpiece	Crushing hazard Shearing hazard	5.1 5.2
		Manual operations between the areas of changing mechanisms, e.g. tool changer / workpiece changer or pallet changer	Drawing-in or trapping hazard	5.2
		Feed motion of tool to the workpiece	Crushing hazard Shearing hazard Ejected parts	5.1 5.2
		Manual operations near to the workpiece or machine spindle	Entanglement hazard	
		Clamping of tools and workpieces	Crushing hazard Shearing hazard	5.2.5
1.2	Moving elements	Operations in the near area of moving axes and in the area of automatic loading/ unloading devices during processing, setting, maintenance, repair Operations on tool changer/ workpiece changer/ pallet changer Operations in the area of operating platforms	Impact hazard Drawing-in or trapping hazard Crushing hazard Shearing hazard	5.1 5.2
1.3	Rotating elements	Unintended contact with the rotating tool or rotating workpiece or tool cleaning device	Drawing-in or trapping hazard Friction or abrasion hazard	5.1 5.2
1.4	Cutting parts, sharp edges	Unintended contact with sharp edges of machine elements, workpiece or tool	Stabbing or puncture hazard Friction or abrasion hazard	5.1 5.2
1.5	Falling or ejected objects	Ejection or fall of work material and chips during machining, machine setting, tool changing, maintenance, or shut down — falling workpiece; — tool break ; — ejected broken machine element(s) at or near machine	Crushing hazard Impact hazard Stabbing or puncture hazard	5.1 5.2 5.8 5.12 Annex A , Annex B and Annex E

Table 2 (continued)

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas at milling machines	Possible consequences	Relevant clause in this document
1.6	Gravity	Falling of moving machine elements during machine setting, e.g. during tool changing or workpiece changing and weight loaded axes Breakage during operation Dropping or falling of machine elements during transport or setup, e.g. activities in the vicinity of gravity-loaded axes Operations in the area of operating platforms or pits	Crushing hazard Shearing hazard Impact hazard	5.2.5.5 5.2.5.6 Annex G, G 3.1.1
1.7	Height in relation to the floor	Fall from high situated work places	Impact hazard Slip, trip, and fall hazards	5.15
1.8	High pressure	At hydraulic elements during stay at or near machine, especially during installation of the machine Start-up and working on coolant systems	Penetration or impact of media under pressure into the skin/eyes	5.8.1 b) 5.8.1 c)
1.9	Lack of stability	Unrestrained machine or machine part falls or overturns during stay at or near machine	Impact hazard Crushing hazard Shearing hazard	5.13
1.10	Rough, slippery surface	Operations on ground and in the area of stairs around the machine, as well as work at height due to: — ejection or spillage of metal cutting fluid, lubricants or hydraulic fluid; — residuals, contained in ejected fluids; — insufficient railing or other restraining facilities, especially at places where a fall hazard exists	Slip, trip, and fall hazards	5.13 5.14 5.15
2	Electrical hazards			
2.1	Live parts	Contact with live parts	Electric shock hazard	5.3
2.2	Parts which have become live under fault	Contact with parts which are live by fault	Electric shock hazard	5.3
3	Thermal hazards			
3.1	Objects or materials with high/low temperature	Ejection of hot swarf or workpieces during milling operation during stay at and/or near machine, and hot/cold surfaces	Burn hazard Frostbite hazard	5.6
3.2	Explosion		Burn, fall, and bump hazards	5.6 Annex E Annex F

Table 2 (continued)

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas at milling machines	Possible consequences	Relevant clause in this document
3.3	Flame		Burn hazard	5.6 Annex E Annex F
4	Noise hazards			
4.1	Manufacturing process and moving elements	Vibration of tool and/or work material while processing, drive and transmission elements, during stay at or near machine blowing air for cleaning	Permanent hearing loss All further (e.g. mechanical, electrical) problems due to Interference with speech communication or acoustical signals	5.4
5	Vibration hazards			
5.1	Vibrating elements	Transfer of vibrations from the milling process to the operator	Discomfort Neurological disorder	5.7
6	Radiation hazard			
6.1	Low- and high-frequency electromagnetic radiation	At electrical equipment, especially during setup or maintenance	Burn hazard	5.5
6.2	Optical radiation (infrared, visible and ultraviolet), including laser	At measuring equipment especially during setup or maintenance	Eye and skin injuries	5.5
7	Material/Substance hazard			
7.1	Biological or microbiological substance (viral or bacterial)	Contact with contaminated coolant during stay at and/or near machine	Infection hazard	5.6
7.2	Fluid	Skin contact with coolant, during stay at and/or near machine	Skin damage	5.6
7.3	Mists and vapour	Inhalation and ingestion of substances used or generated during operation (e.g. coolant) during stay at and/or near machine	Difficulties of breathing poisoning.	5.6
7.4	Combustible dust	Operating with: — combustible dust, e.g. aluminium-, titan-, magnesium swarf, and/or — flammable coolant, e.g. oily coolant	Fire and explosion hazard, burns.	5.6 Annex E Annex F

Table 2 (continued)

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas at milling machines	Possible consequences	Relevant clause in this document
8	Ergonomic hazards			
8.1	Design or location of visual display units	Misinterpretation of displayed information at work place of operator	All further (e.g. mechanical, electrical) problems due to human errors	5.7
8.2	Design, location or identification of control devices	Maloperation of the machine at work place of operator		5.7
8.3	Excessive effort	At control devices and during handling	Fatigue	5.7
8.4	Body posture		Musculoskeletal disorders	5.7
8.5	Repetitive activities	Inadequate consideration of anatomy of hand/arm or foot/leg during workpiece or tool changing Inadequate consideration of body posture during maintenance tasks	Fatigue, Motivation for defeating of safeguarding equipment	5.4 , 5.7
8.6	Visibility, local lighting	Operations during handling/positioning of work material and the tool, during loading/unloading, during machine setting, tool changing and maintenance	Judgement and accuracy of manual actions impaired Fatigue Human errors	5.7
8.7	Human error / human behaviour	Reasonably foreseeable misuse of the machine Incorrect work material and milling tool handling and setting Insufficient design of work place and/or organization of the machining process Inadequate consideration of anatomy of hand/arm or foot/leg Faulty mounting	All above listed hazards	5.11
9	Hazards related to the operational environment of the machine			
9.1	Electromagnetic interference	Uncontrolled movements (including changes in speed, unintentional, unexpected start-up)	Crushing, shearing, trapping, entanglement hazards	5.8.7

Table 2 (continued)

No.	Causes of hazards and hazardous situations	Examples of operations, hazardous situations and hazardous areas at milling machines	Possible consequences	Relevant clause in this document
10	Combination of hazards			
10.1	Failure of the power supply	Fall or ejection of moving machine elements or clamped work-piece or tool Failure of stopping moving elements	Crushing hazard Shearing hazard	5.8 5.9
10.2	Restoration of energy supply after an interruption	Uncontrolled movements (including change of velocity) unintended/unexpected start-up	Impact hazard Cutting or severing hazard	5.8
10.3	Failure/disorder of the control system	Fall or ejection of moving machine elements or clamped work-piece or tool Failure of stopping moving elements Uncontrolled movements (including change of velocity) Unintended/unexpected start-up Other hazardous situations due to failure or inadequate design of the control system	Entanglement hazard Drawing-in or Trapping hazard Stabbing or puncture hazard Friction and abrasion hazard	5.8 5.9

5 Safety requirements and/or protective/risk reduction measures

5.1 General requirements

5.1.1 General

Machinery shall comply with the safety requirements and/or protective/risk reduction measures of this clause. In addition, machinery shall be designed according to the principles of ISO 12100 for relevant but not significant hazards, which are not dealt with in this document.

For guidance in connection with risk reduction by design, see ISO 12100:2010, 6.2, and for safeguarding measures, see ISO 12100:2010, 6.3.

Machinery shall be designed and safeguarded in accordance with the specific requirements and/or protective measures listed in this clause. All requirements and/or protective measures are given in this clause.

NOTE An analysis of the failure of machine components, including failure in the control system(s), is part of the risk assessment guidance on this subject and is given in ISO 13849-2. Generally used safety functions and their required performance level (PLr), including all associated categories in accordance with ISO 13849-1, are listed in [Tables J.2 to J.22](#). Typical demand rates are specified in [Table I.1](#).

5.1.2 Required characteristics for guards of all machine groups

5.1.2.1 General

The work zone shall be enclosed by fixed and/or interlocked movable guards during machining operations.

Guards shall be in accordance with ISO 14120. The fixing systems of fixed guards shall remain attached to the guards or to the machinery when the guards are to be removed in accordance with the intended use of the machine for routine cleaning, setting and maintenance operations by the user of the machine.

5.1.2.2 Fixed guards

The requirements are the following.

- a) Where enclosure is not reasonably practicable (e.g. due to the size of the workpiece, its geometry, other special characteristics of the machine or its application), operators and other exposed persons shall be safeguarded by a combination of other means (e.g. protected operator position by a cabin perimeter fence, other protective devices). For example, where external equipment (e.g. crane) is used to load/unload workpiece to a large size machine, cabin and perimeter fence are more practical safeguards rather than an enclosure.
- b) Where guards are floor-mounted (e.g. perimeter fencing), they shall be fixed securely and have at least a height of 1 400 mm and a distance in accordance with ISO 13857:2008, Table 2 to prevent access to the hazard zone. Any opening between the bottom of the guard and the floor shall not exceed 200 mm (see ISO 11161:2007/Amd1:2010, 8.5.2). Where operator access through these guards is required (e.g. load/unload) ergonomic reasons dictate that these requirements can be waived as long as the relevant requirements of [Table J.6](#), [Table J.8](#), [Table J.9](#) and [Table J.10](#) are met and there is no hazard posed to the operator in carrying out this task.
- c) For the guarding of drives, access to mechanical power transmission drives (e.g. chains and sprocket wheels, gears, feed screws, ball screws, etc.) shall be prevented by fixed guards (including telescope type guards), unless they are safe by sufficient distances (see ISO 13857:2008, Table 2). If access to these parts is required during normal operation of the machine more frequently than once per shift, interlocked movable guards shall be provided.

5.1.2.3 Moveable interlocked guards

- a) Movable interlocked guards shall be interlocked with or without guard locking in accordance with ISO 14119 in order to prevent access to hazardous areas where hazardous machine movements take place. It shall be ensured that the hazard zone cannot be reached when opening an interlocking guard before the hazardous machine motion has stopped (see ISO 13855:2010, 9). The selection of interlocking devices shall be in accordance with ISO 14119:2013, 6.
- b) A detected failure in the interlocking device, i.e. function or arrangement, shall result in a stop of the machine initiated by a safety related stop function according to [Annex J](#). Only for control with integrated safety technology, SOS in accordance with IEC 61800-5-2 satisfies the above-mentioned requirements (SS2-stop). This measure does not apply in all cases, where the stop itself is also afflicted by error (e.g. energy loss).

5.1.3 Power-operated moveable guards for user access

5.1.3.1 General

Requirements regarding accessing the work zone (see [5.2.3.1](#)) shall also apply.

It shall not be possible in MSO 1 to start the movement of the machine until the guard is fully closed. Closing of the guard can be used as a start command for the machine, if the guard system meets the requirements of ISO 12100:2010, 6.3.3.2.5.

Movements of gravity loaded power-operated guards shall not result in any hazardous situation when power loss takes place.

Power operated movable guards for user access can be realized as automatic power operated movable guards or manually controlled power operated movable guards.

5.1.3.2 Power-operated moveable guards where motion is initiated automatically by the control system

- a) Where whole body access to the work zone is not foreseen

Pressure sensitive edges or reduced forces shall be provided. They shall be in accordance with ISO 12100:2010, 6.3.3.2.6 and ISO 14120:2002, 5.2.5.2 and shall be equipped with a protective device to avoid shearing hazards at the front edge or shall be provided with round edges with a radius of at least 2 mm for each edge and a combined value (sum of the two radii) of at least 6 mm.

- If pressure-sensitive edges are provided, they shall be fitted on the total length of the front edge up to a maximum height of 2 700 mm above the floor or platform (ISO 13857:2008, 4.2.1.3). The pressure-sensitive edge shall be in accordance with ISO 13856-2. While opening there shall be no hazards posed by crushing and shearing edges.
- If reduced forces are used, the force to prevent the guard from closing shall not exceed 75 N and the kinetic energy of the guard shall not exceed 4 J. When the guard is fitted with a protective device which automatically initiates reopening of the guard on actuation, this may be a maximum of 150 N and the kinetic energy a maximum of 10 J.

Limitation of energy and forces shall be done according to ISO 14120 and length of time period according to EN 16005.

- b) Where whole body access to the work zone is foreseen

In addition to 5.1.3.2 a), further additional measures according to 5.2.3.2 c) 3) shall be provided to prevent entrapment in the hazard zone and a start command for closing of the power operated moveable guard shall only be possible from outside the accessible hazard zone.

5.1.3.3 Manually controlled power-operated moveable guards

For manually controlled power-operated movable guards, one of the following protective measures shall be provided.

- a) Manual operation of the power-operated guard by means of two-hand control. Fixed operator position in case of movement of the power-operated guard by means of arranging the operator panel in a position in sufficient distance to the hazard area (ISO 13855:2010, Clause 8), at least 100 mm with adequate shrouding with the two buttons B1 (first hand) and B2 (second hand) of a two-hand control (according to ISO 13851);

Or

- b) Manual operation of the power-operated guard by means of enabling device (ISO 12100) and direction control.

- A minimum distance to the hazard area is not mandatory for the operator.
- Enabling device and direction control are mounted on an operating desk or on a portable manual operating desk to ensure full visibility to the hazard area for the operator.
- As long as there is only an impact hazard (gap > 300 mm), travel speed up to 25 m/min is allowed.
- When the gap between the movable power-operated guard and the fixed guard is less than 300 mm presenting a shearing or crushing hazard, a maximum travel speed of only 5 m/min is allowed.
- By releasing the enabling device (first hand) or the direction control device (second hand), the drive should decelerate to a standstill as quickly as possible (IEC 60204-1:2009, 9.2.2);

Or

- c) Manual operation of the power-operated guard by single-handed control. For single-handed control, the location of the hold-to-run control device shall be in a fixed safe position. By releasing the single-handed control device, the drive shall decelerate to a standstill initiated by a safety related stop function according to [Annex J](#).

NOTE Safety functions are to be found in [Table J.13](#).

5.2 Specific requirements resulting from mechanical hazards

5.2.1 Protective measures for Group 1 machines

The following requirements for safeguarding of Group 1 machines shall be fulfilled.

- a) To inhibit access to the cutting tool (figures in [D.1](#)), adjustable cutter guard(s), adjustable guard(s) or interlocked movable guard(s) shall be provided. Guards shall be in accordance with ISO 14120, interlocking shall be in accordance to ISO 14119.
- b) An electrical interface shall be provided to connect an interlocked movable guard with the control of the machine, e.g. to prevent spindle rotation when the guard is open.
- c) Regarding handwheels, the hazard of entrapment, trapping and impact resulting from power rotation of handwheels shall be prevented, e.g. by automatic disengagement or by using plain solid (no spokes) handwheels with either no pegs or sprung to safe position pegs.
- d) Protective clothing and training are important. As the operator is not completely protected from ejection hazards in the work zone, special attention shall be given to the documentation, i.e. the instructions for use, to ensure that the operator has the required qualification and uses the personal protective equipment (PPE), e.g. safety glasses, tight fitted clothing, etc. (see instructions in [6.3.1 p](#)) and, as far as possible, uses additional safety devices, adapted to the pending machining process.
- e) Continuous powered axis feed rate shall not exceeding 2 m/min and/or a hold-to-run controlled rapid traverse axis speed not exceeding 5 m/min.

If Group 1 machines provide continuous powered axis feed speed exceeding 2 m/min and/or hold-to-run controlled rapid traverse axis speed exceeding 5 m/min, then the requirements of [5.2.2](#) for Group 2 shall also apply to Group 1 machines.

5.2.2 Protective measures for Group 2 machines

The characteristics of guards and specific requirements for Group 2 machines are the following.

- a) The work zone shall be guarded with fixed and/or interlocked movable guard(s) (see [Figure D.2](#)). Guards shall be in accordance with ISO 14120, interlocking shall be in accordance with ISO 14119. Guard locking (ISO 14119) shall be provided when opening of the interlocked movable guard provides access to any hazards during deceleration (i.e. run-down); see ISO 13855:2010, 9.
- b) Any machine movements shall only be possible when the interlocked movable guard(s) are/is closed. Interlocking devices shall be in accordance with ISO 14119. Opening of an interlocked movable guard shall cause the hazardous movements to stop and to be inhibited. The stop shall be in category 0 or category 1 according to IEC 60204-1:2009, 9.2.5.3. For control with integrated safety technology, SOS, SS2, SS1, and STO in accordance with IEC 61800-5-2 satisfy the above-mentioned requirements.
- c) When powered machine movements are required with the movable guard open (e.g. for setting), these movements shall only be permitted under the following restrictions:
 - 1) Axis feed moving speed shall be limited to 2 m/min and initiated and maintained with a hold-to-run control device (ISO 12100:2010, 3.28.3).

- 2) Spindle rotation shall be initiated and maintained by one of the following means:
- a hold-to-run control device;
 - a spindle start device together with an enabling device. When a manual data input (MDI) followed by command “cycle start” is carried out, the axis and spindle movement shall be initiated and maintained only while the enabling device is actuated. Releasing the enabling device shall initiate a safety related stop function according to [Annex J](#). For control with integrated safety technology, SOS, SS1, SS2, and STO in accordance with IEC 61800-5-2 satisfy this requirement.
- 3) The rotational speed of the spindle shall be limited by the capability to stop the rotation, while the moveable guard is open and the safety functions are effective. After a stop command, the spindle shall stand still within 2 revolutions without tool. In case of power loss or errors in the control or the power elements, coast of spindle drive is permissible.
- d) Fixed and/or interlocked movable guard(s) shall be provided to prevent access to moving machine elements with linear speeds greater than 15 m/min; where only an impact hazard exists; or 2 m/min where a crushing, shearing or trapping hazard exists. The safety distances for guards to prevent the operator or other exposed persons from reaching into the hazard zone shall be according to ISO 13857:2008, Table 4 to Table 7.

5.2.3 Protective measures for Group 3 and Group 4 machines

5.2.3.1 Access to the work zone

Guards shall be provided to reduce the risks listed in [Table 2](#) (e.g. entanglement, crushing, shearing, etc.) by preventing access to dangerous parts/areas of the machines (see [Clause 4](#)). General guidance for the selection of safeguards, where the hazards from moving parts cannot be avoided by design, is given in [5.1.2](#) and in ISO 12100:2010, Table B.1. For features of guards used to minimize the hazards of ejection, see [5.12](#).

The work zone shall be enclosed where reasonably practicable by fixed and/or interlocked movable guards during machining operations. Where enclosure is not reasonably practicable (e.g. due to the size of the workpiece, its geometry, other special characteristics of the machine or its application), operators and other exposed persons shall be safeguarded by a combination of other means (e.g. protected operator position by a cabin, perimeter fence, other protective devices). For example, where external equipment (e.g. crane) is used to load/unload workpiece to a large size machine, cabin and perimeter fence are more practical safeguards than an enclosure. See [5.16](#) for more information on operator cabins and perimeter fencing.

All protective equipment for detecting access to the work zone, such as ESPE or PSPD, shall be in accordance with the following standards:

- ESPE, see IEC 61496-1, IEC 61496-2, IEC 61496-3;
- PSPD, see ISO 13856-1, ISO 13856-2, ISO 13856-3.

NOTE See [3.1.8](#) for ESPE and [3.1.10](#) for PSPD.

Distances between the protective equipment (e.g. AOPDs) and the work zone shall be in accordance with ISO 13855 in regards to the approaching speed.

5.2.3.2 Characteristic of guards

The characteristics of guards and specific requirements for Group 3 and Group 4 machines are the following:

- a) Mounting: Where reasonably practicable, work zone guarding shall be fixed to the structure of the machine (see ISO 14120:2015, 3.2.1). For examples, refer to [Figures D.3](#) to [D.8](#).

- b) Observation: Where routine observation of the machine operation is required, means (e.g. windows) shall be provided so that this can be achieved without the need to open, remove or suspend any work zone guarding or other protective device(s) (see also [Table 2](#), 8.6 on visibility and local lighting).
- c) Interlocking of guards:

- 1) All guards through which frequent access of more than once per shift to hazardous movements is required during operation, shall be designed as interlocked movable guards. The opening of a guard or actuation of a protective device, in any MSO, shall cause the safety requirements of the selected MSO to be initiated (see ISO 14118). If opening of an interlocking movable guard exposes the operator(s) to crushing, shearing, cutting or severing, entanglement, drawing in or trapping, impact, stabbing or puncture hazards, guard locking shall be provided (ISO 14119).

If prolonged movement (e.g. coast of spindle) is to be expected after a power failure, access to the machine shall be prevented by guard locking device in de-energized state.

- 2) Measures to minimize possible defeat of interlocking device(s) shall be taken (see ISO 14119:2013, 7).
- 3) When persons can have whole body access or can remain in the hazardous zone(s) without being visible to the operator, means to inhibit restart shall be provided. These means can be
 - presence-sensing protective equipment,
 - door closure inhibition by technical means (e.g. secured by padlock),
 - double acknowledgement (inside and outside the protective device), or
 - acknowledgement from a position that allows viewing the hazardous area (direct activation of the guard locking device)

Protective devices (e.g. gravity, spring operated or padlock) shall be available to prevent unattended closing of guards and trapping of persons or there shall be devices available (e.g. gravity or spring operated) to prevent closing of the guards.

- 4) Interlocking guards with a start function (control function) shall only be used if all requirements of ISO 12100:2010, 6.3.3.2.5 are fulfilled.
- 5) When interlocking devices with guard locking are used and whole body access is possible, either the locking is power-on applied, power-on released (ISO 14119:2013, 4.3.3) or an escape released (ISO 14119:2013, 5.7.5.2) shall be provided.
- d) Multiple work zones: Where more than one work zone is provided on a single Group 3 machine, safeguards (e.g. fixed or movable interlocked guards or protective devices) shall protect the operator(s) from adjacent active work zone hazards (e.g. when loading or unloading workpieces in a non-active work zone, cleaning). Unauthorized movement of the machine into an adjacent non-active work zone shall be prevented using a limiting device, e.g. mechanical stops, range limit switches, light beams.
- e) Alternatives to enclosures:
 - Access to the work zone by operator(s) from the normal (fixed) operating position shall be prevented by local guarding (typically forming a cabin; see [Figure D.6](#)). See also [5.16.3](#) for requirements of accessing the operator cabin/platform and/or [5.16.4](#) for requirements of accessing machinery that is safeguarded by perimeter fencing.
 - Access to the work zone by persons other than the machine operator shall be prevented (see also [5.16.3](#) for requirements of accessing cabin/platform and/or [5.16.4](#) for requirements of accessing machinery by usage of perimeter fencing).

5.2.4 MSO of machine operation

5.2.4.1 General requirements

[Table 3](#) gives an overview of the mandatory, optional or not allowed modes of safe operation (MSO).

Table 3 — Overview of machine groups and modes of safe operation

Mode of safe operation (MSO)	Group 1 Manually controlled boring and milling machines without numerical control	Group 2 Manually controlled boring and milling machines with limited numerical controlled capability	Group 3 Numerical controlled milling machines, milling and machining centres	Group 4 Transfer and special purpose machines
MSO 0 manual mode	Mandatory	Mandatory	Not allowed	Not allowed
MSO 1 automatic mode	Not allowed	Mandatory see 5.2.2	Mandatory	Mandatory
MSO 2 setting mode ^a	Not allowed	Optional	Mandatory	Mandatory
MSO 3 special mode for manual intervention under restricted operating conditions ^a	Not allowed	Not allowed	Optional	Optional
MSO Service^a service mode	Not allowed	Optional	Optional	Optional

^a In order to allocate access authorization, it may be necessary to provide different key switches (or other appropriate access means) for one machine.

NOTE 1 Example of implementation:

Key 1: Access to setting mode (and automatic mode) for setting staff [see [6.3.1 a\) 3](#)];

Key 2: Access to NC program code and user related NC-parameter modifications for adequately trained staff [see [6.3.1 a\) 3](#)].

Key 3: Access to mode of safe operation 3 for adequately trained and authorized staff [see [6.3.1 a\) 3](#)].

Key 4: Access to service mode for trained service staff of the machine user [see [6.3.1 a\) 3](#)].

NOTE 2 In most applications, key switch 1 (setting mode) and key switch 2 (NC program code access) can be identical.

If the machine is designed and built so that several modes of safe operation (MSO) of machine operation (see [Table 3](#)) with different protective measures and/or methods of operation are possible, the machine shall be equipped with a MSO selection device.

5.2.4.2 Requirements for MSO selection system (Group 2, Group 3 and Group 4 machines only)

The selection of a MSO shall be done according to [Figure 1](#).

The MSO selection system consists of a security system (named Security in [Figure 1](#)) and a safety system [named Safety (SRP/CS) in [Figure 1](#)]. The sole purpose of the security system is the prevention of unauthorized access to the safety system, which contains the actual MSO selection device and the MSO activation device. The security system itself is not a safety related part of the control system (SRP/CS).



Figure 1 — Border between security system and safety system

The MSO access device (security) and the associated control system arrangements (SRP/CS) shall ensure that only one MSO is selected and enabled at any time. For requirements concerning safety functions, see [Annex J](#).

The selection of a MSO shall only be permitted from outside the hazardous areas.

The MSO selection system shall be capable of being locked in the selected position. Mode selection by itself shall not initiate machine operation. The following requirements shall be fulfilled for MSO selection.

- a) If more than one location (control console) is available for MSO selection at a hazard zone of several machines or interacting partial machines and a different mode of safe operation than MSO 1 is selected from an arbitrary control console of a dedicated hazard zone, the automatic cycle shall be interrupted for this particular hazard zone before access to this hazard zone is enabled.
- b) Every selected MSO shall be indicated visually [e.g. by visual display on the operating panel, by coloured signal lamps or a text on the user interface (HMI – Human Machine Interface)]. See also [5.2.4.8](#) and [Table 4](#). In special cases, if necessary, audible signals can also be used (ISO 11161:2007, 8.10).
- c) Dynamic mode selection is not permitted when the machine is running. A dynamic transition between MSO 1 and MSO 3 is applicable to Group 3 and Group 4 machines only (see [5.2.4.6](#)).
- d) Where a machine has more than one control station, measures shall be provided to ensure that initiation of commands from different control stations do not lead to a hazardous situation (IEC 60204-1:2009, 9.2.5.1).

5.2.4.3 Mode of safe operation 0: Manual mode (MSO 0)

When MSO 0 is selected, the following requirements apply.

- a) If interlocked moveable cutter or interlocked moveable table guards are provided, the spindle rotation shall only be initiated manually by a control device provided for that purpose when these guards are closed. Movement of spindle with these guards open shall only be initiated and maintained with the enabling device actuated. Releasing the enabling device shall initiate a safety related stop function of the spindle rotation according to [Annex J](#).
- b) Axis feed movements shall be possible with interlocked moveable table guards closed and traverse movement speed shall be limited to 5 m/min. Axis feed movement with open interlocked moveable table guards shall be manually selectable and shall only be possible by hold-to-run control with 2 m/min limited speed.
- c) Rapid traverse movements shall be manually selectable and shall only be possible by hold-to-run control.

- d) With controllable power-driven feed axes, only one feed axis movement is allowed at a time. The spindle is permitted to rotate at the same time. Releasing the enabling device stops the spindle and feed motion initiated by a safety related stop function according to [Annex J](#).

5.2.4.4 Mode of safe operation 1: Automatic mode (MSO 1)

MSO 1 is the standard mode for production and can use the full performance of the machine. Manual movement of the machine axes and operation with running spindle drive is permitted with all safeguards active and guards closed via hold-to-run device or MPG (i.e. electronic handwheel) operation. When MSO 1 (automatic mode) is selected, the following conditions apply before the machine is started.

- a) Moveable interlocked guards which give access to the work zone shall be closed and the protective devices shall be active to permit and maintain operation in automatic mode.
- b) If whole body access to the hazardous area is possible, it shall be ensured that no persons are present in that area. If it cannot be ensured that persons can be seen from the position where the control devices for start/restart are located, additional protective measures are to be provided, such as presence-sensing devices or double acknowledgement inside and outside the accessible work zone, or audible or visual warning (ISO 11161:2007, 8.10).
- c) Where multiple main control cycle start devices are provided and the operators can therefore put each other in danger, only one shall be enabled at any time [ISO 12100:2010, 6.2.11.8 e)]. If it is possible to start the same hazardous element by means of several controls, the control circuit shall be arranged that only one control is effective at any given time.
- d) For start/restart in MSO 1, the following requirements shall be fulfilled:
- the start/restart shall only be initiated from a control station where no hazard exists;
 - all protective devices including their safety related functions shall be properly arranged and active;
 - it shall be ensured that a start/restart is not initiated unintentionally (e.g. shrouded push button);
 - the control device(s) for start/restart shall be located to allow a clear and unobstructed view to persons within the hazardous area.

Movements only associated with loading/unloading of tools/workpieces in MSO 1 with guards open shall be possible with specific requirements stated in [5.2.5.1 e](#) (machine with tool magazine), [5.2.5.2 c](#) (machine with tool changer), [5.2.5.3 d](#) (machine with workpiece handling mechanism), [5.2.5.4](#) (machine with workpiece setting station) and [5.2.5.5 b](#) (machine with workpiece clamping mechanism).

- e) Machining in MSO 1 is permitted by operating machine axes with a hold-to-run control or an electronic handwheel when guards are closed.

5.2.4.5 Mode of safe operation 2: Setting mode (MSO 2)

5.2.4.5.1 Basic specifications

MSO 2 is a mode of operation which allows the operator to perform adjustments for the following machining process with movable interlocked guards open and/or protective devices suspended. Assessment of the tool and workpiece position, e.g. by touching the workpiece with a probe or tool, is part of the setting mode.

No machining is permitted in MSO 2 with either the moveable interlocked guards closed or open.

When changing to MSO 2 from any other MSO, the working cycle shall firstly be interrupted and then access to the work zone can be enabled (e.g. by unlocking the interlocked guard with guard locking).

When a hold-to-run control device or electronic handwheel is used, single axis movement and spindle rotation shall be initiated and maintained only while the enabling device is actuated. Releasing the enabling device shall initiate a safety related stop function according [Annex J](#). An enabling device is not required if the hold-to-run control device or electronic handwheel complies with the safety requirements according to [5.8.5](#).

When a manual data input (MDI) followed by command 'cycle start' is carried out, single axis and spindle movement shall be initiated and maintained only while the enabling device is actuated. Releasing the enabling device shall initiate a safety related stop function according [Annex J](#).

The required movements in MSO 2 shall be limited to pre-set sequential steps, which, however, shall not represent a full automation.

5.2.4.5.2 Range of functions

When any interlocked movable guard is open and/or a protective device is suspended, hazardous powered machine movements shall only be permitted under the following conditions:

- a) singular linear axis feed movements
 - shall be limited to a maximum of 2 m/min, or
 - the movement shall be in steps with a maximum increment of 10 mm;
- b) for rotary axes (including workpiece and workholding spindle),
 - peripheral speeds shall be limited to 15 m/min, and
 - rotation speed shall be limited to 50 r/min (ISO 23125:2015, 5.2.4.4.1 f);
- c) spindle speed shall be limited by its braking ability. After a stop command the spindle shall stand still within two revolutions without tool.

NOTE The number of two revolutions only refers to the displacement/angle covered by the deceleration procedure. Response time of the operator is not included, e.g. releasing the enabling device and control are not included.

- d) Where whole body access is possible, the limits of rotational speed or axis feed movements or incremental distance [defined in a), b) and c) above] shall be monitored (see [5.8.6](#) and speed limit control in [Table J.17](#), 17.3 and 17.4). A stop shall be initiated when the speed limit is exceeded. The stop function of the movement shall be initiated by a safety related stop function according to [Annex J](#). If whole body access is not foreseen, an enabling device or a hold-to-run device may be implemented instead of speed monitoring.
- e) Means shall be provided to prevent hazardous movements of vertical or slant axes under gravity (e.g. brakes, counter balance, [Annex G](#)).
- f) Unguarded swarf/chip conveyor movements shall only be initiated and maintained by a hold-to-run control device or an enabling device (first hand) in conjunction with a direction control (second hand) (see J.11.2 to J.11.4) but not in conjunction with feed axes and spindle movement.
- g) For Group 3 and Group 4 machines only: Automatic tool- and workpiece changing mechanisms shall remain inhibited in case of pending operations within the work zone. Initiation of their automatic movement shall only be possible by reselection of MSO 1. Manually controlled single movements of tool- and workpiece changing mechanisms are permitted in conjunction with an enabling device. Every movement shall be initiated by a start command. This can be achieved by, e.g. MDI.

5.2.4.6 Mode of safe operation 3: Optional special mode for manual intervention under restricted operating conditions (MSO 3)

5.2.4.6.1 Basic specifications

MSO 3 permits use of the machine under manual or numerical control with guards open and/or protective devices suspended.

The risk in MSO 3 is significantly higher than in MSO 1 due to open guards and suspended protective devices respectively. To adequately reduce the overall risk over the service life of the machine, the duration of use, and therefore the fraction of MSO 3 shall be limited to the absolute necessary minimum. The overall risk decreases proportionally with a shorter period of use of MSO 3.

By limiting the machine's performance in MSO 3, a motivation to switch back to the higher performing MSO 1 mode, is given in this document.

The change from MSO 1 to MSO 3: First the operating conditions of MSO 1 shall be reduced to those demanded in MSO 3 and shall be monitored. Then the relevant safety requirements (e.g. the possibility for temporarily/partly opening of guards or the interruption of protective devices) shall be allowed.

The change from MSO 3 to MSO 1: First the higher safety requirements of MSO 1 (e.g. movable guards closed or light curtain activated) shall be activated and monitored, then the higher values of the operating conditions of MSO 1 shall be allowed.

MSO 3 shall only be provided when details of the intended application are known and the operators are trained and authorized by the machine manufacturer or supplier. The required skill level of operators shall be defined in the instruction handbook (see 6.3.1, a), 3).

Turning operations are not permitted in MSO 3 (see ISO 23125).

5.2.4.6.2 Range of functions

When MSO 3 is provided and activated, the following conditions shall apply.

- a) Individual axis speed shall
 - be limited to 5 m/min, or
 - the movement shall be in steps with a maximum increment of 10 mm.
- b) For rotary axes (including workpiece and workholding spindle),
 - peripheral speeds shall be limited to 15 m/min and
 - rotation speed shall be limited to 50 r/min [see also ISO 23125:2015, 5.2.4.4.1 f)].
- c) Spindle speed shall be limited by its braking ability. After a stop command the spindle shall stand still within five revolutions without tool.

NOTE The number of five revolutions only refers to the displacement/angle covered by the deceleration procedure. Response time of the operator is not included, e.g. releasing the enabling device and control are not included.

- d) Where whole body access is foreseen, the limits of rotational speed or axis feed movements or incremental distance [as defined in a), b) and c) above] shall be monitored (see 5.8.6 and speed limit control in Table J.17, 17.3 and 17.4). When the speed limit is exceeded, a safety related stop function according to Annex J shall be initiated.
- e) Non-programmed movements shall be achieved as follows.
 - 1) Spindle rotation shall be initiated by a spindle start control device together with an enabling device and maintained by the enabling device.

- 2) Axis movements shall be initiated and maintained by one of the following means:
- a hold-to-run device; or
 - an electronic handwheel; or
 - manual data input (MDI) followed by cycle start together with an enabling device.
- f) Execution of a program shall be initiated by a cycle start control device in conjunction with an enabling device and maintained by the enabling device.
- g) The requirements of MSO 2 in [5.2.4.5.2](#), e), f) and g) shall also apply.
- h) In any of the above cases, the release of the enabling device shall initiate a safety related stop function according to [Annex J](#).
- i) Where ergonomic considerations in the application of MSO 3, make the use of an enabling device impractical (e.g. because the duration of necessary process observation/intervention exceeds an acceptable fatigue time for the machine operator to actuate the enabling device or the manipulation of multiple parameter control devices prevents the sustained operation of an enabling device), then a combination of alternative engineering control measures, to reduce entanglement and crushing risks, shall be substituted for the enabling device. Two examples of accepted alternative engineering control measure combinations are:
- 1) A standing position safe from the machine movements for the operator that is monitored by an active optical protection device (ESPE), e.g. a scanning device or light curtain, but excluding the use of a pressure sensitive mat or similar easily defeated device, together with
 - activation with a MSO selection device,
 - a readily accessible emergency stop control device shall be provided,
 - a design that initiates a stop function by triggering a pressure sensitive protective device(s) (PSPD) shall be applied to all moving machine elements that pose a crushing risk,
 - the monitoring for reduced spindle and axes speeds shall satisfy the requirements of [Table J.17](#), 17.3 and 17.4 (see also [5.8.6](#)), and
 - identification of appropriate personal protective equipment (PPE), e.g. safety goggles, protective shoes, etc., shall be provided in the Instructions for Use [see [6.3.1 a\)2](#)) and p) and [6.3.8](#)].
 - 2) Protection against entanglement risk by means of a fixed guard enclosing the rotating spindle and cutter or an ESPE (e.g. AOPD, light curtain) around (or in front of) the rotating spindle and cutter (the position of AOPD shall fulfil the requirements of ISO 13855) together with
 - activation with a MSO selection device,
 - a readily accessible emergency stop control device shall be provided,
 - pressure sensitive protective device(s) shall be applied to all moving machine elements that pose a crushing risk,
 - the monitoring for reduced spindle and axes speeds shall satisfy the requirements of [Table J.17](#), 17.3 and 17.4 (see also [5.8.6](#)), and
 - identification of appropriate personnel protective equipment (PPE) shall be provided in the Instructions for Use [see [6.3.1 a\)2](#)) and p) and [6.3.8](#)].

NOTE Examples of work situations and work tasks, where MSO 3 is needed, are given in ISO/TR 16090-2¹⁾.

1) To be published.

- j) To reduce ejection risks, the cutting speed employed in any MSO 3 application shall be in accordance with ISO 15641.

5.2.4.7 Mode of safe operation, service (MSO Service)

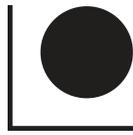
MSO Service shall only be provided to service staff, who is trained and authorized by the machine manufacturer.

- a) Appropriate safety instructions shall be provided in the instructions for use.
- b) Movements of automatic workpiece changing mechanisms shall, if applicable, be carried out with reduced speeds. The individual steps shall be initiated in succession.
- c) Means shall be provided to prevent hazardous movement of vertical or slant axes under gravity, e.g. redundant restrain system (see [Annex G](#)). For requirements concerning safety functions, e.g. control function, to prevent unintended descent of vertical or slant axes, see [Annex J](#);
- d) Additional safety measures shall be provided, such as secondary guards, barriers or screens in combination with warning signs;
- e) MSO Service will enable restricted automatic functionality of the machine or parts of it, at which the main guards of the individual work zone can be open. The restrictions are as follows.
 - 1) Before selecting MSO Service, a chain with warning sign shall be set up. The warning sign indicates that service operations are being conducted on the machine and that unauthorized persons are not permitted to pass beyond the point of the chain.
 - 2) Machining is not permitted in service mode and shall be systematically prevented as far as possible.
 - 3) Simultaneous rotation of the spindle and axis motion is allowed only for measurement and calibration tasks.
 - 4) If movement of tool changer and/or tool magazine is foreseen, automatic tool changing movements or tool magazine movement shall be initiated by a hold-to-run control device or start button. It shall be possible to initiate the individual steps successively.
 - 5) If the hazard analysis indicates that the pressure of coolant injection can create hazards while interlocking guards are open, the coolant ejection shall be disabled.
 - 6) Movement shall be initiated from a control device located outside the reach of hazardous movements or, if feasible, a movable control station.
- f) Multiple axes interpolation is permitted.

5.2.4.8 Symbols for displaying MSO on machines

For identification of the mode of safe operation for machines, the letter code (e.g. MSO 0 or manual mode) or the following standardized symbols shall be used on the command devices and if necessary on the SPS/NC display:

Table 4 — Symbols for displaying modes of safe operation on machines

Mode of safe operation	ISO 369/ISO 7000 reference no.	Symbol	en: Meaning fr: Référent de: Bedeutung
MSO 0 Manual mode	ISO 369-5.1-13 ISO 7000-0096		en: Manual control fr: Commande manuelle de: Handbetätigung, Handsteuerung
MSO 1 Automatic mode	ISO 369-5.1-15 ISO 7000-0017		Automatic control (closed loop) en: Commande automatique (boucle fermée) fr: mée) de: Automatikbetrieb (geschlossener Kreislauf)
MSO 2 Setting mode	ISO 369-5.1-12 ISO 7000-0910		en: Setting fr: Réglage de: Einrichten
MSO 3 Automatic mode with manual intervention	ISO 7000-1942		en: Test run fr: Session d'essai de: Testlauf
MSO Service Service mode	ISO 369-5.1-44 ISO 7000-0717		en: Call for maintenance fr: Appeler le service de maintenance de: Kundendienst rufen

5.2.5 Optional or additional equipment for machines

5.2.5.1 Additional requirements for tool magazine(s)

If the machine is equipped with tool magazine(s), the following requirements shall be fulfilled.

- a) Access to hazardous movements of the tool magazine shall be prevented by fixed and/or interlocked movable guards (see ISO 14119:2013, Clause 7 and Annexes) or the hazardous movements shall be suspended or inhibited by protective devices. Where routine observation of the tool magazine is required, means (e.g. windows) shall be provided.
- b) When the interlocked movable guards are opened or the protective devices are suspended, the tool magazine drive(s) and other hazardous movements shall be stopped and further movements shall be inhibited.
- c) Access openings shall be in accordance with ISO 15534-1 and ISO 15534-2.
- d) Where whole body access into the hazard zone of the tool magazine is foreseen the same requirements as for the work zone shall also be applied if applicable for a tool magazine (see 5.2.4.4 for MSO 1, 5.2.4.5 for MSO 2 and 5.2.4.6 for MSO 3).
- e) Powered movements of the tool magazine with guards open/protective devices suspended are permitted when carried out in accordance with the following:

Movements shall be initiated and maintained in a position with a sufficient distance from the hazard area (as defined in ISO 13855:2010, Clause 8) by either:

- an enabling device together with direction control

Movement shall be at a reduced speed of a maximum of 15 m/min where only an impact hazard exists or where a crushing, shearing or trapping hazard exists either be able to stop in less than 4 mm or be a maximum of 2 m/min.

Or

- a two-hand-control

The requirements of ISO 13851 type III B and C shall be fulfilled however, the minimum button separation of 260 mm in ISO 13851 can be suspended if there is no way to actuate the two hand devices with one hand, for example by 2 independent knob switches or rotary type switches. The distance requirements of ISO 13857 and ISO 13855:2010, Clause 8 (at least 100 mm) are required.

Or

- an enabling device in fixed position in conjunction with a start button.

The distance requirements of ISO 13857 and ISO 13855:2010, Clause 8 (at least 100 mm) are required.

Releasing the enabling device or one of the two hand control devices shall initiate a safety related stop function according to [Annex J](#).

- f) No hazardous machine movements shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2009, 10.1.4).
- g) Means shall be provided to prevent hazardous movements of vertical or slant axes under gravity, e.g. brakes.

Safety functions for control of tool magazines are listed in [Table J.10](#).

5.2.5.2 Additional requirements for tool changer(s)

If the machine is equipped with tool changer(s), the following requirements shall be fulfilled.

- a) Access to hazardous movements of the tool changer(s) from any direction shall be prevented by fixed and/or interlocked movable guards (ISO 14119:2013, 7 and Annexes).
- b) When the safeguarding measures are suspended, the tool changer drive(s) and other hazardous movements shall be stopped and further movements shall be inhibited.
- c) Powered movements of the tool changer with guards open/protective devices suspended and no whole body access are permitted when carried out in accordance with the following:

Movements shall be initiated and maintained in a position with a sufficient distance from the hazard area (as defined by ISO 13855:2010, 8) by either:

- an enabling device together with direction control

Movement shall be at a reduced speed of a maximum of 5 m/min where only an impact hazard exists or where a crushing, shearing or trapping hazard exists either be able to stop in less than 4 mm or be a maximum of 2 m/min.

Or

- a two-hand-control

The requirements of ISO 13851 type III B and C shall be fulfilled, however, the minimum button separation of 260 mm in ISO 13851 can be suspended, if there is no way to actuate the two hand devices with one hand, for example by two independent knob switches or rotary type switches. The distance requirements of ISO 13857 and ISO 13855:2010, 8 (at least 100 mm) are required.

Releasing the enabling device or one of the two hand control devices shall initiate a safety related stop function according to [Annex J](#).

Measures shall be taken to prevent hazards from ejected tools under all operating conditions and/or failure of power supply when the interlocked guard is open by securing the tools into the tool changer.

- d) Where whole body access is foreseen, information about the residual danger due to the presence of persons shall be provided in the documentation. The same requirements as for the work zone shall also be fulfilled ([5.2.4.4](#) for MSO 1, [5.2.4.5](#) for MSO 2, and [5.2.4.6](#) for MSO 3).
- e) No hazardous movements of the tool changer shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2009, 10.1.4). In order to prevent falls or ejections, tools shall, under all operating conditions and/or failure of power supply, be securely held within the holders of the tool changer.
- f) Means shall be provided to prevent hazardous movements of vertical or slant axes under gravity, e.g. brakes.

Safety functions for control of tool changers are listed in [Table J.9](#).

5.2.5.3 Additional requirements for workpiece handling mechanisms

If the machine is equipped with automatic workpiece handling mechanisms, the following requirements shall be fulfilled.

- a) The positions for operators at workpiece load/unload mechanisms shall be located outside the work zone and away from other hazardous machine movements.
- b) Access to hazardous movements from any direction of the workpiece handling mechanisms shall be prevented by fixed and/or interlocked movable guards (ISO 14119:2013, 7 and Annexes).
- c) When the interlocked movable guards are open, the workpiece handling mechanism drive(s) and other dangerous movements shall be stopped and further movements shall be inhibited.
- d) Powered movements with movable interlocked guards open and/or protective devices suspended shall be initiated and maintained in a position with a sufficient distance from the hazard area by either:

— an enabling device together with direction control:

movement shall be at a reduced speed of a maximum of 15 m/min where only an impact hazard exists or where a crushing, shearing or trapping hazard exists either be able to stop in less than 4 mm or be a maximum of 2 m/min;

Or

— a two hand control:

The requirements of ISO 13851 type III B and C shall be fulfilled, however, the minimum button separation of 260 mm in ISO 13851 can be suspended if there is no way to actuate the two hand devices with one hand, for example by two independent knob switches or rotary type switches. The distance requirements of ISO 13857 and ISO 13855:2010, 8 (at least 100 mm) are required.

Releasing the enabling device or one of the two hand control devices shall initiate a safety related stop function according to [Annex J](#).

- e) Where whole body access into the hazardous zone of the handling mechanism is foreseen the same requirements as for the work zone shall be fulfilled ([5.2.4.4](#) for MSO 1, [5.2.4.5](#) for MSO 2, and [5.2.4.6](#) for MSO 3).

- f) No hazardous machine movements shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2009, 10.1.4).
- g) Means shall be provided to prevent hazardous movements of vertical or slant axes under gravity, e.g. brakes.

Safety functions for control of workpiece handling mechanisms are listed in [Table J.6](#).

5.2.5.4 Additional requirements for workpiece setting stations

If powered movement of the workpiece setting station is required (e.g. to rotate a pallet with workpiece) while interlocked guards are open or protective devices are suspended (e.g. to clean the workpiece or to carry out measurements) then this shall be possible by using either

- an enabling device together with a direction control; In this case, movement shall not exceed the maximum of 15 m/min, if only an impact hazard exists. Where crushing, shearing or trapping hazards exist also, the movement shall be able to be stopped within a travel distance of 4 mm or the maximum travel speed shall not exceed 5 m/min;

Or

- a two-hand control; In this case, the requirements of ISO 13851 type III B and C shall be fulfilled, however, the minimum button separation of 260 mm as stated in ISO 13851 can be suspended, if it is impossible to actuate the two-hand control with one hand (e.g. by two independent knob switches or rotary type switches). The distance requirements of ISO 13857 and ISO 13855:2010, 8 (at least 100 mm) shall be fulfilled.

Releasing the enabling device or one of the two-hand control devices shall initiate a safety related stop function according to [Annex J](#).

Where whole body access into the hazardous zone of the workpiece setting station is foreseen, the requested requirements as for work zones shall be fulfilled (see [5.2.4.4](#) for MSO 1, [5.2.4.5](#) for MSO 2 or [5.2.4.6](#) for MSO 3).

No hazardous machine movements shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2009, 10.1.4).

5.2.5.5 Additional requirements for powered workpiece clamping mechanisms

If the machine is equipped with powered workpiece clamping mechanisms, the following requirements shall be fulfilled.

- a) General requirements
 - 1) Measures shall be taken to prevent unintended loosening of workpieces due to gravity, e.g. by clamps or support devices.
 - 2) The state of the powered workpiece clamping mechanism shall be monitored (when connected and if the required actuating force, e.g. monitored by pressure, current, etc., (indirect measuring is possible) is not reached the start of operation shall be prevented, or a stop command shall be initiated if operation has already commenced (see [Table J.4](#), 4.2, 4.3).
 - 3) No hazardous movement of workpiece clamping device shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2009, 10.1.4).
- b) Movement of power operated workpiece clamping device while movable interlocked guards are open shall be
 - 1) restricted to a 4 mm clamping stroke or less (see ISO 13857:2008, 4.2.4.1, Table 4), or

- 2) initiated and maintained by means of an enabling device together with a direction control, or
 - 3) initiated and maintained by means of two-hand control (for two-hand controls, the requirements of ISO 13855:2010, 8 and ISO 13851, shall be fulfilled), or
 - 4) if it is required to support the workpiece by hand for fixation or adjustment, the movement shall be controlled by a three-step footswitch (category 3) and reduced speed of maximal 5 m/min. The compression of the three-step footswitch leads to an emergency stop or the activation of the movement in the release direction.
- c) For magnetically operated workpiece clamping mechanisms, the following requirements shall be fulfilled:
- 1) the requirements of [5.2.5.5](#) a) 1) and b) shall be fulfilled;
 - 2) connection via plug and socket.

When the electrical control system is connected to the magnetic clamping plate by means of an electrical plug connection, the workpiece shall be released or clamped by actuating a control device while the control system is connected. The generated clamping force or its nominal value calculated by indirect measurement shall be displayed on the electrical control device prior to disconnection and axis movements are only permitted after verification that the displayed clamping force meets or exceeds the application requirements and that the clamping device has been unplugged. Once disconnected, the magnetic clamping force shall remain in the clamping plate. Confirmation that the clamping force continues to meet or exceed the application requirements shall be done at specified intervals according to the manufacturer's specifications by reconnecting the device. Specifications shall be given in the instruction for use (see [6.3.1](#)).

NOTE A safety function according to ISO 13849-1 is not definable for these clamping devices because once they are unplugged, there is no connection to the clamping device.

3) Continuous connection

When the electrical control system is permanently connected to the magnetic clamping plate, the workpiece shall be released or clamped by actuating a control device. The generated clamping force or its nominal value calculated by indirect measurement shall be displayed on the electrical control device and axis movements are only permitted after verification that the displayed clamping force meets or exceeds the application requirements. If metal is being removed in the working process, it is not allowed to change the clamping force during the machining process. Confirmation that the clamping force continues to meet or exceed the initial application requirements shall be done at specified intervals according to the manufacturer's specifications. Specifications shall be given in the instruction for use (see [6.3.1](#)). The safety functions for workpiece clamping mechanisms listed in [Table J.4](#) are applicable for these clamping devices.

4) Connection via sliding contacts

When the electrical control system is permanently connected to the magnetic clamping plate by sliding contacts or brushes, the workpiece is released or clamped by actuating a control device. This method allows multi-purpose applications for milling and turning operations. The requirements of [5.2.5.5](#) c) 3) are applicable.

The magnetically operated workpiece clamping mechanism can be used without PL.

NOTE For the time being, there is no performance level available from the manufacturers.

- d) For workpiece clamping mechanisms operating with vacuum, the following requirements shall be fulfilled.
- 1) The requirements of [5.2.5.5](#) a) and b) shall be fulfilled.

- 2) For these clamping devices, the safety functions for workpiece clamping mechanisms in [Table J.4](#), 4.2 and 4.3 shall be implemented.
- e) For machine warm up, filling the machine or finishing production, it shall be possible to run the machine without workpiece(s) in the fixture in automatic mode of operation with guards closed. In that case, the monitoring of the workpiece clamping may be disabled. The muting function shall have the same safety level as the detection of an incorrectly clamped workpiece (see [Table J.4](#), 4.3). The warm up cycle shall be done in MSO 1.

5.2.5.6 Additional requirements for workpiece clamping mechanisms in case of turning operation

The general conditions are as follows.

- a) Workpiece clamping devices, except collets, shall be clearly marked with their maximum permissible speed. The work table shall be such that manual clamping devices, primarily positive fitting, can be mounted. Mounting of clamping devices which are guided in slots shall primarily be done in such a way that the slots are closed in outside direction or bolts are fitted to open slots to prevent loose clamping devices from being ejected. Design of vision panels and steel sheets (also roof sections) for jaws with a mass of max. 2,5 kg shall be in accordance with ISO 23125.
- b) When the workpiece is rotating, it shall not be possible to loosen the workpiece clamping device by manual operation, regardless of how the workpiece is clamped. Unclamping shall only be possible during a standstill under safe speed monitor (SSM, $n = 0$ r/min; see ISO 61800-5-2:2008, 4.2.3.14). Non-return valves shall be provided when hydraulic or pneumatic clamping devices are used.
- c) For machines equipped with clamping devices other than collets and where programmable workholding spindle speed is available, a program shall not run in automatic mode unless the following conditions are fulfilled.
- 1) Machines shall have facilities for entering and/or validating the maximum workholding spindle speed (milling/turning table) taking into account the maximum permissible speed of the workpiece clamping device.
 - 2) Rotary movement shall only be initiated when at least one of the following conditions is fulfilled:
 - i) clamping device is designed for the maximum permissible speed of the worktable;
 - ii) the maximum permissible rotational speed shall be monitored (see [Table J.4](#), 4.9); or
 - iii) when the requested rotary speed is lower than the speed limit of the clamping device.
 - 3) The clamping device shall be designed such that necessary clamping forces and torques can be transferred to the workpiece.
 - 4) An actuating force (e.g. by monitoring hydraulic or vacuum pressure) sufficient for the safe clamping of the workpiece shall be maintained until the workholding spindle (milling/turning table) has come to rest (in accordance with ISO 16156:2004, 5.2.1), e.g. by non-return valves on the hydraulic system or a self-locking workpiece clamping device.
 - 5) Means shall be provided to monitor the workpiece clamping device actuating force (e.g. by monitoring hydraulic or vacuum pressure) of power-operated workpiece clamping devices (for further explanation, see Note).
 - 6) For power operated clamping systems the following applies.
 - i) If the required actuating force of power operated clamping device is not reached, initiation of rotary movement shall be prevented.
 - ii) If the workholding spindle (milling/turning table) drive is running and the actuating force falls below a pre-set value or any other monitoring system of the workpiece clamping is

activated, movement shall stop initiated by a safety related stop function according to [Annex J](#). If a clamping device cannot be monitored during machining, alternative safety measures shall be provided, e.g. unbalance detection, additional workpiece retaining device, workpiece present monitoring.

- d) For machines with counter workholding spindles that transfer the workpiece to another spindle while both spindles are rotating with the same speed, it shall be possible to run a spindle without workpiece in the workholding spindle in automatic mode of operation with guards closed. In this case, the monitoring of the workpiece clamping in either the main spindle or the counter spindle may be disabled. Means shall be provided to ensure that at least one of the spindles is running with an activated monitoring of the workpiece clamping.
- e) No hazardous movements of the workpiece clamping device shall be initiated from the actuation of any sensor or feedback device while the interlocked guards or monitored guards are open (see IEC 60204-1:2009, 10.1.4).
- f) The position workpiece clamped and clamped without workpiece of power operated systems shall be monitored by the machine control in order to enable start functions for turning movements. If position monitoring of power operated workpiece clamping systems is not possible, other safety measures shall be provided.
- g) Safety functions for control of clamping conditions for the workpiece are listed in [Table J.4](#).

5.2.5.7 Additional requirements for swarf/chip conveyor and removal system

If the machine is equipped with swarf/chip collection and removal system, the following requirements shall be fulfilled:

- a) Access to hazardous moving parts of swarf/chip collection systems shall be prevented by means of fixed guards. Where operators have a need to access more frequently than once per shift, interlocked movable guards shall be provided. Guards shall be in accordance with ISO 14119 and ISO 14120.
- b) Opening an interlocked movable guard, which provides access to hazardous moving parts of a swarf/chip collection and removal system, shall initiate a safety related stop function according to [Annex J](#).
- c) If movement of a swarf/chip system with an interlocked guard open is essential (e.g. for cleaning purposes), the movement shall only be
 - 1) permitted by means of a hold-to-run control device according to [5.8.5](#), or
 - 2) permitted by means of an enabling device together with a start device and reduced peripheral speed of max. 5 m/min. The movement shall be initiated and maintained only while the enabling device is actuated. Releasing the enabling device shall initiate a safety related stop function according to [Annex J](#), or
 - 3) initiated and maintained by means of two-hand control. For two-hand controls, the requirements of ISO 13851:2002, Clause 8, shall be fulfilled. Distance requirements of ISO 13857 and ISO 13855:2010, Clause 8 (at least 100 mm) shall be fulfilled. The movement shall be initiated and maintained only while the two-hand control device is actuated. Releasing the two-hand control device shall initiate a safety related stop function according to [Annex J](#).
- d) For the swarf/chip discharge area (removal area), the following applies.
 - 1) Design and safety distances for guards according to ISO 13857:2008, Table 3, where any other additional measures are not provided.
 - 2) If the measure Y in [Figure 2](#) is shorter than 850 mm, additional measures shall be taken to prevent reaching into the hazardous movement of the chip conveyor. [Figure 2](#) shows a design

example structure for a conveyor that fulfils this requirement. The following protective measures shall be done:

- funnel dimensions according to [Figure 2](#);
- at least three sides of the chip container shall reach higher than the lower edge of the discharge funnel so that the funnel reaches fully inside the container;
- design to minimize the chance of chips being held up in the funnel;
- provide a lockable device to switch off the movement of the chip conveyor at the chip discharge area;
- place warning labels (pictogram are preferable) according to ISO 7010-P015 at each visible side of the funnel;
- a warning sign yellow-black on the floor surrounding the funnel.

State in clause “Information for use” that a yellow and a black marking on the floor shall be noted by the user.

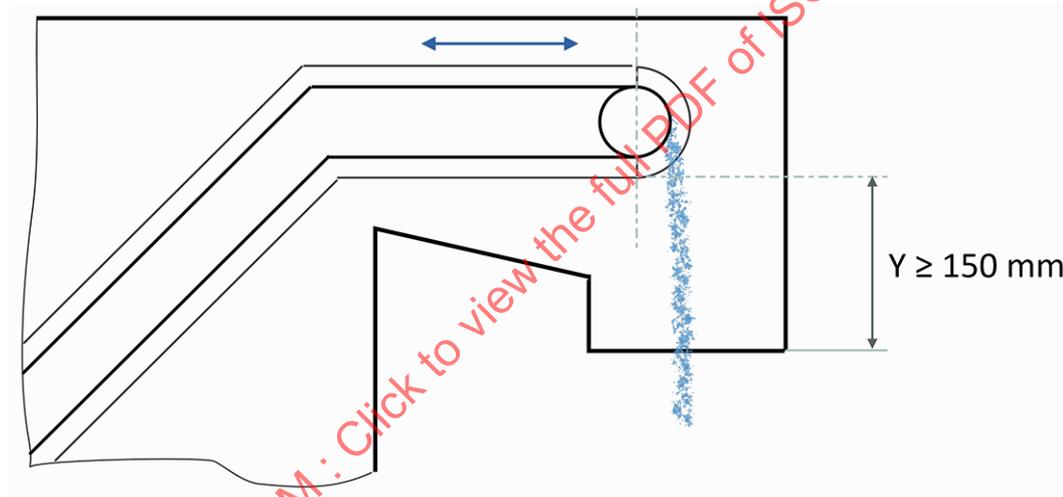


Figure 2 — Safe area of conveyor

- e) Information regarding operating/handling the chip conveyor and container shall be provided in the instruction for use [see [6.3.1 c](#)].
- f) For Group 4 machines only: Means shall be provided to enable the collection and removal of swarf/chips without the need to remove guards (e.g. fixture design to promote swarf/chip shedding, directed flows of metal working fluid).
- g) Requirements for guards with a start function (control guards) of ISO 12100:2010, 6.3.3.2.5 shall be observed.
- h) Safety functions for control of the swarf/chip collection and removal system are listed in [Table J.11](#), [Table J.16](#) and [Table J.17](#).

5.2.5.8 Additional requirements for pits

If the machine construction includes pits, the following requirements shall be fulfilled.

- a) Pits shall be covered (e.g. floor grids) or secured against persons falling into them. If coverage is not possible, one of the following alternatives in given priority order shall be installed to prevent persons from falling into the pit:
 - 1) railings according to ISO 13857 and ISO 14122-1 to ISO 14122-4,
 - 2) cables with roll-up devices or barrier chains, tapes or cables with a warning sign located at least 1 m, but no more than 2 m in front of the hazardous area, or
 - 3) chains yellow/black with a warning sign 1 m in front of the hazardous zone (pit).
- b) Where access to pits is necessary for observation, maintenance or adjustment purposes, entry into the pit shall be possible via movable guards which prevent machine movement. Where powered machine movements are necessary, machine elements may be moved under the conditions set out in [5.2.4](#), [5.2.5.3](#) and [5.2.5.4](#).
- c) Minimum gaps between moving machine elements and pit walls or other fixed parts shall be in accordance with ISO 13854. Where these minimum gaps cannot be achieved, additional protective measures shall be provided to minimize the risk of crushing or trapping.
- d) If impact hazards may also be present, the access to the moving parts of machinery shall be prevented.

5.3 Specific requirements resulting from electrical hazards

- a) Direct contact with electrical equipment:
 - 1) Electrical equipment shall be in accordance with IEC 60204-1, unless otherwise specified in this document.
 - 2) The following requirements in the relevant clauses of IEC 60204-1 shall be fulfilled:
 - i) Clause 7 for protection of equipment, against short circuit, feeder circuit excluded and overloading. The machine manufacturer shall provide the user with information on how to provide the protection against short circuit of the feeder circuit (see [6.3.9](#));

NOTE The protection against short circuit of the feeder circuit is not up to the machine manufacturer.

- ii) Clause 8 for equipotential bonding;
 - iii) Clause 12 for conductors and cables;
 - iv) Clause 13 for wiring practices;
 - v) Clause 14 for electrical motors and associated equipment.
 - 3) Electrical enclosures shall not be exposed to the risk of damage from the ejection of tools and/or workpieces. Live parts shall not be accessible (see IEC 60204-1:2009, 6.2.2). The risk of fire is not considered significant for machines where power circuits are protected against over current (see IEC 60204-1:2009, 7.2.2).
- b) For indirect contact with electrical equipment, the machine manufacturer shall provide the protective bonding system of the machine up to the PE terminal and shall provide the user with information on how to complete protection against electrical shock due to indirect contact (see [6.3.9](#)).

NOTE See IEC 60204-1:2009, 3.27, for the definition of "indirect contact"

- c) The degree of protection of all electric components outside the enclosure and the enclosures for electrical components themselves shall be at least IP 54 if liquids can come into contact with them

and IP 5X if not in accordance with IEC 60529. Live parts inside electrical enclosures shall have at least IP 2X.

5.4 Specific requirements resulting from noise hazards

When designing the machine, the available information and technical measures to reduce noise at its source shall be taken into account (see, for example, ISO/TR 11688-1, ISO/TR 11688-2). The design shall take into account noise from every possible source. Appropriate technical measures for reducing noise at the main sound sources of machines are listed below:

- a) usage of low-noise machine components;
- b) transmission noise by gearbox damping;
- c) pneumatic exhaust through silencers;
- d) power generation sounds by damping or absorption;
- e) noise during cutting process by damping or absorption inside the work zone enclosure;
- f) during workpiece/tool change by damping or absorption inside the work zone enclosure.

The above list is not exhaustive. Alternative technical measures for noise reduction with identical or greater efficiency may be used.

Where noise levels must be reduced beyond those achievable by design at source, the machine shall be provided with protective measures (e.g. noise enclosures, screens fitted to the machinery, silencers).

Operating conditions for noise measurement shall be in accordance with [Annex K](#). The determination of the noise emission shall be in accordance with ISO 230-5. The declaration of the noise emission values shall be in accordance with [6.3.6](#).

5.5 Specific requirements resulting from radiation hazards

- a) For low-frequency radiation, high-frequency and microwaves radiation, see [5.8.7](#). See also IEC 61000-6-2 and IEC 61000-6-4 for more information.
- b) Built-in laser feedback systems shall be designed to prevent exposure to beam paths or specular reflections in accordance with IEC 60825-1.
- c) Strong magnetic fields, which may be encountered at e.g. linear drives, can cause irreversible injuries. Through constructive measures, e.g. guards, direct access during normal operation shall be prevented.

Warning signs shall be set up, which emphasize the danger. The persons particularly at risk are those with cardiac stimulator and prostheses which react to magnetic fields.

5.6 Specific requirements resulting from material or substance hazards

5.6.1 Combustible coolants

Machinery designed to make usage of combustible coolants shall be equipped with devices which minimize the risk from the production of combustible mixtures or an ignition source, especially in MSO 1:

- a) Dimension of coolant circuit shall be such (pipe cross section, reservoir, pumps, nozzle forms and positioning, etc.) that sufficient and continuous amount of coolant supply is ensured at processing site.
- b) Preventing start-up of machines working cycle, when coolant supply is not functioning properly.

c) In case of a not properly functioning coolant supply, the machining process shall automatically be brought to a stop in an appropriate manner, e.g. separation of workpiece and tool and shut off of tool drives.

d) Use of adequate exhaust systems:

The suction power shall be as such that at least a negative pressure (below the atmospheric pressure) in the work zone is maintained so as to securely prevent coolant vapours and aerosols from escaping the work zone.

In case of an incorrectly functioning exhaust system, start-up of machines working cycle shall be prevented or a currently running machining process shall automatically be brought to a stop in an appropriate manner, e.g. separation of workpiece and tool and shut off of tool drives. For safety requirements, see [Table J.12](#) and [J.14](#).

Piping of exhaust systems shall be such that fluids flow back into the machine, so that the pipes are empty.

All metal parts within the work zone including pipes of exhaust system shall be fully connected to the protective bonding circuit to prevent electrostatic charge.

Vents within the work zone shall be as such that swarf/chips or greater amounts of fluid cannot be sucked in.

If fire and explosion risks cannot be excluded by these systems, additional measures for limiting the consequences of fire and explosion events shall be provided in accordance with ISO 19353 and EN 1127-1.

These include the following measures:

- pressure-resistant enclosure of the work zone including windows and if necessary pressure relief in a direction not dangerous to personal;
- preventing flames and hot gases from work zone escaping into the operating area outside the work zone and vicinity of the machine, e.g. flame arresting labyrinth seals on movable parts of the guards (circumferential). For examples, see [E.2](#);
- adequate fire extinguishing devices;
- the machine, including the control, shall be such that connecting fire detecting devices, e.g. fire extinguishing systems, fire alarm, pressure relief valves, etc. are possible according to the manufacturer's recommendations (interface description).

For accessible machines and use of fire extinguishing devices with oxygen suppressing quenching gases, mechanical interlocking capability for the quenching gas supply shall be provided. Additional measures shall be taken to prevent personnel from being trapped within the work zone, e.g. possibility for unlocking the door from the inside without the need of power supply by means of a guard locking device with an escape release (ISO 14119). In addition, the extinguishing system shall be provided with a release button which shall be actuated only from outside the work zone. The automatic extinguishing system is only activated after the release button has been actuated and can only then, after a sensor signal has been triggered, be set in a condition where quenching gas can stream into the work zone.

NOTE 1 It could otherwise be possible to unintentionally close and lock the door from the inside while the machine is switched off and quenching gas could perhaps stream inside.

NOTE 2 For further information, see also [Annex E](#).

For machines which are intended to be connected to a central exhaust system, measures or devices shall be provided, which in case of fire

- prevent fire from spreading into the central exhaust,
- prevent further air flow into the work zone, and

- prevent exhaust of extinguishing agent, e.g. flame arresters (see example in [E.3](#)), butterfly valve for exhaust air.

Integrated decentralized exhaust systems shall automatically shut off in case of fire or explosion.

- e) Safety functions for extinguishing systems shall be in accordance to [Table J.14](#).

NOTE 1 Further measures of risk reduction depend on the actual conditions of use of the machine and have to be considered individually.

NOTE 2 Accumulation of fluid and dried materials and contact with hot swarf/chips within the piping can cause a fire.

5.6.2 Minimum quantity lubrication (MQL)

For minimum quantity lubrication, the risk of fire and explosion is primarily determined by the amount of flammable swarf/chips and dusts.

The flashpoint of minimum quantity lubricant used shall be considered. In principle, lubricants with a flashpoint of at least 150 °C shall be used. When used in accordance with its intended use, evolution of a dangerous explosive air-/vapour mixture is not likely to occur if the consumption rate remains below 100 ml/(m³/h). If this is not ensured, a machine extraction system is mandatory.

5.6.3 Dry processing and combustible dust

A mechanical interface for an air-extraction system is mandatory [see [6.3.1 q](#)] for documentation requirements].

An explosion risk shall be considered for accumulations of combustible dust (as an example for graphite dust) and especially for light metal dusts, e.g. aluminium, titanium and magnesium. Dispersion of deposited combustible dust can lead to a hazardous explosive atmosphere. If fire ignition from aluminium, titanium and magnesium dust is foreseen with the intended use of the machinery appropriate gasses or dry powders shall be used in the extinguishing system such as CO₂ or inert gas.

A higher risk of fire exists in areas in which great amounts of combustible swarf/chips and dusts emerge and accumulate. In addition to the work zone of the encapsulated system, the pipes and filter area of the exhaust system in which fine dust can be separated and dispersed shall also be considered. If fine dry combustible dust particles are cleaned up or dispersed, a possible risk of explosion exists. In these areas, it is not permitted to use compressed air as this will cause dispersion of the dust particles during machining (see [Annex F](#) and [Annex J, J.4, Table J.14](#)).

Machining shall be stopped in case of failure of the swarf/chip removal or exhaust within sealed machines.

5.6.4 Requirements for biological or microbiological hazards

The following are the requirements for biological or microbiological hazards:

- a) the total content of the metalworking fluid systems shall be circulated in normal use so that no stationary volume within the reservoir exists except where settlement is required by design;
- b) to avoid stagnant areas remaining within the machine, metalworking fluid shall drain under gravity from the machine towards the reservoir. Otherwise, elevating pumps with level monitoring shall be provided to pump the metalworking fluid from the machine back into the reservoir;
- c) discharge pipework shall have a sufficient diameter and slope to minimize sludge settlement;
- d) the metalworking fluid system shall be provided with filtration;
- e) when sediment build-up occurs, the design shall facilitate cleaning (e.g. rounded corners in reservoirs). Cleaning shall not require drainage of the whole system, see ISO 14159;

- f) the inside of reservoirs shall not contribute to the growth of bacteria (e.g. smooth, unpainted surfaces);
- g) metalworking fluid reservoirs shall have covers designed to prevent the ingress of foreign matter;
- h) contamination of the metalworking fluid by oil or grease from external sources such as lost machine lubrication shall be avoided or means shall be provided for their systematic removal. It shall be possible to add a separation or removal system for oil or grease, if necessary;
- i) where a machine is provided with enclosed guards used with metal removal fluid (coolant), that enclosure shall be designed to provide an interface between the guard enclosure and an extraction system. The positioning of the interface shall take into consideration the internal airflows generated by the machine when in normal operation to enable effective operation of the extraction system;
- j) provision shall be made to empty metalworking fluid reservoirs completely;
- k) means shall be provided to enable
 - fluid samples to be taken,
 - sumps and pipework to be cleaned, and
 - filters to be changed

with the least possible exposure of operator to the fluid.

5.7 Specific requirements resulting from neglect of ergonomic principles hazards

Machines shall be designed in accordance with the ergonomic principles given in:

- ISO 12100;
 - ISO 6385;
 - ISO 14738;
 - ISO 15534-1;
 - ISO 15534-2;
 - EN 1005-1, EN 1005-2 and EN 1005-4.
- a) The requirements for unhealthy posture or excessive efforts (repetitive strain) include the design of machines in accordance with ergonomic principles so as to avoid excessive effort, unhealthy posture or fatigue during use and in particular:
- 1) workpieces, tooling and accessories shall be easy to move. For requirements on lifting equipment, see [6.3.1 i\)](#).
 - 2) where work handling equipment, hoists or lifting devices are required, provision shall be made for their installation and operation (e.g. by making work zone access possible through the top of the machine when movable guards are partially open);
 - 3) where parts are manually loaded, their fixtures, tool pockets or tool holders shall be positioned to prevent excessive reaching into the machine (see ISO 9241-400, ISO 9241-410 and ISO 11228-1);
 - 4) control devices to operate clamping or gripping devices (e.g. drawbars, chucks) shall be positioned to avoid excessive reaching while supporting the weight of the tool or workpiece (e.g. application of foot controls), (see ISO 9355-3:2006, 4);

- 5) moveable guards shall be power-operated where use of them will lead to repeated excessive effort (see also ISO 12100:2010, 4.2.2).
- b) For adequate consideration of hand-arm or foot-leg anatomy, the positioning of control devices and points for observation or service, such as those for filling and draining of reservoirs, shall be chosen to satisfy the ergonomic principles given in ISO 6385, ISO 9241-400, ISO 9241-410; ISO 9355-1, ISO 9355-2, ISO 9355-3; ISO 11228-1, ISO 13855.
- c) Work zone lighting shall be provided in all safe operation modes. It shall be at least 500 lx at the tip of the tool with the interlocked moveable guard open.
- d) For design location or identification of manual controls, input devices (e.g. keyboards, keypads and push buttons) shall be in accordance with ISO 9355-1 and ISO 9355-3.
- e) For design or location of visual display units, screen displayed information shall be clear and unambiguous. Reflections and glare shall be minimized (see ISO 9241, ISO 9355-1 and ISO 9355-2).
- f) Equipment and accessories indicated in the Instruction handbook and not readily available, for adjusting and maintaining the machine shall be provided.

5.8 Specific requirements resulting from unexpected start-up, over-run or over-speed hazards

5.8.1 General

The requirements are the following:

- a) Electrical control systems and SRP/CS shall be designed in accordance with
 - IEC 60204-1,
 - IEC 62061 or ISO 13849-1, and
 - ISO 13849-2.
- b) pneumatic systems shall be in accordance with ISO 4413;
- c) hydraulic systems shall be in accordance with ISO 4414;
- d) where access is provided to programmable functions for alterations in MSO 1 (automatic mode), e.g. for tool geometry offset correction, it shall be lockable to prevent unauthorized access to program data or programmable functions. This may be achieved by the use of a password, key switch or adequate access device;
- e) safety-related software shall be protected against unauthorized reconfiguration. In particular, it shall not be possible for the user to suspend the operation of safety function (including interlocked guards) by means of sequences inserted in or called up by the part program. This may be achieved by the use of a password, key switch or adequate access device.

5.8.2 Starting

The requirements for starting are the following.

- a) Where multiple hold-to-run control device locations are provided (e.g. main control station, hand-held pendant), only one shall be functional at a time (see [Table J.15](#), 15.2 for switching control sovereignty).
- b) In MSO 1 (automatic mode), the machine shall only be started or restarted when the guards are closed by actuation of the start device provided for that purpose, or if the requirements for guards with start function in accordance with ISO 12100:2010, 6.3.3.2.5 are fulfilled, the closure of a movable interlocked guard can result in a restart of moving machine parts.

- c) Unexpected start-up of hazardous movements shall be prevented in accordance with ISO 14118:2000, 6 when the movable guards are open or in MSO 0 (manual mode). See [J.2](#) for safety function 8 (SF 08).

5.8.3 Normal stop

- a) Machinery shall be fitted with a control device whereby the machinery can be brought to a complete stop.
- b) Each machine shall have a stop function according to IEC 60204-1:2009, 9.2.5.3 and 9.2.2.
- c) The machinery's stop control shall have priority over the start control.

5.8.4 Emergency stop

Each machine shall be fitted with one or more emergency stop devices. When a sequenced shutdown is required, the emergency stop functions shall be category 0 stop or category 1 stop in accordance with IEC 60204-1:2009, 9.2.5.4.2, ISO 12100:2010, 5.5.2 and ISO 13850.

An emergency stop function shall be initiated by an emergency stop device(s) which shall be in accordance with IEC 60204-1:2009, 10.7 and ISO 13850. An emergency stop device shall be provided at each operator's position including

- a) the main control panel,
- b) each portable control panel(s) (if provided), and
- c) inside the tool magazine or workpiece setting station where whole body access to the enclosure is possible, but it can be omitted if presence is short (see [3.1.18](#)) and it is possible for a person to release oneself from inside the enclosure.

Group 4 machines shall additionally provide a "pull wire" actuated emergency stop device along the length of the machine. Alternatively, discrete emergency stop devices shall be installed at a distance of max. 10 m (ISO 13850:2015, 4.4).

Where emergency stop devices are detachable, the requirements of ISO 13850:2015, 4.3.8 shall be followed.

5.8.5 Safety related parts of control system (SRP/CS)

The combination of safety related parts of a control system starts at the point where safety related signals are generated (e.g. emergency stop device, position switch) and ends at the outputs of the power control unit (e.g. main contacts of a contactor). If no hazards occur in de-energised state, power units such as motors or actuators are not considered to be parts of SRP/CS. If external forces take effect (e.g. on vertical axes), power units shall additionally be equipped with safety related parts (e.g. non return valve on actuators, additional mechanical brake).

Safety functions shall meet the requirements for the performance level of ISO 13849-1 as given in [Tables J.2](#) to [J.22](#). In addition to the safety functions given in [Annex J](#), the following applies.

- a) Hold-to-run control device: If the required performance level (PLr) as stated in [Annex J](#) cannot be achieved by the sole application of a hold-to-run control device, a combination of hold-to-run control and enabling device shall be applied (that complies with PLr = d, category 3 according to ISO 13849-1).
- b) Electronic handwheel: If the required performance level (PLr) as stated in [Annex J](#) cannot be achieved by sole application of an electronic handwheel a combination of electronic handwheel and enabling device shall be applied (that complies with PLr = d, category 3 according to ISO 13849-1).
- c) Emergency stop device: Although the required performance level according to [Annex J](#) is PLr = c, the emergency stop device shall be wired in category 3 according to ISO 13849-1 (see [Figure 3](#))

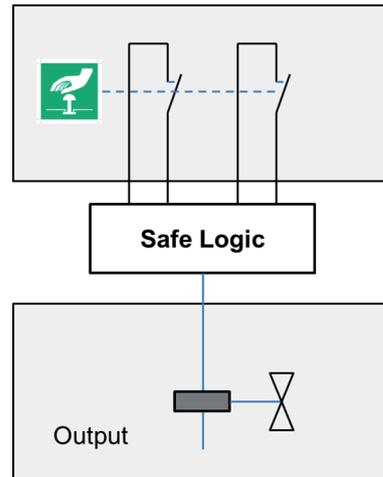


Figure 3 — Schematics of an emergency stop circuit

- d) Enabling device and wiring: Category 3 according to ISO 13849-1 shall be used.

5.8.6 Monitoring rotational speed limits and limits of linear and rotary movements

The following requirements apply only to machines of Group 2, Group 3 and Group 4 (they do not apply to Group 1 machines).

- The maximum permissible spindle speeds and other linear speeds and rotary speeds shall be monitored in accordance with [Table J.17](#), 17.3 and 17.4 in MSO 2 and MSO 3 with guards not closed.
- Movements caused by electrical, hydraulic or pneumatic, which are not required to be monitored, shall only be initiated and maintained in conjunction with an enabling device while guards are not closed. The speeds shall be reduced according to the selected MSO (see [5.2.4](#)) and, if applicable, the requirements stated in [5.2.5](#) for optional or additional equipment shall also be fulfilled.
- If the maximum permissible rotary speed or the speed limit of a monitored motion is exceeded, a stop shall be initiated automatically by a safety related stop function according to [Annex J](#).

5.8.7 Requirements for electromagnetic compatibility of electrical equipment

The requirements for electromagnetic compatibility of electrical equipment are the following.

- Immunity: Electronic and electrical components used in the machine shall be designed in accordance with IEC 61000-6-2. Regarding Electro Static Discharge (ESD), the machine shall be designed in accordance with IEC 61000-4-2 and for BURST with IEC 61000-4-4.
- Emission: Electric/electronic design shall apply technical information and physical measures to limit electromagnetic emissions depending on required local prerequisites:
 - mixed environment, light-industrial environment, IEC 61000-6-3, or
 - industrial environment, IEC 61000-6-4.

EN 50370-1 and EN 50370-2 are also applicable.

5.9 Specific requirements resulting from failure of any power supply

Requirements at the event of failure of power supply are the following.

- Inadequate pressure or voltage shall be detected and the machine shall be stopped.

- b) Interruption or failure of the power supply shall not result in a hazardous loss of workpiece clamping or tool clamping (e.g. by means of voltage and/or pressure dependant devices).
- c) Restoration of the energy supply shall not result in automatic restart of interrupted movements of machine parts or reactivation of fluid supply, etc. or the machine itself (see ISO 12100:2010, 6.2.11.4 and ISO 14118).
- d) Interruption or failure of the power supply shall not result in hazardous movement of vertical or slant axes under gravity. See [Annex G](#) for requirements regarding the safety control function to prevent unintended descent of a vertical or slant axis.
- e) Systems shall be designed so that a line rupture in any circuit (e.g. broken wire, pipe or hose) will not result in the loss of a safety function (see IEC 60204-1, ISO 4413 and ISO 4414).
- f) Means shall be provided for the isolation of the energy supply (see ISO 4413:2010, 5.4.7.2.1; ISO 4414:2010, 5.2.8 and IEC 60204-1:2009, 5.3.) For the dissipation of stored energy, see also ISO 14118:2000, 5.3.
- g) If the machine is provided with its own hydraulic unit and/or pneumatic compressor, the electrical disconnection of the machine shall also disconnect the electricity for the motor of the pump and/or the compressor. If the machine is supplied with external hydraulic and/or pneumatic energy, the machine shall be provided with reliable manually operated and lockable devices (e.g. ball valve) which fulfil the requirements of ISO 14118:2000, 5 for a disconnection from the supply. If automatic dissipation of energy is not possible due to isolation (see ISO 14118:2000, 5.3.1.3), facilities for discharging the remaining pressure shall be provided. These devices may include valves but the disconnection of pipes is not permitted.

NOTE In case of power failure or errors in the control or the power switches, coast of spindle drives cannot be excluded. Also, slight sag of gravity loaded axes cannot be prevented due to the response time of the mechanical holding brake.

5.10 Release of trapped and/or clamped persons

If there is a risk for persons to be trapped, jammed, clamped or crushed by the machine with power supply (e.g. workpiece clamping with doors open), manual operated means shall be available to depressurise and de-energize the relevant actuators to release the trapped person. These means are for example:

- manually operated relief valves to depressurise systems under pressure;
- manual actuated valves, which shall be clearly marked with signs in the local language where the machine is used or a pictogram; and/or
- manual operated facilities to start counter motions (only suitable for horizontal axis).

5.11 Specific requirements resulting from errors of fitting hazards

Any part dismountable by the user for setting or maintenance purposes (e.g. tool holder and mechanical devices), shall have provisions for preventing errors of fitting, e.g. pins, asymmetrical mounting (see [6.3.1](#)).

5.12 Specific requirements resulting from ejected fluids or parts

5.12.1 General requirements

Guards shall protect the operator from reaching into hazardous movements of the machinery and shield the operator from ejected parts (e.g. chips), fluids and compressed media, which occur during the regular machining process of workpieces. It shall not be the sole responsibility of these guards to protect the operator from ejected workpieces/equipment which do not belong to the scope of this document.

Guards shall be designed in accordance with ISO 14120:2015, Clause 8. These may take the form of a deflecting adjustable guard fixed to the spindle head to direct processed material/metalworking fluid towards their collecting area, or of a fixed guard covering the whole area of ejection.

5.12.2 Ejection of parts — Guard strength

Fixed and/or adjustable guards shall be provided to contain chips/swarf and/or metalworking fluids and parts and to deflect them towards the collection area. The area of the work zone of the machine shall be surrounded by guards in such a way that ejected chip/swarf and/or metalworking fluids and parts are intercepted. The guards shall be designed in such a way that accumulation of swarf/chips and fluids on the guard structure is prevented.

Standardized calculations shown in [Annex A](#) shall be applied to determine the potential kinetic/impact energy which are generated by ejection of parts. The guard strength is a function of guard thickness and guard material. [Annex B](#) shows minimum required guard thicknesses depending on used materials to withhold an impact energy generated by a projectile weighing 100 g. [Annex A](#) (calculation of kinetic/impact energy) and [Annex B](#) (required guard thickness depending on guard material) shall be applied to determine guard thickness (as function of applied material) in order to minimize the risk of ejection of parts. If it is foreseeable that parts which belong to the original delivery scope of the machine and are heavier than 100 g, can be ejected during regular machining operations, an impact test according to [Annex A](#) shall be done by the manufacturer of the machine taking appropriate masses into consideration. Shooting equipment as illustrated in [Annex B](#) can be used.

For machines that provide additional operations, such as turning operation or grinding operation, similar calculations are provided in the relevant standards (for turning operations use calculations of ISO 23125:2015, Annex A and for grinding operations use calculations of ISO 16089). The operation that requires the highest guard strength shall be used for the final guard design of the machinery.

In addition, measures regarding clamping (see [5.12.3](#), [5.2.5.5](#), [5.2.5.6](#), [Table J.4](#) and [Table J.2](#)) and following proper instruction for use (see [Clause 6](#)) are given to reduce the risk of ejection.

NOTE The hazards associated with ejected workpieces and parts of the machine are significant. This standard uses current, state-of-the-art methods to determine guard thicknesses which will retain the majority of these within the enclosure in the event of an incident which has been used successfully for many years (see [Annex A](#)). However, it is a physical impossibility to guarantee that all types of such items will be retained (dependent upon their weight, size and ejection energies, etc.). New calculation methods regarding impact energies of these items will be included in future revisions of this document as they are produced by industry and academia.

Where guards are fitted with viewing panels which are also intended to contain ejected parts, special consideration shall be given to the selection of materials and methods of fixing (see ISO 14120:2015, 5.4.2). Materials such as polycarbonate, which have a reduction in impact resistance over time (aging) due to contamination (e.g. by lubricants, metalworking fluids, cleaning agents, solvents) and abrasion, shall be provided with additional protection (e.g. sealed multi-layer or laminated constructions) or additional thickness to counter this harmful effect during the anticipated service life of the machine. Information on guards with reinforced viewing panels (e.g. additional thickness) along with replacement/maintenance intervals shall be given in instruction for use.

NOTE [Annex A](#) outlines a test procedure for the strength of materials in relation to maximum spindle speeds, cutting tool diameters, insert masses.

5.12.3 Power-operated workpiece and tool clamping

- a) Power-operated workpiece and tool clamping shall be designed to avoid risks of ejection due to intervention of the emergency stop or failure of the power supply. Tool/workpiece clamping force shall remain intact until standstill (e.g. by using non-return valves on the hydraulic system or a self-locking clamping device).
- b) The tool clamping cylinder shall be monitored so that a failure to achieve correct registration or clamping of the tool shall inhibit spindle start or stop a running spindle in all modes of safe

operation. Unclamping of the tool by actuation of the tool clamping cylinder during spindle rotation shall be prevented.

- c) The workpiece clamping cylinder of powered workpiece clamping mechanism shall be monitored at least indirectly (e.g. indirect hydraulic pressure measurement via a rotary coupling system) so that a failure to achieve correct registration or clamping of the workpiece shall inhibit start-up in all modes of safe operation. Unclamping of the workpiece by actuation of the workpiece clamping cylinder during spindle rotation shall be prevented.

5.12.4 Additional requirements for Group 3 and Group 4 machines

In addition, for use in MSO 1, plain fixed and movable interlocked guard(s), if access is necessary, shall be provided at the operator platform or machine bed and shall extend over at least 1 800 mm from the operator position floor and have the width of the operator platform or machine bed. Any movable part of this safeguarding shall be interlocked [see 5.2.3.2 c)] with the drive system(s) for displacement(s). The displacement of this safeguarding shall be interlocked with guard locking to the machine bed displacement.

It shall be ensured that the hazard zone cannot be reached when opening an interlocked guard without guard locking before the hazardous machine motion has been stopped (see ISO 13855:2010, Clause 9).

5.13 Specific requirements resulting from loss of stability hazards

Machines shall be designed and constructed so that they are stable under foreseeable operating conditions and without risks of overturning, falling or unexpected movement. When the use of foundation bolting is one of the measures used to help prevent overturning, manufacturers shall specify the bolts and foundation requirements necessary.

5.14 Requirements resulting from slips, trips, and fall of persons hazards

- a) Places of work and means of access on machines (such as ladders, platforms and walkways) shall be designed to minimize the likelihood of slips, trips, and falls by the provision of handholds, footholds, and, where necessary, slip-resistant surfaces. Warnings about hazards and precautions shall be given in the information for use (see 6.3).
- b) To avoid contamination of floors by coolants, the work zone shall be designed to prevent coolant from escaping. The pipe work from and to the coolant system shall be securely installed in order to prevent pipe damage and trips and falls. Appropriate details shall be provided in the Information for use.

5.15 Requirements resulting from accessibility for maintenance or troubleshooting on high parts of the machine

Where frequent access is required (i.e. at least once per shift), permanent means of access, such as fixed working platforms with fixed railings and toe boards against falling hazards (see ISO 14122-2) or stairways and ladders (see ISO 14122-3), shall be provided.

If only occasional access is required and the height is above 2 m, one or both of the following means shall be provided: supports for safety belt and/or means to attach movable ladders. For occasional access, see also [Clause 6](#).

5.16 Requirements for machinery with operator cabins and perimeter fencing

5.16.1 General

Due to geometrical dimensions of some machinery, it is in some cases necessary in order to operate the machinery properly that

- a) one or more person(s) need to enter the work zone,
- b) operator(s) need to leave or access the control cabin, which is in the work zone, or
- c) large workpieces (2 m or more in heights) need to be machined.

In these cases, additional requirements need to be fulfilled. Information regarding these requirements shall be described in the instruction for use section (see [6.3](#)).

5.16.2 Overall concept for entering/leaving machinery

The overall concept of entering and leaving the machinery shall be in that way, that the first person entering the machine has actively to allow further person(s) to enter in the safeguarded zone of the machine. This can be done by controlling one of several interlocked guards with guard locking, in combination with a security device, mainly with an electronic key system or equal measures.

A concept to leave/access the control station (e.g. cabin) from/to a non-hazardous area outside the guards/perimeter fencing during machine operation shall be worked out (see also [Annex H](#)).

NOTE Doing it this way, the person inside the machine allows actively other person(s) to enter the machine and is, therefore, aware who and how many other person(s) are inside the safeguarded zone of the machine at any time.

Access to the cabin in MSO 1 shall not require entry into the hazard zone enclosed by perimeter fencing or other protective devices. Where this is not possible, because of the machine configuration or other operational constraints, additional safeguarding for an access route to the operator position shall be provided.

The overall concept of leaving the control cabin in MSO 2 or MSO 3 shall ensure that the person, which is outside the control cabin, but within the safeguarded zone, has the direct control of movements of the machine.

Secondly, it is to ensure that the person is wearing safety belts by entering workpieces in height.

5.16.3 Requirements for moveable/adjustable operator cabins and operation platforms

5.16.3.1 General

For design, testing, marking, documentation for use and maintenance requirements make reference to EN 528. The following specifications prevail on EN 528 in case of conflicts.

5.16.3.2 Strength and stability

Cabins/platforms shall be designed so that any failure due to fatigue, aging, wear and corrosion is prevented. The rated load (excluding persons) and the number of persons and maximum permitted load to travel on the machine are the design data to be stated by the manufacturer.

Fixed or moving cabins/platforms shall be designed with a safety factor of 1,3 for stability.

An operator platform/cabin shall be designed and constructed to withstand the overload in the static tests without permanent deformation. For static testing procedures, the operator platform/cabin shall withstand 1,25 times its load. For dynamic testing procedures, the operator platform/cabin shall withstand 1,1 times its load (see EN 528:2009, 9.5.1).

Signs shall be placed at the operator platform/cabin for its maximum allowable load capacity and the maximum number of people allowed on platform or in cabin at one time.

5.16.3.3 Limiting the load

Operating platforms/cabins shall be fitted with a device to prevent a hazardous movement and warn the operator when the maximum permissible load capacity or the permissible load or overturning moment is exceeded.

5.16.3.4 Functional design

The walk-in of the operator platform/cabin shall have a minimum width of 600 mm, preferably 800 mm, and headroom shall be at least 2 100 mm (ISO 14122-2).

Operating platforms/cabins shall be fitted with skirting and be equipped for fall protection with a railing of at least 1 100 mm in height, if the height of the operator platform/cabin is higher than 500 mm; (ISO 14122-2 and ISO 14122-3).

Surfaces of floors of operating platforms/cabins shall be as such that they reduce the risk of slipping. The difference in height of adjacent flooring at the same level shall not exceed 4 mm (ISO 14122-2; see also EN 528:2009, Clause 6).

For protection of operator(s) from high pressurized media or the ejection or falling of objects, the platform/cabin shall be equipped with screens that absorb the energy of those predictably thrown objects (see 5.12).

The operator platform/cabin shall be adequately illuminated (300 lx) and sufficiently ventilated.

Access to the operator platform/cabin shall be possible without any risk. Interlocked guards shall be provided to protect against crashes and prevent access to hazardous movements. Interlocked guards shall be secured against accidental opening and shall only open in one direction in order to prevent any risk of falling.

Moving parts shall be designed in a way that squeezing, pulling, shearing, etc. is not possible to occur.

The operator platform/cabin shall be designed so that vibrations cannot cause any harm to the health of passenger(s) respectively operator(s).

If access to the machine from an operating platform/cabin is required, the access options to hazardous zones of the machine shall be designed in accordance with the requirements of MSO 1, MSO 2 and MSO 3.

If it is required to open a door of the operator platform/cabin in a raised position (e.g. to step on a workpiece), the platform/cabin shall be equipped with suitable anchor devices, designed and tested according to EN 795.

When the platform/cabin is raised, the operator(s) shall confirm by appropriate means to wear a suitable fall protection device before the door can be opened.

During normal operation, the area under the operating platform/cabin shall be inaccessible. If there is a crushing hazard to persons situated under or above the operator platform/cabin or between the platform and other stationary parts of the machine, provision shall be taken to block or turn off the motion of the operator platform/cabin for sufficient clearance.

5.16.3.5 Actuators, limitation of movement

The platform/cabin shall be equipped with hold-to-run devices to control the movements. Those actuators have priority over all other controls, except the emergency stop devices. The movement of the operator platform/cabin shall only be possible with doors closed. An acceleration or deceleration of the movement of the operator platform/cabin shall not cause any hazard.

In order to prevent collisions between the operator platform/cabin with any obstacles and also against collisions of moving obstacles with the operator platform/cabin, appropriate means to shut down the movement shall be provided (e.g. ESPE, PSPD). If the colliding speed is lower than 15 m/min, no means are necessary.

5.16.3.6 Protective measures and safety devices

A mechanism and/or device shall be provided to bring the platform/cabin to a standstill without exposing persons to hazardous situations. This mechanism and/or device shall also function at maximum load and maximum speed.

In case of power failure, means shall be provided, which allow leaving the platform/cabin, even in its elevated position (e.g. through emergency descent by means of a ladder or depressurization or by uninterrupted power supply (UPS) supplying energy for the required movements).

In case of power failure or prolonged shutdown or changes in environmental conditions (e.g. temperature), the platform/cabin shall not independently change its position if this leads to a collision. If necessary, appropriate holding devices, monitoring devices and readjustment devices shall be provided.

Means shall be provided that allow the control of the platform/cabin, which is control of motion and the opening of doors (e.g. to release people), from the ground level and outside the platform/cabin.

5.16.3.7 Testing and commissioning

Appropriate measures to ensure proper functioning of the platform/cabin have to be taken when first putting it into service. That requires performing static and dynamic tests of the platform/cabin. In case the assembling of the platform/cabin cannot be done at the manufactures site, there shall be appropriate means taken at the place of use.

The manufacturer of the platform/cabin shall provide information in the documentation on what kind of service inspections are required and what intervals those inspections shall take place.

5.16.3.8 Additional requirements for cabins located in the work zone

When the machine operator requires access to the work zone from the protected (fixed) operating position (cabin), e.g. for setting purposes, the cabin shall be designed so that access is possible through an interlocked movable guard from within the cabin. Alternatively, the movement of a movable control station from the cabin position shall have the same effect as the interlocked guard above. Operation of the machine in MSO 1 (automatic mode) shall only be possible when the movable control station (above) is relocated in the cabin. Any other powered movement of machine elements shall only be achieved by selection of the appropriate MSO (see [5.2.4](#)).

Where a cabin is provided for Group 2 and Group 3 machines, it shall be possible to access/leave the cabin in MSO 1 (automatic mode) without any risk.

If the operator leaves the cabin from a safe position (e.g. rear area of the machine) and the cabin is moving not more than 5m/min, it is possible to leave without stopping the operator cabin (see [Table J.17](#)), otherwise, the cabin movements shall be stopped before leaving. During the leave and return to cabin, the acceleration shall not exceed 0,5 m/s².

For accessing and leaving the cabin the following applies.

- During operation in MSO 1, it shall be possible to traverse the cabin to the position in which the cabin is accessible.
- If it is necessary to exit at a position other than the normal position for e.g. measuring purposes, the requirements of [5.16](#) shall be applied.

The exit shall be at the side which is directed away from the machining process. If the cabin is elevated, an interlocked guard with guard locking shall be activated in order to prevent falling (see examples in [Annex H](#)).

Where a cabin is provided for Group 2 and Group 3 machines, it shall be possible to leave and return to the cabin in MSO 2 and MSO 3 without any risk. During operation in MSO 2 or MSO 3, it shall be possible to have access to the workpiece in each position.

If the cabin is in an elevated position higher than 2 m above ground level, the following shall apply.

- All operator(s) shall have the possibility to sling the safety belt onto the inside of the control cabin.
- The operator(s) left in the cabin have to confirm, before leaving the cabin, that all person(s) inside the cabin wear the safety belt; without confirmation, it shall not be possible to open the interlocked guard of the control.
- No movement of the machine will take place, when the interlocking guard with guard locking is opened.
- The initiation of movements shall only be possible with a movable control station (e.g. pendant) featuring an enabling device and which has precedence over the control panel within the cabin.

5.16.4 Requirements for perimeter fencing

The requirements for perimeter fencing given in ISO 11161:2007, 8.5.2 are applicable

When access to the work zone is prevented by perimeter fencing all the provided access points (e.g. gates) shall be interlocked (see [Annex H](#)).

5.17 Verification of the safety requirements and/or protective measures

Verification of conformity with the safety requirements and/or protective measures shall be done in accordance with [Table 5](#).

Table 5 — Verification methods

Clause/ sub- clause	Item	Verification method				
		Visual inspection	Functional test	Measurement	Calculation	Documentation
5	Safety requirements and/or measures					
5.1	General requirements					
5.1.1	General	X	X			X
5.1.2	Required characteristics for guards of all machine groups					
5.1.2.1	General					X
5.1.2.2	Fixed Guards	X		X		X
5.1.2.3	Moveable inter- locked guards	X	X			X
5.1.3	Power-operated moveable guards					
5.1.3.1	General		X			X
5.1.3.2	Automatic mo- tion initiation by control system		X	X	X	X
5.1.3.3	Manually pow- er-operated moveable guards	X	X	X	X	X

Table 5 (continued)

Clause/ sub- clause	Item	Verification method				
		Visual inspection	Functional test	Measurement	Calculation	Documentation
5.2	Specific requirements resulting from mechanical hazards					
5.2.1	Protective measures for Group 1 machines	X	X	X		X
5.2.2	Protective measures for Group 2 machines	X	X	X		X
5.2.3	Protective measures for Groups 3 and Group 4 machines					
5.2.3.1	Access to the work zone	X				X
5.2.3.2	Characteristics of guards, specific requirements	X	X	X		X
5.2.4	MSO of machine operation					
5.2.4.1	General requirements	X	X			X
5.2.4.2	Requirements for MSO selection system (Group 2, Group 3 and Group 4 machines only)	X	X	X	X	X
5.2.4.3	MSO 0: manual mode	X	X	X	X	X
5.2.4.4	MSO 1: automatic mode	X	X	X	X	X
5.2.4.5	MSO 2: setting mode					
5.2.4.5.1	Basic specifications	X	X			X
5.2.4.5.2	Range of functions	X	X	X		X
5.2.4.6	MSO 3: automatic mode	X	X	X		X
5.2.4.7	MSO Service	X	X	X		X
5.2.4.8	Symbols for MSO	X				X
5.2.5	Optional or additional equipment for milling machines					
5.2.5.1	Machines equipped with tool magazine(s)	X	X	X	X	X
5.2.5.2	Machines equipped with tool changer(s)	X	X	X	X	X
5.2.5.3	Machines equipped with workpiece handling mechanisms	X	X	X	X	X
5.2.5.4	Workpiece setting position	X	X	X		X

Table 5 (continued)

Clause/ sub-clause	Item	Verification method				
		Visual inspection	Functional test	Measurement	Calculation	Documentation
5.2.5.5	Additional requirements for powered work-piece clamping mechanisms	X	X	X	X	X
5.2.5.6	Clamping conditions for work-piece if turning operation is provided	X	X	X	X	X
5.2.5.7	Machines equipped with swarf/chip collection/removal system	X	X	X	X	X
5.2.5.8	Additional requirements for machines including pits	X	X	X		X
5.3	Specific requirements resulting from electrical hazards	X	X	X	X	X
5.4	Specific requirements resulting from noise hazards	X	X	X		X
5.5	Specific requirements resulting from radiation hazards	X	X	X		X
5.6	Specific requirements resulting from material or substance hazards					
5.6.1	Combustible coolants	X	X		X	X
5.6.2	Minimum quantity lubrication (MQL)	X	X		X	X
5.6.3	Dry processing and combustible dust	X	X		X	X
5.6.4	Requirements for biological or microbiological hazards	X		X		X
5.7	Specific requirements resulting from neglect of ergonomic principles hazards	X	X			X
5.8	Specific requirements resulting from unexpected start-up, over-run or over-speed hazards					
5.8.1	General	X	X			X
5.8.2	Starting	X	X			X

Table 5 (continued)

Clause/ sub- clause	Item	Verification method				
		Visual inspection	Functional test	Measurement	Calculation	Documentation
5.8.3	Stopping	X	X	X		X
5.8.4	Emergency Stop	X	X	X		X
5.8.5	SRP/CS		X			X
5.8.6	Speed monitoring		X	X	X	X
5.8.7	Electromagnetic compatibility			X	X	X
5.9	Specific require- ments resulting from failure of any power supply		X			
5.10	Release of trapped and/or clamped persons		X			X
5.11	Specific require- ments from errors of fitting hazards	X	X			
5.12	Specific requirements resulting from ejected fluids or objects hazards					
5.12.1	General require- ments	X	X	X	X	X
5.12.2	Guards for Group 3 and Group 4 machines	X	X			X
5.13	Specific require- ments resulting from loss of sta- bility hazards	X	X		X	X
5.14	Specific require- ments resulting from slips, trips and fall of per- sons hazards	X	X			X
5.15	Requirements resulting from accessibility for maintenance or trouble shooting on high parts of the machine	X				X
5.16	Requirements for machinery with operator cabins and perimeter fencing					
5.16.1	General	X		X		
5.16.2	Overall concept of entering/leav- ing machinery	X				X
5.16.3	Requirements for movable/ad- justable operator cabins/platforms	X	X	X		X
5.16.4	Requirements for perimeter fencing	X	X			X

Table 5 (continued)

Clause/ sub- clause	Item	Verification method				Documentation
		Visual inspection	Functional test	Measurement	Calculation	
6	Information for use					
6.1	General	X				X
6.2	Marking	X				X
6.3	Instruction for use					
6.3.1	General	X				X
6.3.2	Tooling	X				X
6.3.3	Workpiece clamping	X				X
6.3.4	Machine func- tions accessible from the NC panel	X				X
6.3.5	Restart	X				X
6.3.6	Noise	X				X
6.3.7	Residual risks to be addressed by the machinery user	X				X
6.3.8	Installation in- structions for the machines	X				X
6.3.9	Cleaning in- struction for the machine	X				X
6.3.10	Machinery with operator cabins and/or perime- ter fencing	X				X

6 Information for use

6.1 General

For general information that shall be provided, see ISO 12100:2010, 6.4.

6.2 Marking

Machines shall bear markings in a distinct and permanent manner in accordance with ISO 12100:2010, 6.4. At least the following markings shall be provided:

- a) for its unambiguous identification:
 - 1) the business name and full address of the manufacturer and, where applicable, the authorized representative;
 - 2) the designation, the series or type of machine;
 - 3) the serial and/or machine number, if any;
 - 4) the year in which the manufacturing process is completed;
- b) in order to indicate its compliance with mandatory requirements, i.e. the mandatory marking;

NOTE The mandatory marking for Europe is the CE marking.

- c) for its safe use:
 - 1) the maximum permissible spindle speed of the spindle(s), in revolutions per minute;
 - 2) the machine shall be provided with an appropriate warning sign, if a fire and/or explosion risk exists. The marking shall also indicate how to extinguish the fire.

6.3 Instruction for use

6.3.1 General

An instruction handbook in accordance with ISO 12100, completed with the specific information for the stated milling machine, shall be provided with the machine.

The instructions for use shall provide all necessary information regarding transport, assembly/disassembly, operation, setting, maintenance, cleaning, etc., to train or qualify the staff sufficiently in intended and safe use of the machine.

The instruction handbook shall specify that it is essential that operators be adequately trained in the safe use, adjustment and operation of the machine. At least the following information shall be given:

- a) specifications on machining processes and modes of safe operation for which the machine is suited. For all modes of safe operation, detailed descriptions for the intended use of these modes of safe operation have to be defined:
 - 1) information about the reasonable foreseeable misuse;
 - 2) possible residual risks, e.g. through any provided mode of safe operation;

NOTE As a protective measure against loss of whole workpieces, the protective enclosure is not always sufficient.

 - 3) the necessary qualification of operators in MSO 1 and particular if the machine provides the mode of safe operation MSO 2, MSO 3 which, for example, requires experience in:
 - i) adjusting and clamping of workpieces and devices;
 - ii) setting, operating and monitoring of milling machines;
 - iii) selection, use and mounting of tools;
 - iv) data input for the machining of workpieces and optimization of the machining process;
 - v) specific hazards and required safety measures;
 - vi) use of personal protective equipment (PPE);
 - 4) if the machine provides MSO Service in accordance with [5.2.4.7](#), the manufacturer of the machine shall additionally specify
 - i) the details of the application(s) of service mode, and
 - ii) the required skills and the skill level for the operator(s) to operate service mode;
- b) a declaration that the safeguards shall be in place and functional before initiating movements for each mode of safe operation;
- c) a requirement for installation (if relevant, also recommendations on means to prevent access to chip discharge area); including instructions for how the initial test and examination of the machine and its guarding system are to be carried out before first use and being placed into production. For machines using combustible coolants, which are equipped with pressure releasing devices, these

also include information on the installation site (keeping the area above the pressure releasing device free);

- d) a requirement for maintenance, including a list of those devices which shall be inspected or tested, how frequently and by what method;
- e) instructions for any test or examination necessary after change of component parts or addition of optional equipment (both hardware and software) to Group 1 and Group 2 machines, which can affect the safety functions;
- f) specification for changing safety relevant parts of control system when their life less than the mission time of the machine and the architecture is less than category 3 according to ISO 13849-1;
- g) the frequency of visual inspections that are necessary to ensure the protective function of vision panels, including the details of:
 - 1) inspection methods and a description of defects which make the vision panel unsuitable for continued use or indicate that replacement is required. This information may include descriptions of unacceptable vision panel condition, e.g. plastic deformation (bulges, dents) due to previous impact events, cracks, damage to edge sealing, coolant penetration into composite making the vision panel dull or discoloured or other damage to vision panels. Polycarbonate vision panels are dangerous as soon as they are tarnished or discoloured and they have to be replaced with new vision panels before that happens;
 - 2) the manufacturer's recommendations for the replacement of vision panels shall take into consideration the material properties of the vision panel in question. For the special case of polycarbonate, see [Figure B.2](#);
 - 3) the recommended methods for cleaning vision panels without causing damage and, where appropriate, the selection and use of suitable cleaning agents;
 - 4) an indication that when changing vision panels, the assembly instructions of the machine manufacturer shall be followed;
 - 5) an indication on the manufacturer's recommended method for cleaning polycarbonate panels without causing damage;

NOTE For g), a checklist can be provided which includes specifications about assessment and the foreseen use of the vision panel.

- h) information defining the limits for the spatial envelope and maximum mass of the workpiece and workholding fixture(s);
- i) recommendations on handling and lifting heavy parts, tools or workpieces, including the location of lifting points of exchangeable components, e.g. tools, parts, clamping devices. Lifting equipment may be required for parts over 10 kg in weight (see ISO 11228-1);
- j) recommendations on selection, preparation, application and maintenance of lubricants for the braking and transmission systems;
- k) recommendations on selection, preparation, application and maintenance of cutting fluids and precautions against their degradation;
- l) recommendations on the measures to prevent spillage of cutting fluids, e.g. cleanliness of collecting gutters;
- m) recommendations on reducing fire- and explosion hazards when choosing combustible coolants. This includes, e.g. information on viscosity and flashpoint as well as reduction of aerosol- and vapour formation by choosing low-emission coolants (see [Annex E](#) and [Annex F](#));

- n) recommendations on additional safety measures when using combustible coolants. This includes information on
- 1) emission of hot gases at door gaps and openings of the machine,
 - 2) hot surfaces and perhaps live parts after a fire,
 - 3) restrike hazard while opening/restarting the machine immediately after a fire, and
 - 4) preventing ingress of foreign matter, such as
 - i) cleaning agents and care products for machinery,
 - ii) cleaning agents and solvents for workpieces,
 - iii) foreign oils, etc., and
 in order to preserve the safety relevant properties of the coolant throughout its service life with regard to fire and explosion hazards;
- o) the instructions to enable the release of trapped persons;
- p) recommendation concerning the use of personal protective equipment (e.g. hand, ear and eye protection, etc.); warning of the hazards arising from sharp tools/components and of the need to wear appropriate personal protective equipment;
- q) the instructions for connection of an extraction system, where the machining process generates hazardous substances (e.g. dusts and mists);
- r) the recommendation to use additional precautions when working with flammable metalworking fluids or pyrophoric material;
- s) the recommendations of the manufacturer of the metalworking liquid which shall be followed, especially the recommendations related to the viscosity and the flashpoint of the liquid, if the machine is designed for the use of combustible metalworking fluids;
- t) instructions on control systems including circuit diagrams for electrical, hydraulic, and pneumatic systems;
- u) in particular for Group 1 machines (manually operated machines) (e.g. manual feed and workpiece load/unload), instructions and guidance shall be provided concerning the safe methods of workpiece holding. This information shall make reference to correct use of suitable clamping devices and the use of suitable milling fixtures;
- v) information for transportation of machine at least including lifting points, lifting equipment and lifting mass shall be provided.

6.3.2 Tooling

- a) Information to enable tools to be selected, fitted and/or changed shall be provided, e.g. data relevant to that part of the tool/machine interface belonging to the machine.
- b) Where applicable, recommendations on tools to be used with the machine shall be provided, e.g. pre-set tools including, where applicable, limits of mass, moment of inertia and spatial envelope for tools in tool changing devices.
- c) Information shall be provided to warn the operator that tools can be hot following machining.
- d) In order to prevent falls or ejections, tools shall be securely held within the holders of the magazine. For whole body access, information about residual danger due to presence of persons shall be provided in the documentation.

- e) Information that milling tools shall be in accordance to ISO 15641 and selected speed shall be less or equal of the maximum permissible tool speed (RPM).

6.3.3 Workpiece clamping

The following information about workpiece clamping and workpiece clamping devices and changeable workpiece clamping devices shall be supplied.

- a) For workpiece clamping devices supplied with the machine, information about how the workpiece clamping device shall be used and maintained (e.g. maintenance and lubrication schedule, measuring clamping forces).
- b) For workpiece clamping devices that can be used, recommendations on the clamping of workpieces, including information on collets or chucks (if applicable) that can be used with the machine, together with the recommendation for use/maintenance from the workpiece clamping device manufacturer.
- c) For replacing/changing the workpiece clamping device, information to enable workpiece clamping devices [e.g. chucks (if applicable) or collets] to be selected, fitted and/or changed, for instance data relevant to that part of the clamping device/machine interface belonging to the machine or unbalance requirements for chucks and faceplates.
- d) For workpiece clamping device modifications:
 - 1) information that modification of workpiece clamping devices supplied with or fitted to the machine may reduce or alter the maximum permissible forces, moments and spindle speeds or the efficiency of these devices;
 - 2) information that workpiece clamping devices shall only be modified within the limits given by the milling machine manufacturer and in accordance with the clamping device manufacturer's recommendations;
 - 3) information on equipment added to or substituted for workpiece clamping devices (e.g. jaws) which would reduce the maximum permissible speed of those devices.
- e) The operator shall be warned that workpieces or parts of it could be hot after the machining process.

6.3.4 Machine functions accessible from the NC panel

The instructions for use shall describe the correct selection and use of machine functions accessible from the NC panel, e.g. tool corrections, mode access and mode changes.

6.3.5 Restart

Information shall be provided on restart procedures.

6.3.6 Noise

The following information on airborne noise emissions shall be provided:

- a) the A-weighted emission sound pressure level at workstations, where this exceeds 70 dB(A); where this level does not exceed 70 dB(A), this fact shall be indicated;
- b) the A-weighted sound power level emitted by the machinery, where the A-weighted emission sound pressure level at workstations exceeds 80 dB(A).

These values shall be either those actually measured for the machinery in question or those established on the basis of measurements taken for technically comparable machinery which is representative of the machinery to be produced.

In the case of very large machines (see [K.3](#)), instead of the A-weighted sound power level, the A-weighted emission sound pressure levels at points equally spaced on a path around the machine at 1 m from the machine surface and 1,6 m above the floor or platform shall be declared.

Whenever sound emission values are indicated, the uncertainties surrounding these values shall be specified. The operating conditions of the machinery during measurement and the measuring methods used shall be described.

The declaration shall be accompanied by a statement of the measuring method used and the operating conditions applied during the test and values for uncertainty, K , using a dual number form of declaration defined in accordance with ISO 4871:

$K = 4$ dB when using ISO 3746 or ISO 11202 (grade 3);

$K = 2,5$ dB when using ISO 3744 or ISO 11204 (grade 2).

EXAMPLE For a sound power level $LWA = 83$ dB(A) (measured value), uncertainty $K = 4$ dB(A) for measurements made in accordance with ISO 3746. Another example for noise declaration can be found in ISO 230-5:2000, Annex E.

NOTE The operating modes mentioned in the example from ISO 230-5 are only general and not represent the modes of safe operation for milling machines according to the definitions [3.4.4](#) to [3.4.7](#).

The noise declaration shall be accompanied by the following statement: "The figures quoted are emission levels and are not necessarily safe working levels. Whilst there is a correlation between the emission and exposure levels, this cannot be used reliably to determine whether or not further precautions are required. Factors that influence the actual level of exposure of the workforce include the characteristics of the work room and the other sources of noise, etc., i.e. the number of machines and other adjacent processes and the length of time for which an operator is exposed to the noise. Also, the permissible exposure level can vary from country to country. This information, however, should enable the user of the machine to make a better risk assessment.

Information on noise emission shall also be provided in the sales literature providing performance data of the machine.

6.3.7 Residual risks to be addressed to the machinery user

Information shall be provided to warn that guards provided or supplied with the machine in accordance with [Annex A](#) are intended to minimize the risks of ejection and not to eliminate them completely.

Advice shall be provided stating that processing substances such as aluminium, titanium or magnesium can cause additional hazards, e.g. fire and explosion or noxious dust.

Information shall be provided to the user for the utilization of appropriate inert gas or dry powder in the extinguishing system if machining of combustible dust such as aluminium, titanium and magnesium is foreseeable.

Instructions shall be provided on the necessary checks following the exchange of components, removal of equipment or change of software where these may affect safety functions (see also [6.2](#)).

Information shall be provided to indicate that machining unbalanced workpieces may create an ejection hazard and that the way to minimize the risk is to counter balance or machine at reduced speeds.

Information shall be provided on machining processes and modes of safe operation for which the machine is suited.

Information on possible residual risks, e.g. through mechanical hazards in MSO 0 (manual mode) and MSO 2 (setting mode), shall be provided (see [6.2](#)).

If the machine provides MSO 3 and/or MSO Service in accordance with [5.2.4.6](#) and [5.2.4.7](#), the manufacturer of the machine shall specify

- the details of the application(s) of this MSO,
- the required skills and the skill level for the operator(s) to operate this modes of safe operation, and
- the operator shall be warned that swarf/chips and workpieces can be hot after processing. Furthermore, warning against cutting and stabbing hazards shall be made because swarf/chips can be sharp edged.

Information shall be provided on the main parameters the user has to consider to lower the noise emission level, e.g.

- tool selection,
- work/tool clamping, and
- maintenance.

If it is foreseen that the machine will be operated unattended, for some or all of the operating cycle, information shall be provided, how to leave the control station of the machine and how to return to it.

6.3.8 Installations instructions of machinery

Information about the foundation design and how to install and support the machine shall be provided. Above all, the safe handling of heavy parts of large machines shall be described.

Information on how to provide protection against electric shock due to indirect contact in the machine shall be provided, e.g. by a device for automatic disconnection of the power supply to be installed by the user in the line powering the machine (RCD).

Information on how to provide protection against short circuits of the feeder circuit as far as relevant shall be provided.

6.3.9 Cleaning instructions of machinery

Information about the foreseen cleaning procedures shall be provided. All utilities (e.g. illumination, handholds, footholds and/or slip-resistant surfaces) shall be described and the way to reach all sides/parts of the machine shall be explained. Information shall be provided, that cleaning personnel shall be adequately trained. It shall be pointed out, on what the cleaning personnel has to pay special attention to.

6.3.10 Machinery with operator cabins and/or perimeter fencing

The overall concept of entering and leaving the machinery as laid out in [5.16.2](#) shall be described in the information for use with details of how it is implemented in the machine.

The measures for leaving from/returning to the control cabin shall be described in the information for use (see [5.16.3](#) and [Annex H](#)).

Annex A (normative)

Impact test method for guards on machines

A.1 General

This annex defines tests for guards used on machines. This annex applies to sample of guard materials as well as to complete guards for machines.

A.2 Test method

A.2.1 Principle

This test method is based upon machines equipped with milling cutting tools driven up to the maximum speed given by [Formula \(A.1\)](#):

$$v_c = B \pi n, \text{ [m/s]} \quad (\text{A.1})$$

where

B is the maximum tool diameter which can be clamped in the machine spindle [m];

n is the maximum spindle speed [sec^{-1}].

This test method may be used for all groups of machines included in this document.

A.2.2 Test equipment

A.2.2.1 Propulsion device

The propulsion device shall allow the projectile to accelerate to $\pm 5\%$ of a pre-set impact speed at the test object; see also [Table B.1](#).

A.2.2.2 Projectile

Shape, mass and dimensions of the projectile are given in [Figure A.1](#).

Projectiles are made from steel with the following mechanical characteristics:

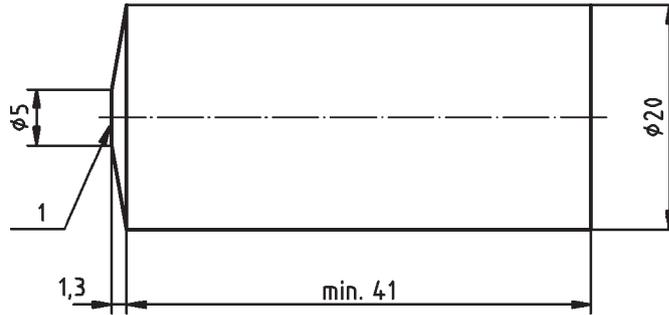
Ultimate tensile strength: $R_m = 560 \text{ N/mm}^2$ to 690 N/mm^2

Yield strength: $R_{0,2} = 330 \text{ N/mm}^2$

Elongation at rupture: $A = 20\%$

Mass: $m = 0,1 \text{ kg}$.

As an alternative, a drop test may be performed with higher mass added to the rear of the projectile, but with 1,6 times greater impact energy (see ISO 23125, A.5.2).



The projectile is hardened to 56_{-0}^{+4} HCR over depth of at least 0,5 mm.

Key

1 front view

Figure A.1 — Test projectile

A.2.3 Speed measurement

The speed of the projectile shall be measured at a point where it is no longer subject to acceleration (i.e. after exiting the barrel or in the barrel beyond suitable pressure relief). The speed shall be measured over a fixed distance using proximity sensors, photoelectric cells or other equivalent means.

A.2.4 Support of the test object

The test is carried out with the guard and/or a sample of the guard material. The guard support shall be equivalent to the guard mounting on the machine. For testing guard materials, samples may be used, fixed on a frame with an inner opening of 450 mm × 450 mm. The frame shall be sufficiently rigid. The mounting of the sample shall be by non-positive clamping.

A.2.5 Test procedure

The projectile ($m = 0,1$ kg) speed and other values shall be calculated as follows:

v_c maximum cutting speed [m/s] (see [A.2.1](#))

v_i measured impact speed [m/s]

Maximum impact energy: $J_c = \frac{m}{2} v_c^2 [J]$

Measured impact energy: $J_i = \frac{m}{2} v_i^2 [J]$

The maximum impact energy shall not be less than the measured energy.

The direction of impact shall as far as possible be perpendicular to the surface. Targets for the projectile shall be the weakest and most unfavourable areas on the guard, or in the centre of the material sample and, in particular, of vision panels.

A.3 Results

A.3.1 Damage

After the impact, any damage found on the guard or material shall be assessed and classified according to the appearance as follows:

- a) buckling/bulging (permanent deformation without crack);
- b) incipient crack (visible only on one surface);
- c) through crack (crack visible from one surface to the other);
- d) penetration (projectile penetrating the test object);
- e) guard window loosened from its fixing;
- f) guard loosened from guard support;
- g) flying outer parts of the guard.

A.3.2 Assessment

- The test is passed if the damage is one of the types described in [A.3.1](#) a) and/or b).
- The test is considered failed if any damage described in [A.3.1](#) c), d), e) f) or g) occurs.

A.4 Test report

The test report shall give following minimum information:

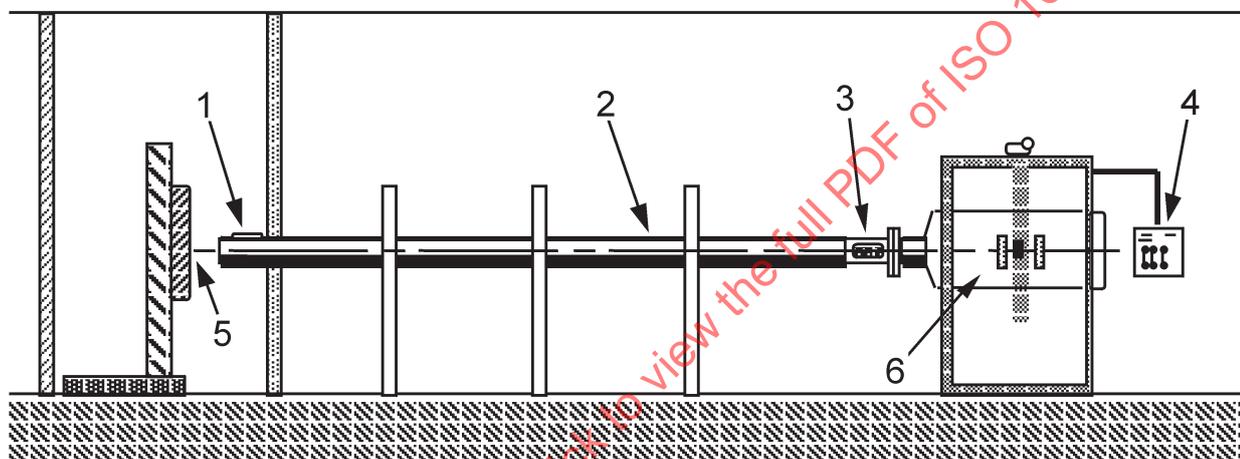
- the date and place of the test and name of the test body;
- the projectile mass, dimension, speed and impact energy;
- the applicant identification;
- the design, material and dimensions of the test object;
- the clamping or fixing of the test object;
- the direction of shot, point of impact of the projectile;
- the test result.

Annex B (informative)

Equipment for impact test and examples of tested materials

B.1 Shooting device

The gun device consists of a compressed air vessel with flanged gun barrel (see [Figure B.1](#)). The compressed air can be released as an impulse by a special valve to accelerate the projectile towards the test object. The air is fed by an air compressor. The speed of the projectile is controlled by the pressure of the air and the volume. The projectile speed is measured near the muzzle of the gun barrel by a suitable velocimeter, e.g. by proximity sensor or photocell.



Key

- 1 velocimeter
- 2 gun barrel
- 3 projectile
- 4 control panel
- 5 test object
- 6 compressed-air vessel

Figure B.1 — Equipment for impact test

B.2 Examples of materials

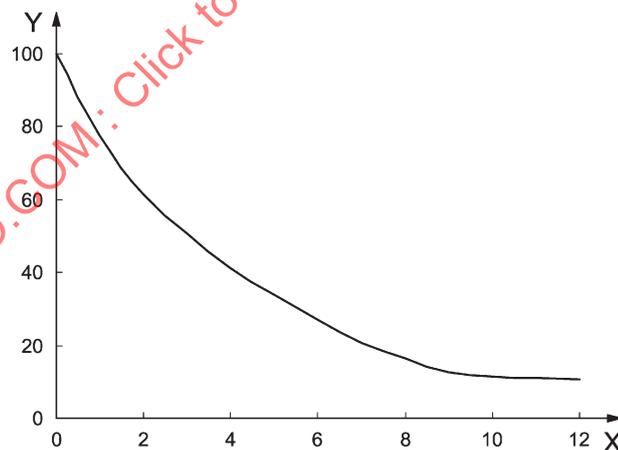
Table B.1 — Impact test results for tested material samples ($m = 0,1$ kg)

Material	Thickness d mm	Tensile strength R_m N/mm ²	Elongation at rupture ϵ_B %	Velocity v_c m/s	Energy E J
St 12.03	1,5	369	28	80	320
	3,0	405	28	115	661
	1,5 + 3,0 ^a	369/405	28	150	1 125
	3,0 + 1,5 ^a	405/369	28	140	980
AlMg ₃	5,0	242	18	120	720
	10,0	242	18	150	1 125
Polycarbonate ^b	4,0	68	80	85	361
	6,0			100	500
	8,0			120	720
	12,0			150	1 125
	2 × 6,0			170	1 445
	2 × 12,0			230	2 645

^a On the work zone side.

^b Test results apply to new material without considering ageing.

[Source: BIA, Saint Augustine, Federal Republic of Germany; JWF TU Berlin, Federal Republic of Germany.]



Key

X time of use, expressed in years

Y impact resistance, expressed as a percentage

Figure B.2 — Ageing curve of unprotected polycarbonate (averaged test points)

Annex C (informative)

Illustrative figures as examples of machines

C.1 Group 1 machines

See [Figures C.1](#) and [C.2](#).

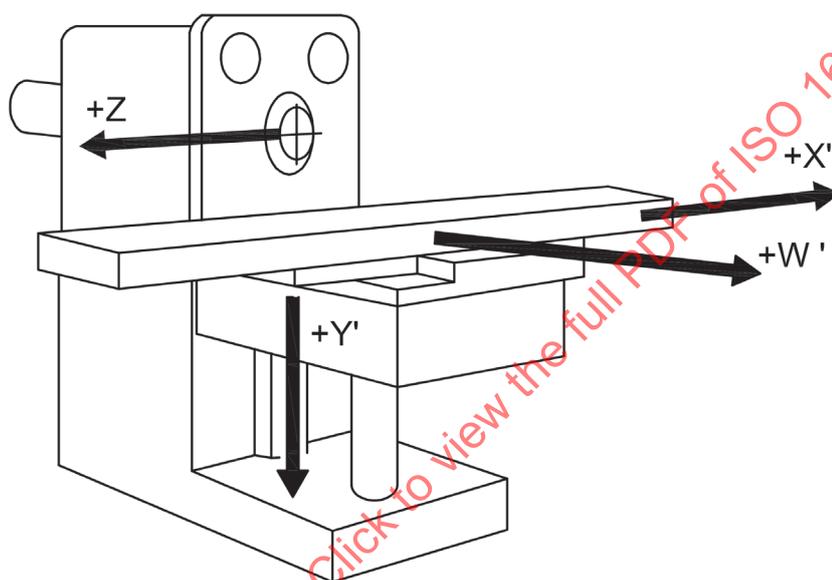


Figure C.1 — Example of a horizontal knee-type milling machine

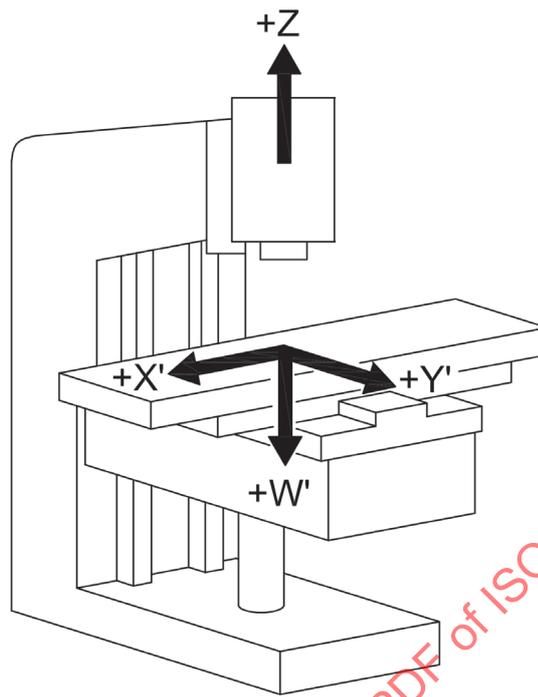


Figure C.2 — Example of a vertical knee-type machine

C.2 Group 2 machines

See [Figures C.3](#) and [C.4](#).

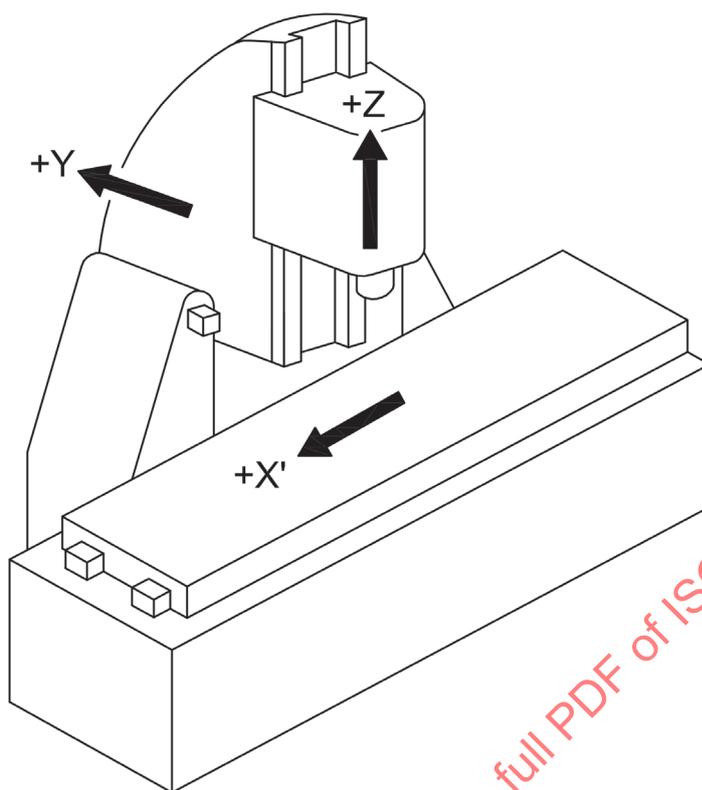


Figure C.3 — Example of a single column bed-type milling machine with vertical spindle

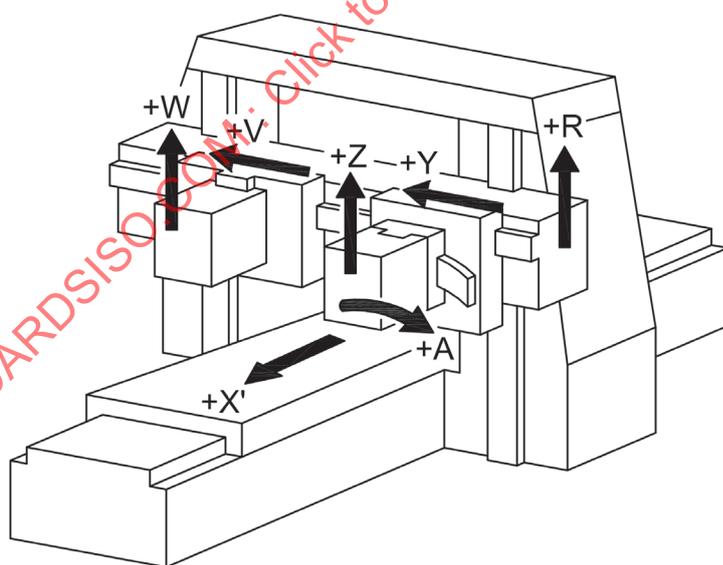


Figure C.4 — Example of a double column bed-type milling machine (portal milling machine)

C.3 Group 3 machines

See [Figures C.5](#), [C.6](#) and [C.7](#).

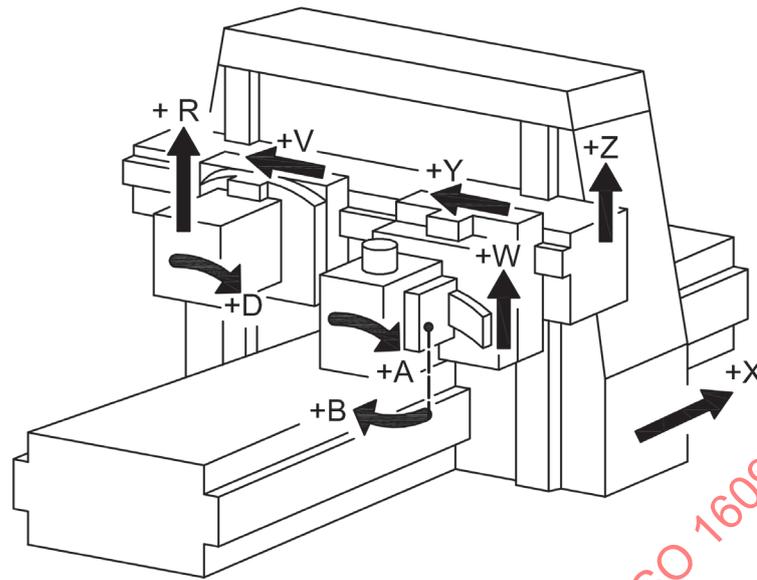


Figure C.5 — Example of a double column bed-type milling machine with moveable portal (gantry milling machine)

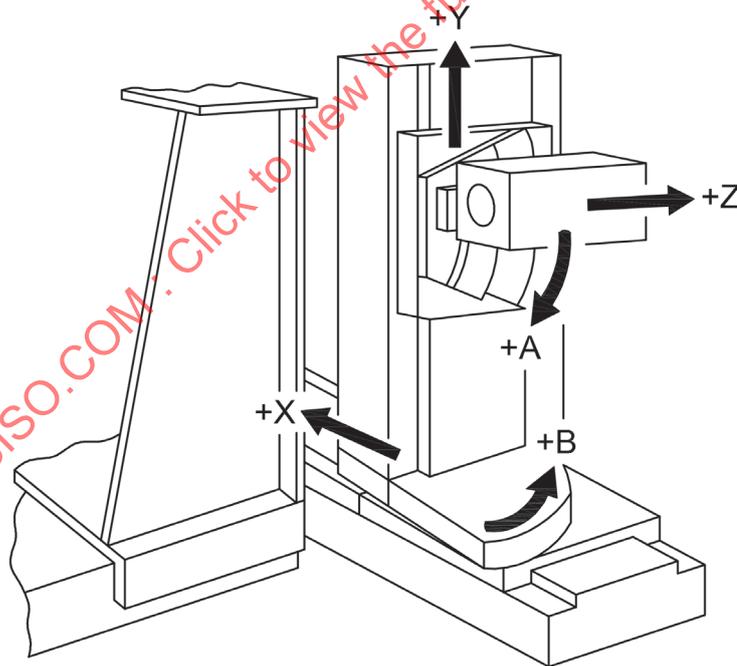


Figure C.6 — Example of a horizontal boring and milling machine

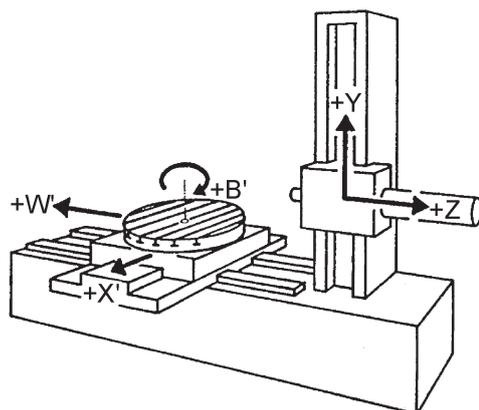
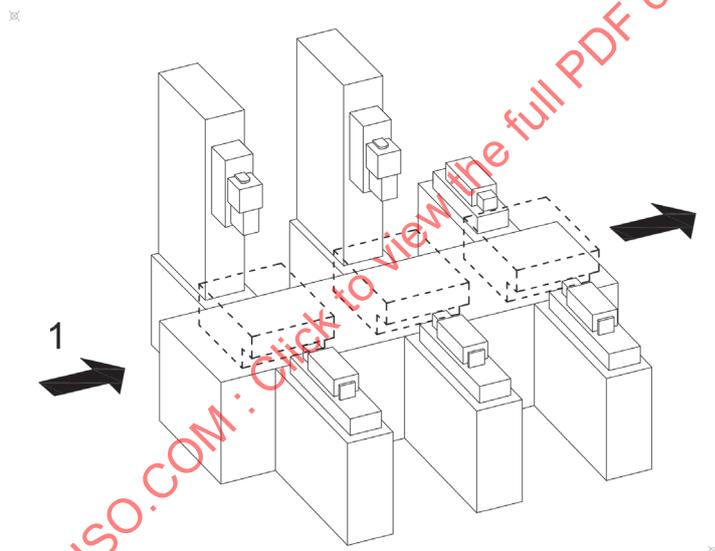


Figure C.7 — Example of a horizontal boring and milling machine

C.4 Group 4 machines

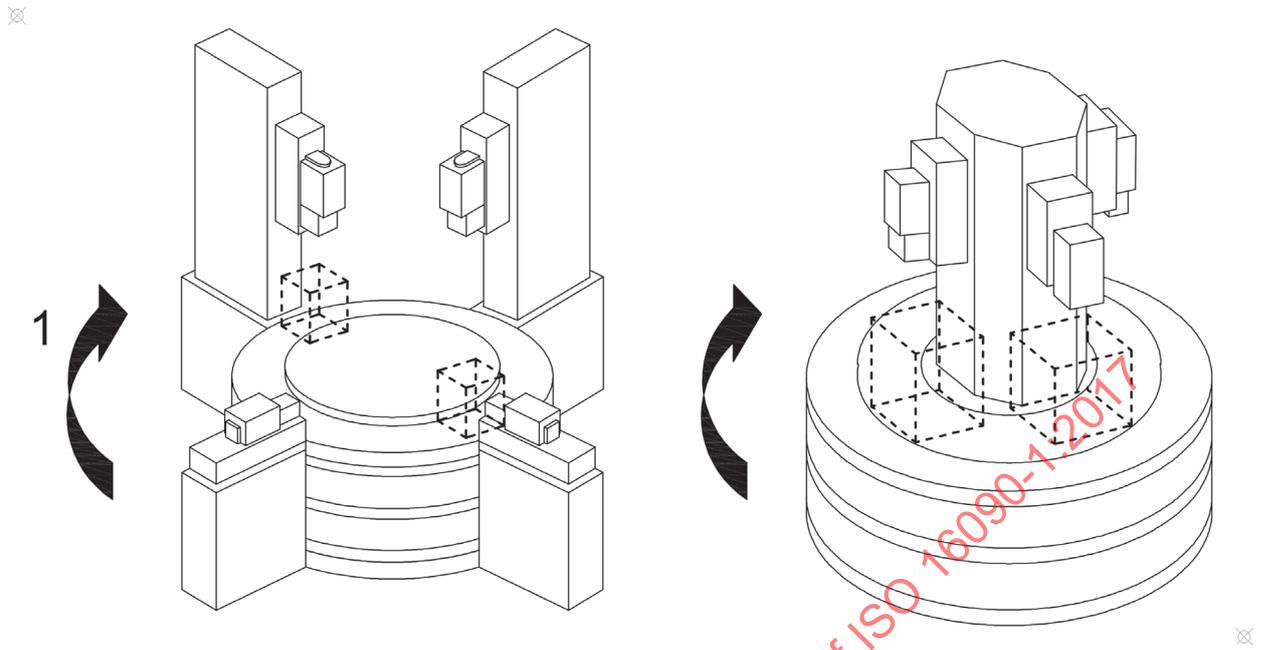
See [Figures C.8 to C.13](#).



Key

1 traverse direction of the workpiece

Figure C.8 — Transfer line (illustrated without guard)

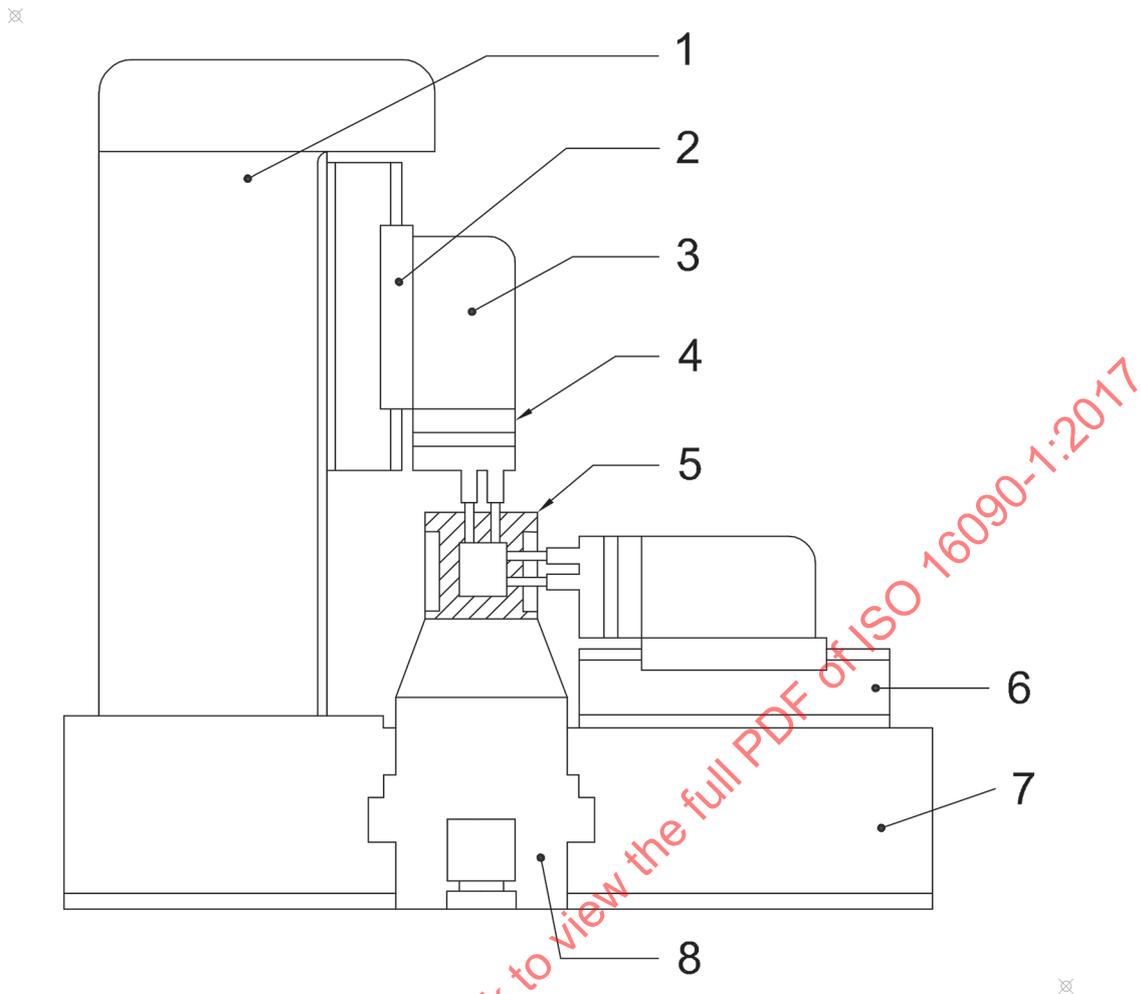


Key

- 1 traverse direction of the workpiece

Figure C.9 — Rotary transfer machine (illustrated without guard)

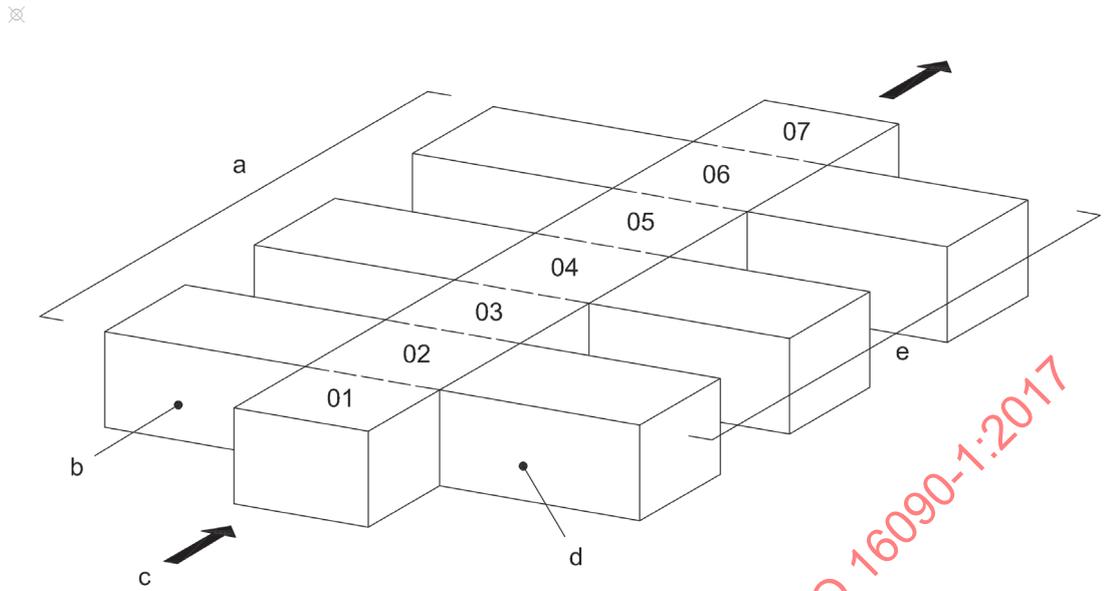
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Key

- | | | | |
|---|-----------------------|---|---------------------------|
| 1 | column | 5 | workpiece clamping device |
| 2 | slide unit | 6 | slide unit |
| 3 | carrier unit | 7 | side unit |
| 4 | multiple spindle head | 8 | middle unit |

Figure C.10 — Side view of a processing unit of a transfer machine



Key

- | | |
|----------------------|---------------------------------|
| 01 loading unit | a side "B" or "left hand" (LH) |
| 02 processing unit | b station "02B" or "02LH" |
| 03 idle station | c workpiece traverse direction |
| 04 processing unit | d station "02B" or "02RH" |
| 05 idle station | e side "A" or "right hand" (RH) |
| 06 measuring unit | |
| 07 unloading station | |

Figure C.11 — Substructure of a transfer machine

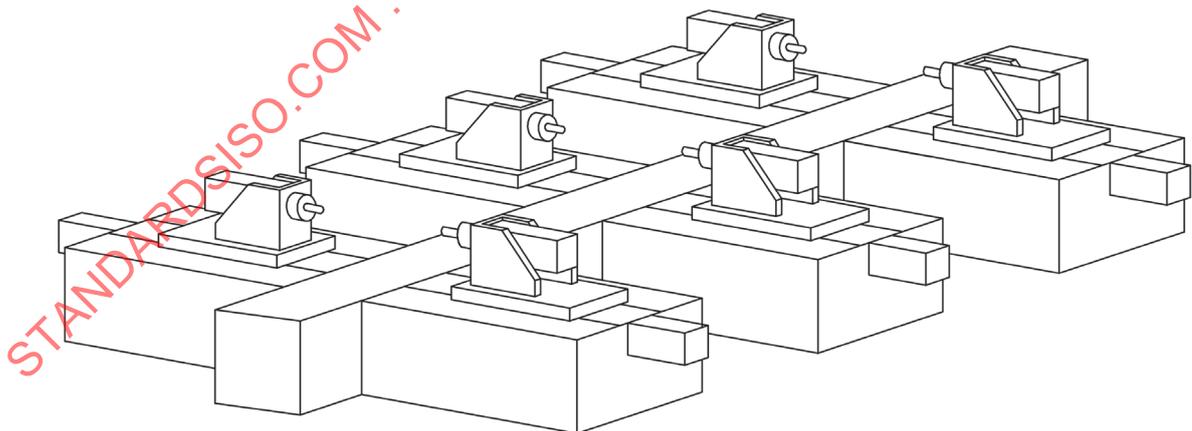
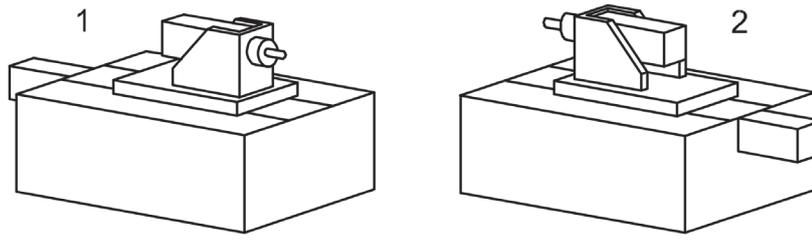


Figure C.12 — Transfer line with three processing units (illustrated without transfer device and guard)



Key

- 1 left unit
- 2 right unit

Figure C.13 — Typical units for transfer machines

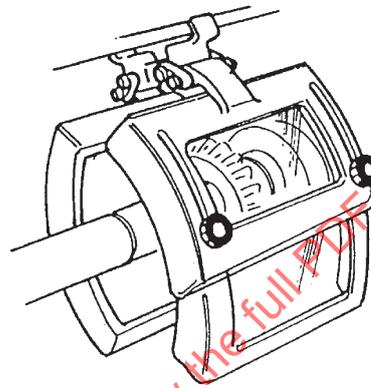
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Annex D (informative)

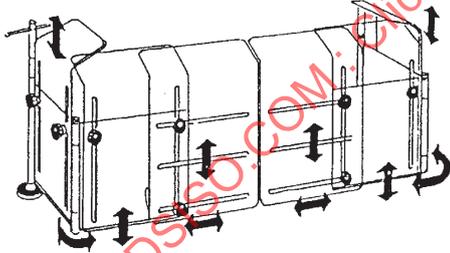
Illustrative figures as examples of guards

D.1 Examples of adjustable guards for milling machines; Group 1 (manual machines)

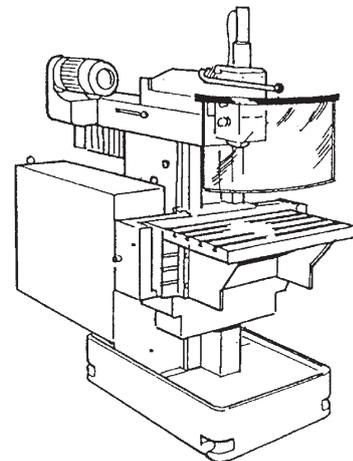
See [Figure D.1](#).



a) Guard for horizontal milling machine



b) Guard for vertical milling machine

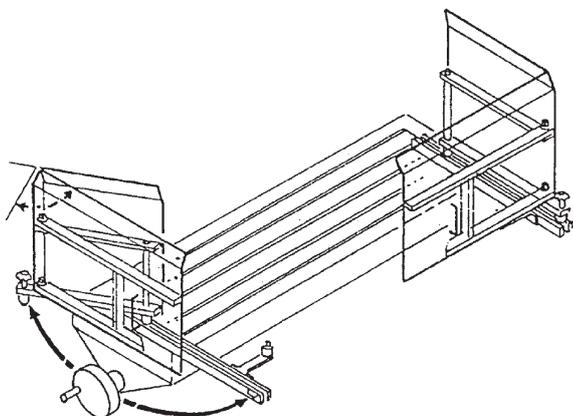


c) Guard for vertical milling machine

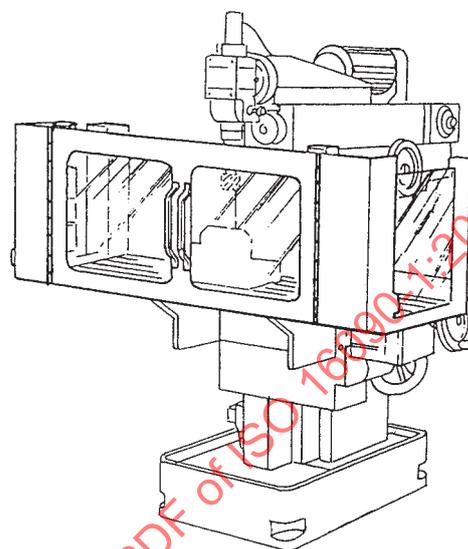
Figure D.1 — Examples of adjustable guards for manually controlled milling machines

D.2 Examples of guards for Group 2 machines (machines with limited NC capability)

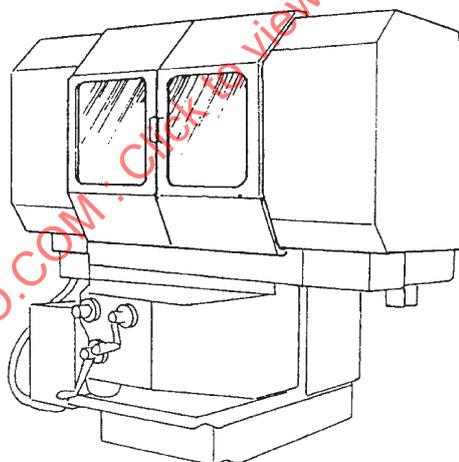
See [Figure D.2](#).



a) Fully opening hinged guards
(NOTE Rear guard not shown)



b) Hinged door type guard

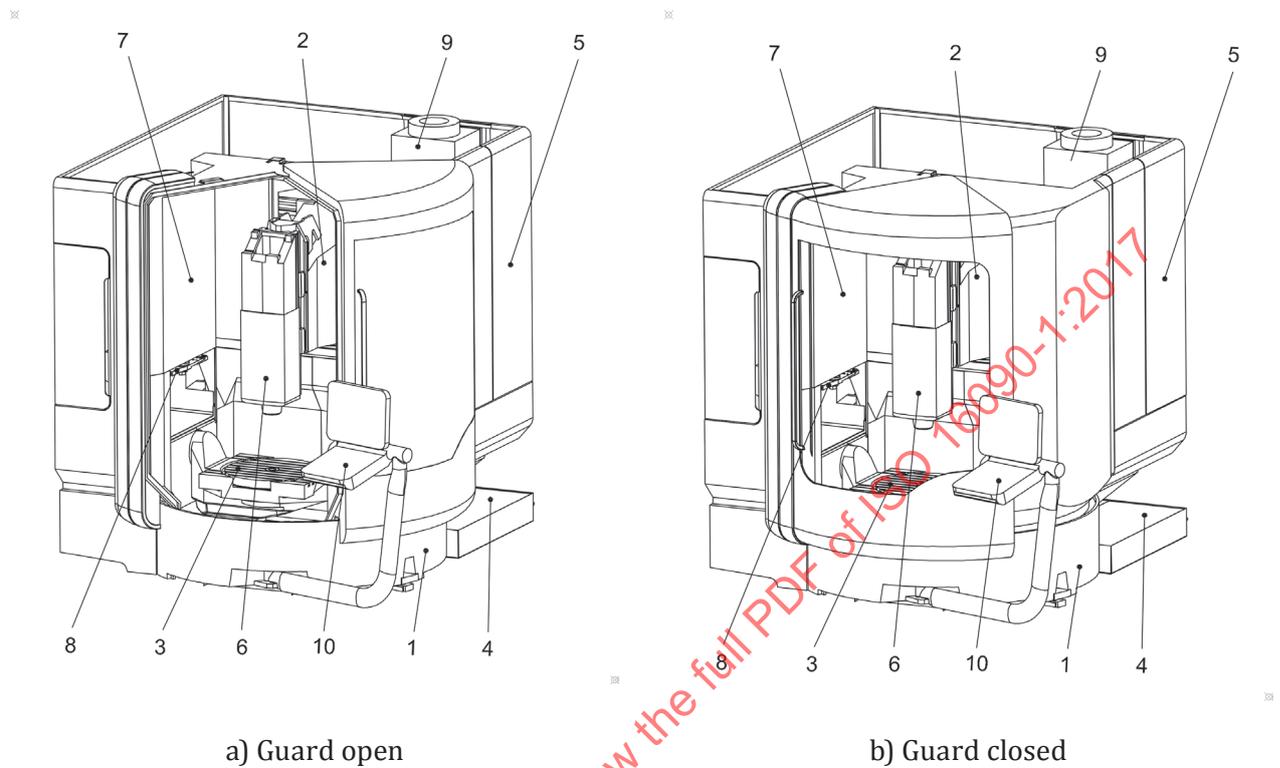


c) Sliding of guards for Group 2 milling machines

Figure D.2 — Examples of guards for Group 2 milling machines

D.3 Examples of guards for Group 3 machines (automatic machines)

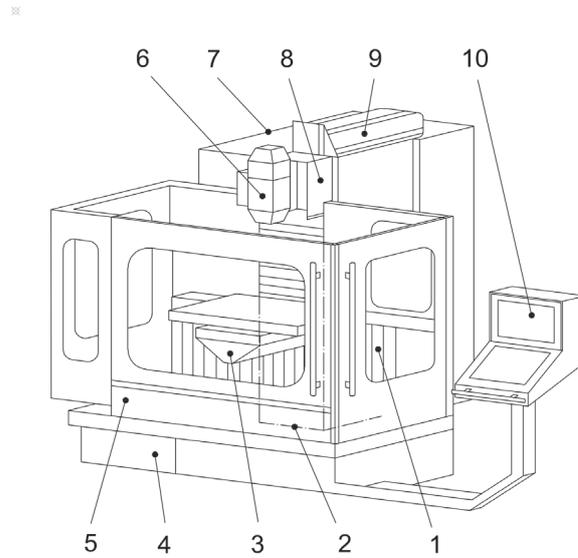
See [Figure D.3](#) to [D.6](#).



Key

- 1 machine column (Y axis)
- 2 Y slide X slide (X axis)
- 3 slewing rotary table (SRT)/rigid table
- 4 cutting fluid system
- 5 machine enclosure
- 6 spindle head with motor spindle (Z axis)
- 7 electrical cubicle
- 8 tool change
- 9 cooling unit
- 10 control panel

Figure D.3 — Examples of guards for Group 3 machines (automatic machines)

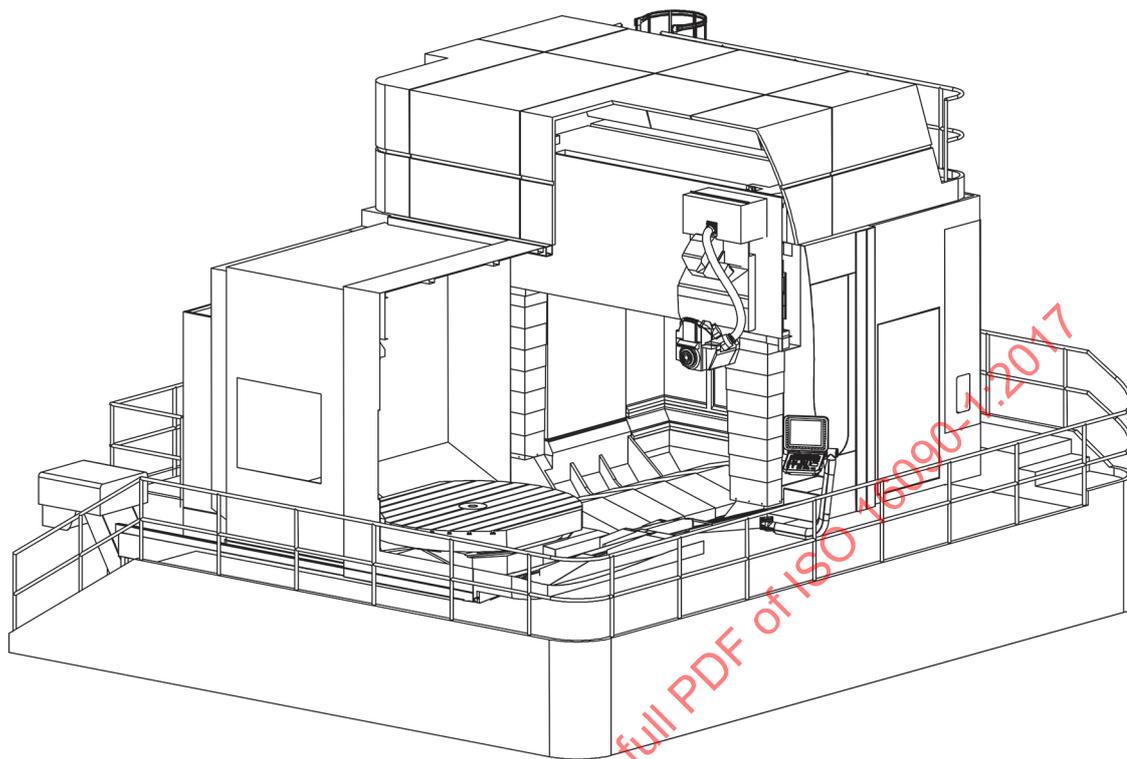


Key

- 1 machine column and feed drive, Y axis
- 2 cross slide with vertical table and feed drive, X axis
- 3 worktable; rigid table or rotary table
- 4 cutting fluid system
- 5 machine enclosure
- 6 milling head with vertical spindle
- 7 electrical cubicle
- 8 spindle head with horizontal spindle and feed drive, Z axis
- 9 main drive
- 10 NC panel

Figure D.4 — Example of interlocking guard(s) for automatic milling machines

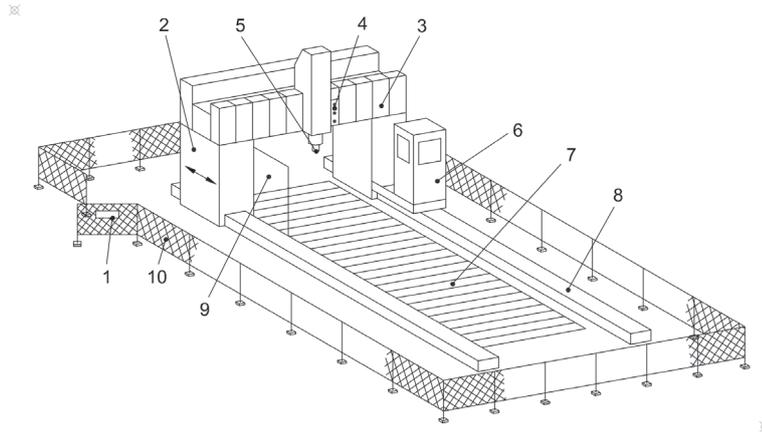
⊗



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Figure D.5 — Example of a large automatic bed-type milling machine with full safe guarding of the work zone

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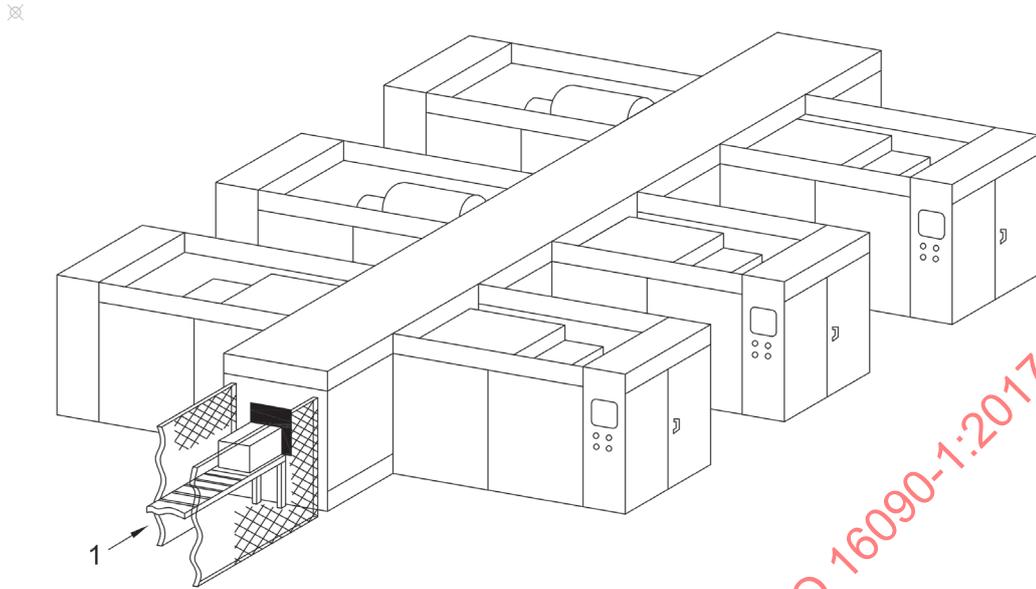
Key

- 1 interlocked access
- 2 travelling gantry
- 3 telescopic steel covers
- 4 auxiliary pendant
- 5 cutter
- 6 cabin (operating station) enclosed on three sides; travels with gantry
- 7 worktable
- 8 slideway cover
- 9 blinker type guard; transparent
- 10 guard fence

Figure D.6 — Example of large double column milling machine with moveable portal (gantry type), perimeter fencing and operator protection

D.4 Examples of guards for Group 4 (transfer and special purpose machines)

See [Figure D.7](#) and [D.8](#).

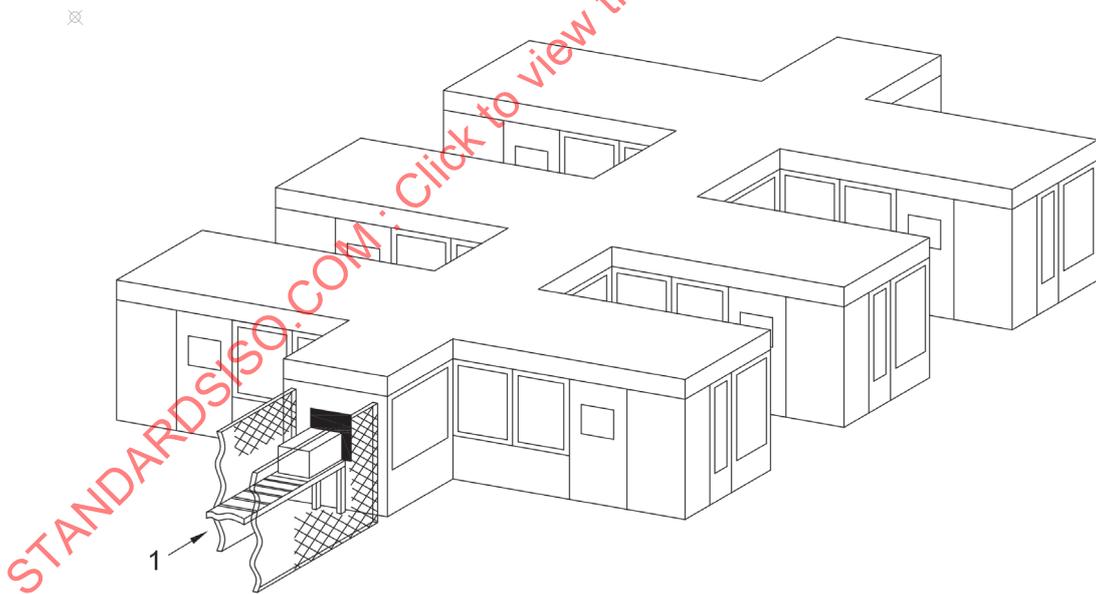


Key

1 traverse direction of the workpiece

NOTE Machines are open on top, the middle transfer unit is covered on top.

Figure D.7 — Transfer line with guards arranged closely to the machine



Key

1 traverse direction of the workpiece

Figure D.8 — Fully enclosed transfer line

Annex E (informative)

Examples of the integration of exhaust and extinguishing systems when using combustible coolants or combustible dust

Monitoring of the coolant system and the exhaust system is essential for the safe functioning of the machine.

Safety measures after fire detection depend on the kind of exhaust system (central or local):

- a) For central exhaust system with guards closed, the following shall apply:
 - 1) immediate stop of all machining operations (with or without controlled tool retraction);
 - 2) flame penetration or loss of extinguishing medium shall be suppressed by means of a closing flap (valve shutter device); although it cannot be avoided that ignition particles reach the pipes of the exhaust system;
 - 3) immediate initiation of the extinguishing system;
 - 4) deactivation of the coolant system if available and if hazards exist from mixing of combustible dust and coolant;
 - 5) possibility for further operation of the central exhaust system.
- b) For the local exhaust system (usually on top of the machine) with guards closed, the following shall apply:
 - 1) immediate stop of all machining operations (with or without controlled tool retraction);
 - 2) deactivation of the exhaust system;
 - 3) immediate initiation of the extinguishing system;
 - 4) deactivation of the coolant supply if available and if hazards exist from mixing of combustible dust and coolant.

In order to implement the above safety functions, the controls of the machine tool, the exhaust system and the extinguishing system have suitable interfaces (see [Figure E.1](#) and [Table J.14](#)).

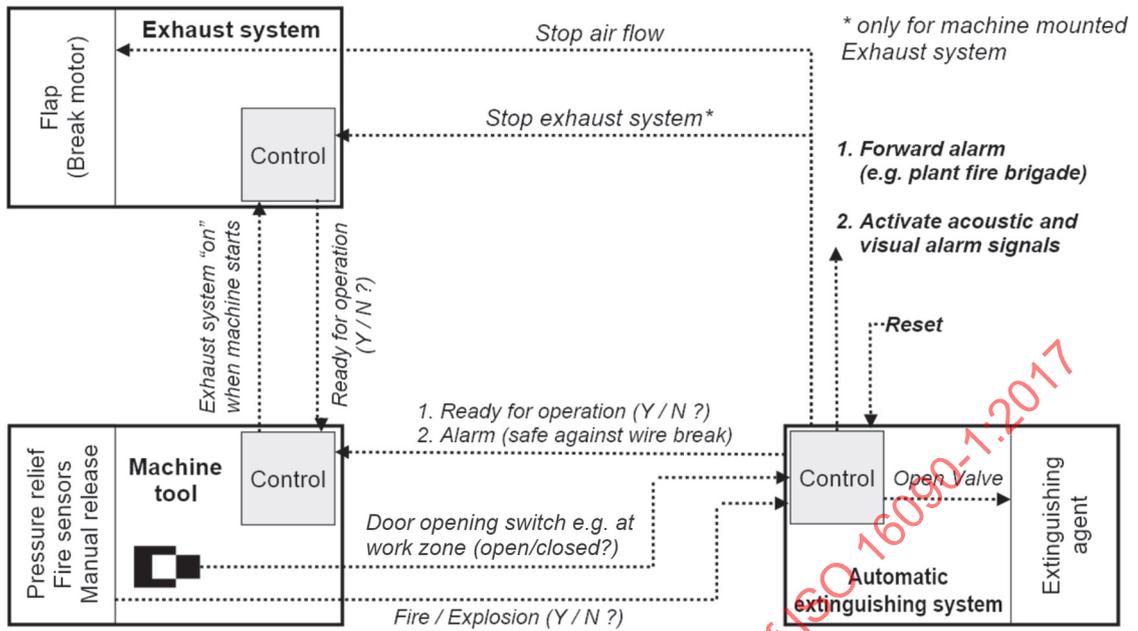


Figure E.1 — Example of the interaction between the machine tool control and the control of the fire extinguishing system

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Annex F (informative)

Provisions when using combustible coolants and combustible dust

F.1 Selection of low emission coolants

Coolants with oil content above 15 % can cause fire or deflagration hazards.

By selecting non water-miscible low-emission coolants, aerosol and vapour formation within the work zone may be reduced and thereby the risk of fire and explosion. Low-emission coolants are characterized by the following properties:

- composition based on low-evaporation mineral oils or synthetic esters and/or special fluids;
- addition of anti-mist additives.

Recommended specifications for selecting low-emission coolants depending on viscosity class and machining process are listed in [Table F.1](#).

Table F.1 — Specification of non water-miscible coolants

Tendency of risk	Viscosity class according to ISO 3448	Viscosity at 40 °C	Flash point according to ISO 2592 (Cleveland open cup method)	Evaporation loss at 250 °C (Noack method)	Machining process (exemplary)
	ISO VG 5	4,14 mm ² /s to 5,06 mm ² /s	>120 °C	<85 %	honing, reaming grinding deep boring turning, milling boring tapping thread rolling broaching
	ISO VG 7	6,12 mm ² /s to 7,48 mm ² /s	>145 °C	<80 %	
	ISO VG 10	9 mm ² /s to 11 mm ² /s	>155 °C	<60 %	
	ISO VG 15	13,5 mm ² /s to 16,5 mm ² /s	>190 °C	<25 %	
	ISO VG 22	19,8 mm ² /s to 24,2 mm ² /s	>200 °C	<15 %	
	ISO VG 32	28,8 mm ² /s to 35,2 mm ² /s	>210 °C	<13 %	
Low	ISO VG 46	41,4 mm ² /s to 50,6 mm ² /s	>220 °C	<11 %	

It is generally recommended to select the coolant with the lowest evaporation loss and the highest flash point at a viscosity given by the machining process, which shall be as high as possible.

F.2 Flameproof labyrinth seals

The egress of flames into the work zone can be prevented to a great extent by application of suitable labyrinth seals on machine tool doors. Labyrinth seals with several redirections for the flame path and gap widths of ≤ 2 mm have proven to be most effective.

Principles of design for flameproof labyrinths:

- gaps narrowing in case of sudden pressure increase within the work zone;
- gap width at constrictions up to a maximum of 2 mm;
- change of flow direction at least $2 \times 180^\circ$;
- possibility for adjusting the gap width (adjustability);
- no use of flammable materials (e.g. plastic brushes);
- direction of outlet not directly towards the operator;
- protection of shearing and crushing points by appropriate means (e.g. edge protection).

The labyrinth seal shown in [Figure F.1](#) is based on the principle of multiple redirections arranged in series and expansion of the entering flames.

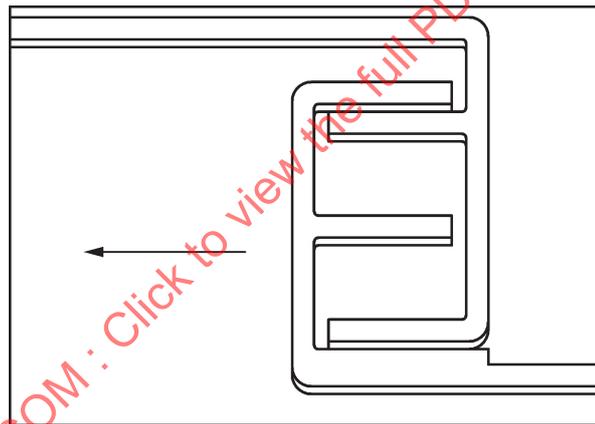


Figure F.1 — Principle scheme of a flameproof labyrinth seal

F.3 Prevention of ingress of flames into the extraction system

The use of a baffle plate in front of the extraction opening in combination with a suitable flame arrester in the extraction path may prevent flame propagation into the (central) extraction system.

The flame arrester shown in [Figure F.2](#) is based on the principle of multiple redirection and expansion of the entering flames.

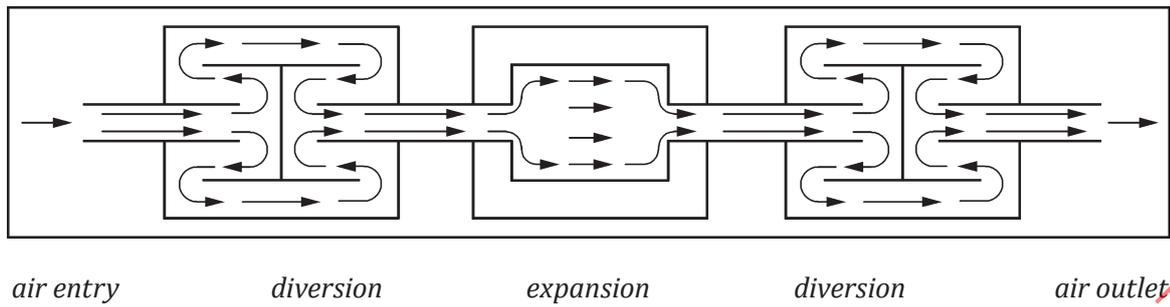


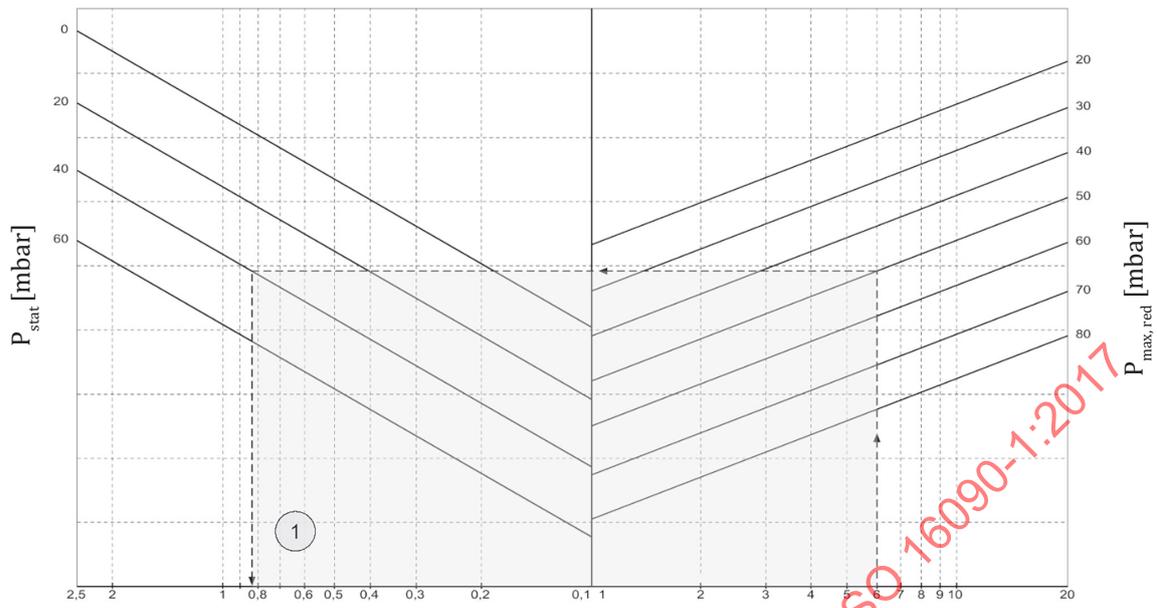
Figure F.2 — Principle scheme of a flame arrester in the extraction path

F.4 Dimensioning of pressure relief areas

Depending on the pressure resistance of the machine enclosure, the integration of a pressure relief device may be necessary to limit the explosion pressure to a non-hazardous extent and to direct escaping flames into a non-hazardous direction (e.g. pressure relief device on the machine top).

In order to determine the correct size of the pressure relief area, illustrated relations in [Figure F.3](#) may be used. The nomogram enables the machine manufacturer, for a given enclosure volume, an estimated explosion strength of the machine enclosure and a static response pressure of the pressure relief device to determine the required pressure relief area in case it is closed with a rupture membrane. If, for example, a pressure relief flap is used, resulting from its discharge capacity in comparison to the rupture membrane is the amount by which the relief area given by the nomogram needs to be corrected. The discharge capacity is the measure for assessing the effectiveness of a pressure relief device in comparison with a rupture membrane of the same relief area. It can be determined in a test and is normally specified by the manufacturer.

A more simple (but certainly less accurate) way to determine the minimum pressure relief area on machine tools is based on the rule of thumb, after that 0,1 m² pressure relief area shall be provided for each m³ of machine work zone volume. In the past, such setups were confirmed by single ignition trails. However, this rule of thumb is neither taking into account the explosion strength of the machine housing nor the response pressure of the pressure relief device.



Key

- 1 degree of filling
- P_{stat} [mbar] static response pressure
- $P_{max,red}$ [mbar] maximum reduced pressure of explosion

Figure F.3 — Explosion relief – Nomogram for estimation of required area

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Annex G (normative)

Gravity-loaded axes

G.1 Design measures for gravity-loaded axes

In case of power failure (loosing energy), gravity-loaded axes (weight-loaded, vertical axes, inclined axes, slant axes) are held solely by the brake which is installed in the electric drive motor (motor brake) or an external brake or a clamping device. The gravity loaded axes could descent in case of failure. Mechanical wear or oil-fouling may cause the braking torque/force of the brakes to fall below its nominal value which may result in an unintended descend or the fall down of the gravity-loaded axes.

If these gravity-loaded axes allow the operator to stay completely or partially under the axis (e.g. for loading of tools/workpieces, for setting and maintenance), measures for minimizing the risk shall be taken.

Depending on the practical case of application and the risk to be reduced, different technical safety devices are suitable to prevent the unintended gravity descent of gravity-loaded axes (see [Table G.1](#) and [G.2](#)).

Safety functions related to gravity loaded or slant axis are defined in [Table J.3](#).

G.2 Measures against unintended descent of gravity-loaded axes

G.2.1 General requirements

The mechanical parts of power transmission shall be at least designed with double weight load to withstand the occurring static and dynamic stresses.

In order to prevent unnecessary wear of the brakes, it is preferable to decelerate with the controller instead of stopping with mechanical brakes.

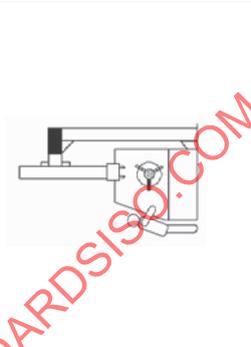
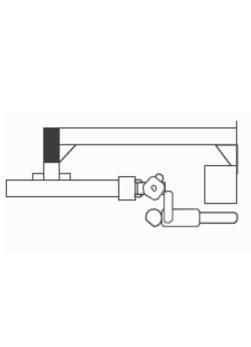
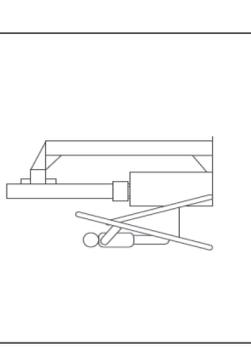
NOTE In the case that no hazard exists because the operator is always in safe position for gravity-load axes, a motor brake can be installed on the machine for faster braking during operations or other reasons.

G.2.2 Information for use

One or several warning signs shall be visibly fixed at the machine pointing out to hazards due to gravity-loaded axes and suspended loads, for example, "Do not stay underneath the vertical axis!".

Operating instructions shall describe measures to protect the operator from a fall-down of those axes. These instructions shall also point out to hazards due to gravity-loaded axes and suspended loads as well the required skill level of the operators.

Table G.1 — Assignment of common braking devices to the individual modes of safe operation

		Typical situations			
		Typical hazardous situations in all MSO, except maintenances	Typical hazardous situations for maintenance		
No	Design of braking device	Requirement for cyclic test; see also G.3			
			G1.1 The gravity-loaded axis is located within the hazardous area. Staying under the gravity-loaded axis with the whole body is prevented by the machine design A hazard exists for the upper limbs.	G1.2 The gravity-loaded axis is located within the hazardous area. Staying under the gravity-loaded axis cannot be prevented.	G1.3 Maintenance, cleaning and repair works are carried out at or next to the gravity-loaded axis. Safe support of the gravity-loaded axis is feasible.
					G1.4 Maintenance, cleaning and repair works are carried out at or next to the gravity-loaded axis. Safe support of the gravity-loaded axis is not feasible.
V1	Single brake	✓	✓	Support or manual mechanical lock	
V2	Motor brake + redundant brake ^a	✓	✓	Support or manual mechanical lock	
V3	Brake where fault exclusion can be justified	No test, fault exclusion required	✓	✓	✓
V4	Motor brake + mechanical counterweight	✓	✓	Support or manual mechanical lock	
V5	Motor brake + hydraulic counterweight	✓	✓	Support or manual mechanical lock	

^a Redundant brake can be internal if a fault to the single transmission system can be excluded (e.g. mechanical break of the motor shaft), otherwise, external redundant brake.

^b For example, a hydraulic counterweight with fault exclusion to “non-returning-blocking” valves with cross monitoring (e.g. double valves).

Table G.1 (continued)

		Typical situations	
		Typical hazardous situations in all MSO, except maintenances	Typical hazardous situations for maintenance
V6	Motor brake + counterweight ^b where fault exclusion can be justified	No test, fault exclusion of counterweight system required	✓
V7	Motor brake + clamping device (e.g. automatic blocking device)	No test, fault exclusion required	✓

^a Redundant brake can be internal if a fault to the single transmission system can be excluded (e.g. mechanical break of the motor shaft), otherwise, external redundant brake.

^b For example, a hydraulic counterweight with fault exclusion to "non-returning-blocking" valves with cross monitoring (e.g. double valves).

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Table G.2 — Additional safety measures and instructions for use

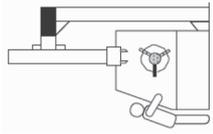
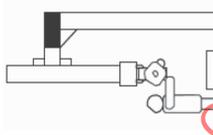
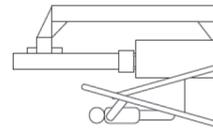
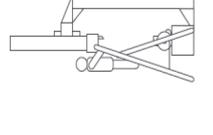
		Typical situations	
		Typical hazardous situations in all MSO, except maintenances	Typical hazardous situations for maintenance
Measures and information for use		G1.1 The gravity-loaded axis is located within the hazardous area. Staying under the gravity-loaded axis with the whole body is prevented by the machine design. A hazard exists for the upper limbs.	
		G1.2 The gravity-loaded axis is located within the hazardous area. Staying under the gravity-loaded axis cannot be prevented.	
		G1.3 Maintenance, cleaning and repair works are carried out at or next to the gravity-loaded axis. Safe support of the gravity-loaded axis is feasible.	
		G1.4 Maintenance, cleaning and repair works are carried out at or next to the gravity-loaded axis. Safe support of the gravity-loaded axis is not feasible.	
Required safety measures	—	—	<ul style="list-style-type: none"> — Observe the regulations in force for maintenance/repair/cleaning, e.g. lockable main switch — Device to be operated automatically or manually for safe fixing of the axis in the defined positions, e.g. fixing device — Clear marking of the positions locked/unlocked — Monitoring of positions by the control locked/unlocked and interlocking with drive control — Disconnect and lock main switch

Table G.2 (continued)

Typical situations	
Typical hazardous situations in all MSO, except maintenances	Typical hazardous situations for maintenance
<p>See G.2.2</p>	<p>See G.2.2 and</p> <ul style="list-style-type: none"> — Describe measures for the use of the devices for safe fixing (e.g. mechanical lock) of the gravity loaded axis — Explain how to disconnect and lock the main switch
<p>See G.2.2</p>	<p>See G.2.2 and</p> <ul style="list-style-type: none"> — Describe measures for safe support of gravity-loaded axis — Explain how to disconnect and lock the main switch
<p>Information for use</p>	<p>See G.2.2 and</p> <ul style="list-style-type: none"> — Describe measures for the use of the devices for safe fixing (e.g. mechanical lock) of the gravity loaded axis — Explain how to disconnect and lock the main switch — Inform on necessity to limit stay under the gravity load axis as far as possible

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G.3 Cyclic test of brake or clamping device at Group 3 and Group 4 machines

An effective measure may be a cyclic test of the single brake (brake test) or a clamping device. For this, a test torque/force is applied to the brake, e.g. motor brake or the clamping device.

This cyclic test interval shall be carried out according to [Table G.3](#). The cyclic test shall take place automatically in the closed protective zone during normal production, e.g. during a process-related stop. If this is not possible, the cyclic test shall be carried out before entering to the hazardous zone.

For the cyclic test, it is reasonable that the gravity-loaded axes, which are to be tested, are located at defined positions, such as:

- positions on which tests (brake and/or clamping device) can be carried out without obstruction/interfering contour (e.g. tool not active);
- positions from which fault recovery after, e.g. a fault at the brake test can be achieved or a safe position can be approached.

For test torque/force to following requirements apply:

- 1 motor/1 brake (or clamping device) system:

The brake or the clamping device is charged with 1,3 times the maximum gravitational load for at least 1 s by the electric drive. If also a permanently present counterweight system is installed, the braking device is charge with 1,3 times the maximum gravitational weight minus the counterbalanced weight.

- 1 motor/2 brakes (or clamping device) system:

The braking devices are tested separately one after the other on 1,0 times the maximum gravitational load.

- 2 motors/2 brakes (or clamping device) system, mechanically connected:

The braking devices are tested together on 2,0 times the maximum gravitational load or one after the other on 1,0 times the maximum gravitational load.

In case of a fault detection occurs during the cyclic test, the following requirements apply.

- The indications given by the machine control shall request for brake repair. In case of guards with locked protective doors, a safe position shall not be approached until an unlock demand signal has been given.
- Further operation of the machine shall only be possible after a new successful cyclic test.

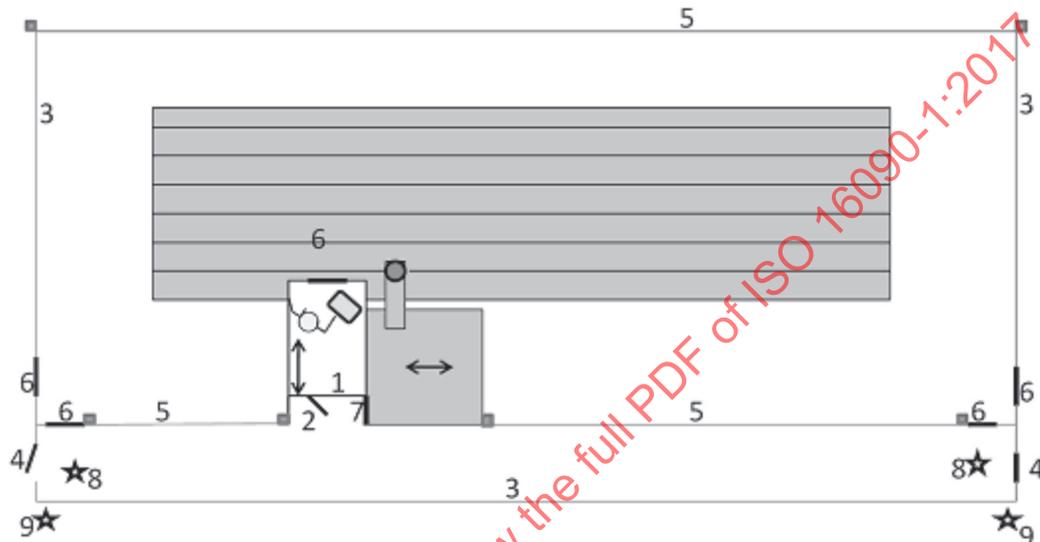
Table G.3 — Brake test intervals

Group 3 and Group 4 machines	Brake test intervals
Machine with manual load-/unloading into the work zone	<ul style="list-style-type: none"> — 8h^{a,c} – once per shift automatically or — test before access to the related hazard zone takes place (move gravity-loaded axes in safe position) and time of 8h^c has run out
Machines with automatic load-/unloading into the work zone	<ul style="list-style-type: none"> — 48h^{b,c} or — test before access to the related hazard zone takes place (move gravity-loaded axes in safe position) and time of 48h^c has run out
<p>^a In case of a complex single workpiece (e.g. large tools for presses or turbine blades, etc.), with an expected machining time longer than 8 h, the cyclic test shall be carried out after finishing the machining of the workpiece. If the cyclic test fails, further operation of the machine shall be inhibited.</p> <p>^b It is assumed that the demand on the safety function with a person staying partially or entirely in the hazard zone, can occur twice per year.</p> <p>^c In case of a redundant motor brake, the minimum test time is increased and has to be initiated every time after powering-on the machine and at least every month.</p>	

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Annex H (informative)

Examples: Concept for leaving/returning to a cabin (control station) at Group 3 and Group 4 machines



Key

- 1 cabin
- 2 cabin guard
- 3 fixed guard
- 4 interlocking movable guard with guard locking with the possibility to open from inside
- 5 guard of protective device
- 6 moveable interlocked guard which leads to the work zone
- 7 protection device
- 8 floor equipped with sensors
- 9 RFID, key transfer system

Figure H.1 — Example for leaving the cabin of a large Group 3 milling machine

To leave and return to cabin (1), the movable interlocked guard (2) of the cabin can be used. Movement of the cabin can cause hazardous situations; a protection device (7), e.g. tactile protection device should be activated. The guards (5) and (6) are then in a safeguarding position and activated.

To leave the cabin, only one of the two movable interlocked guards (4) should be selected and could be opened. To open the guard, a transfer function shall be manually activated, e.g. Floor equipped with sensors and near the movable interlocked guard located within the interior zone which is not accessible from outside the guard (8). This causes a takeover by the protection device of the guard (4) for certain period of time (e.g. 15 s.). Closing the movable interlocked guard after leaving the safe area is followed by a takeover from outside the safe area (9) which initiates the end of the takeover by the protection device of the guard (4). Exceeding the transfer time (e.g. 15 s) causes a warning signal followed by an emergency stop.

To return to the cabin from outside the safe area, a safety measure for identifying the person should be activated (e.g. RFID, key transfer system) so that the guard is taken over for a certain period of time (e.g. 15 s.). Within this time frame, the person should have passed the movable interlocked guard into the safe area and close the movable interlocked guard from within the safe area. After this procedure, the person can enter the cabin while the guard of the cabin is open towards the rear (2) of the machine.

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Annex I
(informative)

**Typical demand rates of safety functions for calculations
according to [Table 5](#) and [Annex J](#)**

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Table I.1 — Provisions of typical demand rates of the safety function

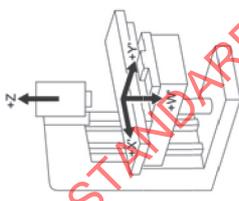
No.	Machine group: Function:	Group 1		Group 2		Group 3		Group 4	
		Illustration	Number of operations	Number of operations	Number of operations	Number of operations	Number of operations	Number of operations	Number of operations
1	Mean operating time in days per year (dop)		300	300	300	300	300	300	300
2	Mean operating time in hours per day (hop)	8	8	8	8	16	16	24	24
3	Emergency Stop	Once per day	Once per day	4 times per day	4 times per day	Once per week	Once per week	Once per week	Once per week
4	Enabling device work zone	Reference values not available	Reference values not available	Once in 6 min (360 s)	Once in 6 min (360 s)	Once in 12 min (720 s)	Once in 12 min (720 s)	3 times per day	3 times per day
5	Enabling device tool magazine	Reference values not available	Reference values not available	Reference values not available	Reference values not available	Once in 15 min (900 s)			
6	Enabling device Workpiece setting position	Reference values not available	Reference values not available	Reference values not available	Reference values not available	Once in 12 min (720 s)			
7	Tool magazine, protection door; manual tool loading	Reference values not available	Reference values not available	Reference values not available	Reference values not available	Once in 15 min (900 s)	Once in 15 min (900 s)	Once in 15 min (900 s)	Once in 15 min (900 s) NOTE 24 h per day make 96 tool loading and unloading processes.

Table I.1 (continued)

8	Opening of the interlocked guard to unload/load the workpiece in the work zone. Short machining period (up to 10 min).	Reference values not available	Reference values not available	Once in 5 min (300 s)	Reference values not available
9	Opening of the interlocked guard to unload/load the workpiece in the work zone. Medium machining period (up to 60 min).	Reference values not available	Reference values not available	Once in 15 min (900 s) NOTE 16 h per day make 64 workpiece loading and unloading processes.	Reference values not available
10	Opening of the interlocked guard to unload/load the workpiece in the work zone. Long machining period (up to 8 h and more).	Reference values not available	Reference values not available	Once in 8 h NOTE 16 h per day make 2 workpiece loading and unloading processes.	Reference values not available
11	Protection door to workpiece setting position for loading of pallet changer, open interlocked guard, load workpiece. Short machining period (up to 10 min).	Reference values not available	Reference values not available	Once in 2 min (120 s) NOTE 16 h per day make 480 workpiece loading and unloading processes.	Once in 2 min (120 s) NOTE 24 h per day make 720 workpiece loading and unloading processes.
12	Protection door to workpiece setting position for loading of pallet changer, open interlocked guard, load workpiece. Medium machining period (up to 60 min).	Reference values not available	Reference values not available	Once in 15 min (900 s) NOTE 16 h per day make 64 workpiece loading and unloading processes.	Once in 15 min (900 s) NOTE 24 h per day make 96 workpiece loading and unloading processes.
13	Protection door to workpiece setting position for loading of pallet changer, open interlocked guard, load workpiece. Long machining period (up to 8 h and more).	Reference values not available	Reference values not available	Once in 8 h NOTE 16 h per day make 2 workpiece loading and unloading processes.	Reference values not available
14	Tool clamber, number of tool changes. Short machining period (up to 10 min).	Reference values not available	Reference values not available	2 times per minute (30 s)	2 times per minute (30 s)

Table I.1 (continued)

15	Tool clamper, number of tool changes. Medium machining period (up to 60 min).	Once per 5 min (300 s)	Once per 5 min (300 s)	Once per minute (60 s)	Once per minute (60 s)
16	Tool clamper, number of tool changes. Long machining period (up to 8 h and more).	Reference values not available	Once per 5 min (300 s)	Once per 10 min (600 s)	Reference values not available
17	Automatic tool changer	See tool clamper	See tool clamper	See tool clamper	See tool clamper
18	Metalworking fluid. High-pressure. Short machining duration (up to 10 min).	Reference values not available	Reference values not available	Twice per minute (30 s)	2 times per minute (30 s)
19	Metalworking fluid. High-pressure. Mean machining duration (up to 60 min).	Reference values not available	Reference values not available	Once per minute (60 s)	Once per minute (60 s)
20	Metalworking fluid. High-pressure. Long machining period (up to 8 h and more).	Reference values not available	Reference values not available	Once per 10 min (600 s)	Reference values not available
21	Workpiece clamping devices (hydraulic, pneumatic) short machining period (up to 10 min)	Reference values not available	Once per 5 min (300 s) NOTE 8 h per day make 96 workpiece loading and unloading processes.	Once per 2 min (120 s) NOTE 16 h per day make 480 workpiece loading and unloading processes.	Once per 2 min (120 s) NOTE 24 h per day make 720 workpiece loading and unloading processes.
22	Workpiece clamping devices (hydraulic, pneumatic) Mean machining period (up to 60 min).	Reference values not available	Once per hour (3 600 s) NOTE 8 h per day make 8 workpiece loading and unloading processes.	Once per 15 min (900 s) NOTE 16 h per day make 64 workpiece loading and unloading processes.	Once per 15 min (900 s) NOTE 24 h per day make 96 workpiece loading and unloading processes.

Table I.1 (continued)

23	Workpiece clamping devices (hydraulic, pneumatic). Long machining period (up to 8 h and more).	Reference values not available		Once in 8 h NOTE 16 h per day make 2 workpiece loading and unloading processes.	Reference values not available
24	Selection of mode of safe operation MSO 1, MSO 2 or MSO 3	Reference values not available	4 times per hour	Once per hour	Once per hour
25	Start/Stop	Once in 15 min (900 s)	Once in 15 min (900 s)	Reference values not available	Reference values not available

Annex J (normative)

Safety functions

J.1 Index of safety functions for [Tables J.1](#) to [J.22](#)

Table No.	Subject	No. of SF	PLr
J.1	Explanation on how to read the table		
1.1	Introduction		
J.2	Tool spindle rotation and tool clamping device		
2.1	Prevent start/restart function initiated by an incorrectly clamped tool in <i>MSO 1</i> <i>MSO 2 and MSO 3</i>	SF 03	<i>None</i> <i>c</i>
2.2	Prevention of unexpected start-up of unclamping movement of the tool-gripper in <i>MSO 1</i> <i>MSO 2 and MSO 3</i>	SF 08-1	<i>b</i> <i>c</i>
2.3	Limited spindle speed initiated by safety related tool parameter in MSO 1, MSO 2 or MSO 3	SF 16	<i>a</i>
2.4	Limited spindle speed – initiated by safety related parameter in MSO 2 or MSO 3 <i>If safety related parameters are not available</i> <i>Otherwise</i>	SF 16	<i>None</i> <i>d, Cat 3</i>
J.3	Gravity-loaded or slant axes		
3.1	Safety-related stop function in MSO 1, MSO 2 or MSO 3 <i>If work zone is not accessible</i> <i>If hazards exist for upper limbs</i> <i>If work zone is accessible (whole body)</i>	SF 01	<i>None</i> <i>c</i> <i>d</i>
3.2	Safety-related stop function in MSO 2 or MSO 3 <i>If work zone is not accessible</i> <i>If hazards exist for upper limbs</i> <i>If work zone is accessible (whole body)</i>	SF 07-1	<i>None</i> <i>c</i> <i>d</i>
3.3	Prevention of unexpected start-up in MSO 2 or MSO 3 <i>If work zone is not accessible</i> <i>If work zone is accessible (upper limbs)</i> <i>If work zone is accessible (whole body)</i>	SF 07-2	<i>None</i> <i>c</i> <i>d</i>
3.4	Prevention of unexpected Start in MSO 1, MSO 2 or MSO 3 <i>If work zone is not accessible</i> <i>If work zone is accessible (upper limbs)</i> <i>If work zone is accessible (whole body)</i>	SF 08-1	<i>None</i> <i>c</i> <i>d</i>
3.5	Safely limited speed (SLS) of linear, rotational and auxiliary axes <i>Hazard zone is not accessible</i>	SF 08-2	<i>None</i>

Table No.	Subject	No. of SF	PLr
	<i>otherwise</i>		<i>d, Cat 3</i>
1.4	Workpiece clamping device for machines with milling and/or turning operation		
4.1	Safety-related stop function of clamping and support devices in MSO 1, MSO 2 or MSO 3	SF 01	
	<i>Workpiece clamping movement <4 mm</i>		<i>None</i>
	<i>Workpiece clamping movement >4 mm</i>		<i>c</i>
4.2	Safety-related stop function in MSO 1, MSO 2 or MSO 3	SF 01	
	<i>Workpiece cannot be ejected</i>		<i>None</i>
	<i>Workpiece can be ejected</i>		<i>a</i>
4.3	Prevent start/restart function in MSO 1, MSO 2 or MSO 3	SF 03	<i>a</i>
4.4	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	
	<i>Movements are with small distances ≤4 mm</i>		<i>None</i>
	<i>No hand is required to fixation/adjustment</i>		<i>c</i>
	<i>Hand is required for fixation/adjustment</i>		<i>d, Cat 3</i>
4.5	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	
	<i>Movements are with small distances (≤4 mm)</i>		<i>None</i>
	<i>Movements with distances >4 mm</i>		<i>d, Cat 3</i>
4.6	Prevention of unexpected start-up of clamping and unclamping movements in MSO 1, MSO 2 or MSO 3	SF 08-1	
	<i>Movements are with small distances (≤4 mm)</i>		<i>None</i>
	<i>Movements with distances >4 mm</i>		<i>d, Cat 3</i>
4.7	Prevention of unexpected start-up workpiece movement in MSO 1, MSO 2 or MSO 3	SF 08-1	
	<i>Manual clamping systems</i>		<i>None</i>
	<i>Workpiece cannot be ejected</i>		<i>a</i>
	<i>Workpiece can be ejected</i>		<i>d, Cat 3</i>
4.8	Prevention of unexpected unclamping of workpiece due to gravity in MSO 1, MSO 2 or MSO 3	SF 08-2	
	<i>No hazard by gravity</i>		<i>None</i>
	<i>Hazard by gravity: Operator not working under gravity axes</i>		<i>c</i>
	<i>Hazard by gravity: Operator is working under gravity axes</i>		<i>d, Cat 3</i>
4.9	Limited workpiece speed in MSO 1, MSO 2 or MSO 3	SF 16	
	<i>Monitoring of the movement</i>		<i>None</i>
	<i>Automatic workpiece feeding</i>		<i>a</i>
	<i>Manual workpiece feeding</i>		<i>a</i>
4.10	Limited workpiece speed in MSO 2 or MSO 3	SF 16	See Table J.17 , 17.3 and 17.4
4.11	Monitoring of workpiece proportional technology – clamping pressure in MSO 1, MSO 2 or MSO 3	SF 16	
	<i>Automatic workpiece feeding</i>		<i>a</i>
	<i>Manual workpiece feeding</i>		<i>a</i>
4.12	Monitoring of workpiece data internal and external gripping/clamping/chucking in MSO 1, MSO 2 or MSO 3 on turning application	SF 16	
	<i>Automatic workpiece feeding</i>		<i>a</i>
	<i>Manual workpiece feeding</i>		<i>a</i>

Table No.	Subject	No. of SF	PLr
4.13	Prevention of unexpected unclamping movement or depressurizing with rotating /moving work-piece in MSO 1, MSO 2 or MSO 3 <i>Workpiece can be ejected</i> <i>Workpiece cannot be ejected</i>	SF 08-1	 <i>None</i> <i>d, Cat 3</i>
J.5	Tailstock		
5.1	Safety-related stop function in MSO 1, MSO 2 or MSO 3	SF 01	<i>c</i>
5.2	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	<i>c</i>
5.3	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	<i>d, Cat 3</i>
5.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	<i>d, Cat 3</i>
5.5	Safely limited speed (SLS) of linear, rotational and auxiliary axes <i>Hazard zone not accessible</i> <i>Otherwise</i>	SF 16	 <i>None</i> <i>d, Cat 3</i>
J.6	Handling devices for workpiece loading/ unloading, workpiece transfer device, pallet changer		
6.1	Safety-related stop function for linear movement (e.g. lift/lowering) and/or rotational movement in MSO 1, MSO 2 or MSO 3	SF 01	<i>c</i>
6.2	Prevent start/restart function in MSO 1, MSO 2 or MSO 3 <i>Manually loaded by operator</i> <i>Automatically loaded</i>	SF 03	 <i>None</i> <i>a</i>
6.3	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	<i>c</i>
6.4	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	<i>d, Cat 3</i>
6.5	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	<i>d, Cat 3</i>
6.6	Safely limited speed (SLS) of linear, rotational and auxiliary axes <i>Hazard zone not accessible</i> <i>Otherwise</i>	SF 16	 <i>None</i> <i>d, Cat 3</i>
J.7	Bar feed device		
7.1	Safety-related stop function in MSO 1, MSO 2 or MSO 3	SF 01	<i>c</i>
7.2	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	<i>c</i>
7.3	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	<i>d, Cat 3</i>
7.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	<i>d, Cat 3</i>
7.5	Safely limited speed (SLS) of linear, rotational and auxiliary axes <i>Hazard zone not accessible</i> <i>Otherwise</i>	SF 16	 <i>None</i> <i>d, Cat 3</i>
J.8	Pallet clamping and movement on milling machines with milling and turning operation		
8.1	Safety-related stop function in MSO 1, MSO 2 or MSO 3	SF 01	<i>a</i>
8.2	Prevent start/restart function in MSO 1, MSO 2 or MSO 3	SF 03	<i>a</i>
8.3	Prevention of unexpected start-up of unclamping movements in MSO 1, MSO 2 or MSO 3 <i>Pallet position horizontal; short presence in hazard zone; pallet may fall out without hazard</i> <i>Pallet position horizontal; presence in hazard zone not short; pallet may fall out without hazard</i> <i>Pallet in any position; short presence in hazard zone; pallet may fall out</i>	SF 08-1	 <i>a</i> <i>b</i> <i>d, Cat 3</i>
8.4	Prevention of unexpected start-up of unclamping movement in MSO 1 <i>Pallet cannot be ejected</i>	SF 08-1	 <i>a</i>

Table No.	Subject	No. of SF	PLr
8.5	<i>Pallet can be ejected</i>		<i>d, Cat 3</i>
	Prevention of unexpected unclamping of pallet clamping by gravity in MSO 1, MSO 2 or MSO 3	SF 08-2	
	<i>Horizontal pallet position, short presence</i>		<i>a</i>
	<i>Horizontal pallet position, presence is not short</i>		<i>b</i>
	<i>Slant or pending pallet position</i>		<i>d, Cat 3</i>
J.9	Hazardous movement of the tool changer		
9.1	Safety-related stop function, initiated by a guard, in MSO 1, MSO 2 or MSO 3	SF 01	<i>c</i>
9.2	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	<i>c</i>
9.3	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	<i>d, Cat 3</i>
9.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	<i>d, Cat 3</i>
9.5	Safely limited speed (SLS) of linear, rotational and auxiliary axes	SF 16	
	<i>Hazard zone not accessible</i>		<i>None</i>
	<i>Otherwise</i>		<i>d, Cat 3</i>
J.10	Hazardous movement of the tool magazine		
10.1	Safety-related stop function, initiated by a guard, in MSO 1, MSO 2 or MSO 3	SF 01	<i>c</i>
10.2	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	<i>c</i>
10.3	Prevention of unexpected start-up MSO 2 or MSO 3	SF 07-2	<i>d, Cat 3</i>
10.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	<i>d, Cat 3</i>
10.5	Safely limited speed (SLS) of linear, rotational and auxiliary axes	SF 16	
	<i>Hazard zone not accessible</i>		<i>None</i>
	<i>Otherwise</i>		<i>d, Cat 3</i>
J.11	Chip conveyor in any case of intended use		
11.1	Safety-related stop function initiated by open interlocked guards in MSO 1, MSO 2 or MSO 3	SF 01	<i>c</i>
11.2	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	<i>c</i>
11.3	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	<i>c</i>
11.4	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	<i>d, Cat 3</i>
11.5	Prevention of unexpected start-up initiated by open interlocked guards in MSO 1, MSO 2 or MSO 3	SF 08-1	<i>c</i>
11.6	Prevention of unexpected start-up initiated by open interlocked guards in MSO 1, MSO 2 or MSO 3	SF 08-1	<i>d, Cat 3</i>
J.12	Coolant, chip flushing low-pressure 0 to 0,5 MPa or high-pressure exceeding 0,5 MPa		
12.1	Safety-related stop function initiated by open interlocked guards in MSO 1, MSO 2 or MSO 3 (low pressure)	SF 01	<i>a</i>
12.2	Safety-related stop function initiated by open interlocked guards rd in MSO 1, MSO 2 or MSO 3 (high pressure)	SF 01	<i>c</i>
12.3	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3 (low pressure)	SF 08-1	
	<i>Operator does not directly stay in the coolant flow</i>		<i>a</i>
	<i>Operator directly stay in the coolant flow</i>		<i>b</i>
12.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3, for high pressure.	SF 08-1	<i>d, Cat 3</i>
J.13	Power-operated safeguards for access by persons		
13.1	Safety-related stop function initiated by a protective device in MSO 1, MSO 2 or MSO 3	SF 01	
	<i>Forces <75 N and kinetic energy <4 J</i>		<i>None</i>

Table No.	Subject	No. of SF	PLr
	<i>Forces <150 N and kinetic energy <10 J and automatic reversing</i>		<i>c</i>
	<i>Other</i>		<i>d</i>
13.2	Safety-related stop function in MSO 2 or MSO 3	SF 07-1	<i>d</i>
13.3	Prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	<i>d</i>
13.4	Prevention of unexpected start-up initiated by open interlocked guards or deactivated protective devices in MSO 1, MSO 2 or MSO 3	SF 08-1	
	<i>Forces <75 N and kinetic energy ≤4 J</i>		<i>None</i>
	<i>Other</i>		<i>d</i>
13.5	Safely limited speed of power operated safeguards for NC controlled axes		<i>a, but at least Cat 2</i>
J.14 Extinguishing system for machines with interlocked guards			
14.1	Safety-related stop function of coolant supply with interlocked guards closed initiated by the extinguishing system in MSO 1	SF 01	<i>a</i>
14.2	Safety-related stop function of extraction system with closed interlocked guards initiated by the extinguishing system	SF 01	<i>a</i>
14.3	Safety-related stop function of sealing-off (shut-off valve in extraction pipe) of extraction system with interlocked guards being closed, initiated by the extinguishing system.	SF 01	<i>a</i>
14.4	Safety-related stop function of machining process inclusive chip conveyor with interlocked guards being closed, initiated by the extinguishing system	SF 01	<i>a</i>
14.5	Release of locking devices of guard locking for access to the hazard zone	SF 04	<i>c</i>
14.6	Prevention of unexpected start-up of the extinguishing process with oxygen displacing gases in MSO 1, MSO 2 or MSO 3	SF 08-1	
	<i>Where there is no access to the work zone</i>		<i>c</i>
	<i>Where there is an accessible work zone</i>		<i>d, Cat 3</i>
14.7	Operation of the machine with closed interlocked guards is only possible if fire extinguishing system is in ready to operate state	SF 08-1	<i>a</i>
J.15 Selection of MSO (not applicable to Group 1 machines)			
15.1	Selection of mode of safe operation initiated by opening of the interlocked guards and the MSO selection device	SF 11	
	<i>When only MSO 1 and MSO 2 are available</i>		<i>a</i>
	<i>When more than two MSOs are available</i>		<i>c</i>
15.2	Selection of authorization, to ensure that only one operator control station is enabled at a time	SF 11	<i>a</i>
J.16 Emergency stop			
16.1	Emergency stop	SF 14	<i>c</i>
J.17 Control functions			
17.1	Start- and restart function to initiate execution (e.g. of a program) in MSO 1, MSO 2 or MSO 3	SF 03	<i>a</i>
17.2	Local control functions to release the locking devices of guard locking for access to the hazard zone	SF 04	<i>a</i>
17.3	Safely limited speed (SLS) of linear, rotational and auxiliary NC controlled axes	SF 16	
	<i>Machine is not accessible</i>		<i>None</i>
	<i>Machine is accessible</i>		<i>d, Cat 3</i>
17.4	Safely limited speed (SLS) of tool spindle or work holding spindle for NC controlled axes	SF 16	

Table No.	Subject	No. of SF	PLr
	<i>Safety related parameters are not available</i>		None
	<i>No NC controlled tool spindle</i>		a
	<i>Others</i>		d, Cat 3
17.5	Fluctuations, loss and return of power supply or loss and return of power supply after an interruption in MSO 1, MSO 2 or MSO 3	SF 17	a
17.6	Safety-related stop function of machining process with interlocked guards being closed, initiated by the CNC/NC/PLC e.g. collision control system (for Group 3 and Group 4 only)	SF 01	a
17.7	Start and restart function to initiate execution by pressing of Start button in MSO 0 (for Group 1 and Group 2 only)	SF 03	c
17.8	Safety related stop function initiated by pressing of Stop button in MSO 0 (for Group 1 and Group 2 only)	SF 03	c
J.18	Hazardous movement in the work zone		
18.1	Safety-related stop function initiated by a guard in MSO 1, MSO 2 or MSO 3.	SF 01	c
18.2	Enabling function for safety-related stop function in MSO 2 or MSO 3	SF 07-1	c
18.3	Enabling function for prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	d, Cat 3
18.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	d, Cat 3
18.5	Safely limited speed (SLS) of linear, rotational and auxiliary axes	SF 16	
	<i>Work zone is not accessible</i>		None
	<i>Otherwise</i>		d, Cat 3
J.19	Hazardous movements in the maintenance area		
19.1	Safety-related stop function, initiated by a guard in MSO 1, MSO 2 or MSO 3.	SF 01	c
19.2	Enabling function for safety-related stop function in MSO 2 or MSO 3	SF 07-1	c
19.3	Enabling function for prevention of unexpected start-up in MSO 2 or MSO 3	SF 07-2	d, Cat 3
19.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	d, Cat 3
19.5	Safely limited speed (SLS) of linear, rotational and auxiliary axes	SF 16	
	<i>Maintenance area is not accessible</i>		None
	<i>Otherwise</i>		d, Cat 3
J.20	Safety interface for loading system – Automation safety features at the interface		
20.1	Safety-related stop function initiated by open interlocked guards in MSO 1, MSO 2 or MSO 3	SF 01	c, Cat 3
20.2	Prevention of unexpected start-up of hazardous movements in MSO 1, MSO 2 or MSO 3	SF 08-1	d, Cat 3
20.3	Emergency stop	SF 08-1	c, Cat 3
J.21	Grinding operation on a milling machine		
21.1	Limited speed – maximum processing speed of the tool in MSO 1, MSO 2 or MSO 3	SF 16	
	<i>If safety related parameters are not available</i>		None
	<i>Limitation of grinding wheel peripheral speed with decreasing diameter</i>		a
J.22	Compressed air for cleaning and measuring processes		
22.1	Safety-related stop function in MSO 1, MSO 2 or MSO 3	SF 01	a
22.2	Safety-related stop function	SF 07	a
22.3	Prevention of unexpected start-up	SF 07-2	b
22.4	Prevention of unexpected start-up in MSO 1, MSO 2 or MSO 3	SF 08-1	b

J.2 Description of safety functions

Safety function, according to ISO 13849-1:2006, Table 8 and Table 9	Numbering of safety function in this documents
Safety-related stop function initiated by safeguard	SF01
Manual reset function	SF02 ^b
Start/restart function	SF03
Local control function	SF04
Muting function	SF05 ^a
Hold-to-run function	SF06 ^a
Enabling device function	SF07-1/SF07-2
Prevention of unexpected start-up	SF08-1/SF08-2
Escape and rescue of trapped persons	SF09 ^a
Isolation and energy dissipation function	SF10 ^a
Control modes and mode selection	SF11
Interaction between different safety-related parts of control systems	SF12 ^a
Monitoring of parameterization of safety-related input values	SF13 ^a
Emergency stop function	SF14
Response time	SF15 ^a
Safety-related parameter such as speed, temperature or pressure	SF16
Fluctuations, loss and restoration of power sources	SF17
Indications and alarms	SF18 ^a
^a Not used in this document.	
^b The manual reset function is not the only risk reduction method. This function is all the time an additional measure to prepare a start function after closing safeguarding. So, SF 03 is the safety function to calculate in this document instead of SF 02.	

NOTE Performance Levels (PL) are defined in ISO 13849-1 and Safety Integrity Levels (SIL) are defined in IEC 62061.

The PLr can be defined with the informative risk graph (ISO 13849-1:2015, A.1) or with the method of IEC 62061. The result with IEC 62061 is a SIL with a defined PFHD-Value (IEC 62061:2005, Table 3). This PFHD-value is also defined in ISO 13849-1:2015, Table 2 and leads to a PL.

SIL 1 refers to a PL = c or PL = b (see ISO 13849-1:2015, Table 3). Bruises and/or lacerations without complication is classified as S1 in ISO 13849-1 and only S1 injuries, according ISO 13849-1, lead to a required PL = b. If the result of class (CL), see in IEC 62061:2005, Table A.6 with SE2 is 11 or with SE1 is 14, than the required PL = b according ISO 13849-1, else the required PL = c.

"PL = a" has no correspondence to IEC 62061 but it is defined with other measures (IEC 62061, Table A.6, see OM) so it is definable with S3 and CL ≤ 7 or SE2 and CL ≤ 10 or SE1 and CL ≤ 13.

J.3 Safety related parameter

The input of safety related parameter usually requires that the operator inserts them. Errors in manual inputting of safety-related parameter in programmable electronic systems can lead to a hazardous situation. Moreover, in those cases, parameters retransmission and/or manual confirmation shall be done (see ISO 13849-1:2015, 4.6.4 and 5.2.7). Possible solutions for data checking can be:

- A data checking system within the safety-related control system, e.g.:
 - check of limits,
 - format and/or logic input values,

- data duplexing/cross-check.
- A data checking by an acceptance test with checksums. The acceptance test is used to check that the safety functions have been correctly parameterized. Using the acceptance test, potential configuring errors are to be identified and the correct configuring is documented.

J.4 Tables of safety functions

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Table J.1 — Explanation on how to read the tables of safety functions (Table J.2 to J.22)

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
1.1	The REQUIREMENT (mandatory)	SF XX	<ul style="list-style-type: none"> — notes — major known accident causes — hazardous situations 	Explanation of which safety function is applicable and when.	required performance level for that requirement

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Table J.2 — Tool spindle rotation and tool clamping device

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
2.1	Prevent start/restart function initiated by an incorrectly clamped tool in MSO 1, MSO 2 or MSO 3.	SF 03	MSO 1 MSO 2 or MSO 3 At each tool change, the correct function of the control components involved, are checked. Undetected software errors or defective tool supports may lead to the loss of the safety function.		none PLr = c
2.2	Prevention of unexpected start-up of un-clamping movement of the tool-gripper initiated by tool spindle speed $n > 0$ in MSO 1, MSO 2 or MSO 3.	SF 08-1	The valve is electrically isolated from the electric power supply voltage according to PL = d. The correct function is frequently tested in MSO 1. Because of sensor flickering it is possible to control a threshold limit (e.g. 1 r/min).	In MSO 1 protection by guards In MSO 2 or MSO 3	PLr = b PLr = c

Table J.2 (continued)

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
2.3	<p>Limited spindle speed initiated by safety related tool parameter in MSO 1, MSO 2 or MSO 3.</p>	SF 16	<p>Fault incident may occur unexpectedly in MSO 2 or MSO 3. Accidents in MSO 2 or MSO 3 are not known. Incorrect input of tool parameters is most common source of failure. The maximum permitted processing speed depends on constructive limitations of the spindle, the clamping means and the size, mass and unbalance of the specific tool. These limitations are given by the manufacturer of the machine.</p>		PLr = a
2.4	<p>Limited spindle speed initiated by safety related parameter in MSO 2 or MSO 3.</p>	SF 16	<p>If safety related parameters are not available. The maximum permitted spindle speed depends on constructive limitations of the spindle, the clamping means and the size, mass and unbalance of the specific tool. Accidents in MSO 2 or MSO 3 are not known.</p>		<p>none</p> <p>PLr = d, category 3</p>

Table J.3 — Gravity loaded or slant axes

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
3.1	<p>Safety-related stop function initiated by opening of the interlocked guards or other protective devices in MSO 1, MSO 2 or MSO 3. The axis is brought to a standstill and is then held in position by, e.g. — a clamping or braking device which acts in the de-energized state, or — in energized state, if there are integrated safety functions in the control unit, a Stop category 2 (IEC 60204-1) with a monitored SOS at standstill shall be done.</p>	SF 01	see Annex G	If the work zone is not accessible (3.3.8)	none
			see Annex G	Hazards exist for upper limbs	PLr = c
3.2	<p>Safety-related stop function initiated by release of enabling device or release of control device in case of open interlocked guards or other protective devices in MSO 2 or MSO 3. The axis is brought to a standstill and is then held in position by, e.g. — a clamping or braking device which acts in the de-energized state, or — in energized state, if there are integrated safety functions in the control unit, a Stop category 2 (IEC 60204-1) with a monitored SOS at standstill shall be done.</p>	SF 07-1	see Annex G	If the work zone is not accessible (3.3.8)	none
			see Annex G	Hazards exist for upper limbs	PLr = c
			see Annex G	If the work zone is accessible (3.3.8) Hazards exist for whole body	PLr = d

Table J.4 — Workpiece clamping for machines with milling and/or turning operations

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
4.1	Safety-related stop function of clamping and support devices initiated by the release of the locking device of the guard locking of the closed guard or the initiation of the protective devices (consider distances according to ISO 13857:2008) and leads to a stop of the hazardous movements of the clamping and support devices in MSO 1, MSO 2 or MSO 3	SF 01		Movements are with small distances (≤ 4 mm). Automatic movements of the workpiece clamping device are prevented in case of open interlocked guards or activated protective devices, if the workpiece clamping movement exceeds 4 mm (ISO 13857:2008).	none PLr = c
4.2	Safety-related stop function initiated by the detection of an incorrectly clamped workpiece, in MSO 1, MSO 2 or MSO 3	SF 01		Workpiece cannot be ejected, e.g. collecting device provided, mass very large or speed/rotational speed low Workpiece can be ejected	none PLr = a
4.3	Prevent start/restart function initiated by an incorrectly clamped workpiece in MSO 1, MSO 2 or MSO 3	SF 03			PLr = a
4.4	Safety-related stop function initiated by release of — enabling device, — two-hand-control, or — hold-to-run control device in case of open interlocked guards or other protective devices in MSO 2 or MSO 3.	SF 07-1	If there is a three-step enabling device, full compression of a three-step enabling device can lead to Emergency stop or to the activation of the movement in the opposite direction. NOTE See also 5.2.5.5 b) 3) and 5.2.5.5 b) 4).	Movements are with small distances (≤ 4 mm) No hand is required at the workpiece for fixation or adjustment A hand is required at the workpiece for fixation or adjustment	none PLr = c PLr = d, Category 3
4.5	Prevention of unexpected start-up initiated with non-actuated — enabling device, — two-hand-control, or — hold-to-run control device in case of open interlocked guards or other protective devices in MSO 2 or MSO 3.	SF 07-2		Movements are with small distances (≤ 4 mm). Movements with distances >4 mm.	none PLr = d, Category 3

Table J.4 (continued)

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
4.6	Prevention of unexpected start-up of clamping and unclamping movements initiated by open interlocked guards or deactivated protective devices in MSO 1, MSO 2 or MSO 3.	SF 08-1		Movements are with small distances (≤ 4 mm). Movements with distances > 4 mm	none PLr = d Category 3
4.7	Prevention of unexpected unclamping of workpiece initiated by any machine movement in MSO 1, MSO 2 or MSO 3.	SF 08-1		Manual clamping systems Workpiece cannot be ejected Workpiece can be ejected.	none PLr = a PLr = d, category 3
4.8	Prevention of unexpected unclamping of workpiece due to gravity initiated by power failure in MSO 1, MSO 2 or MSO 3.	SF 08-2	No hazard by gravity: (if clamping/unclamping function is done horizontally and the workpiece cannot be swivelled, no hazard from gravity can occur.) Hazard by gravity: Fall protection may be made by either a spring mechanism, or fall protection by hydraulic cylinder and non-return valve (depending on workpiece weight), or by a hydraulic swing clamping element with decoupled rotational and axial movement. Hazard by gravity: Fall protection may be made by either a spring mechanism, or fall protection by hydraulic cylinder and non-return valve (depending on workpiece weight), or by a hydraulic swing clamping element with decoupled rotational and axial movement.	Operator is not working under the workpiece during the clamping/unclamping process. Operator is working under the workpiece during the clamping/unclamping process.	none PLr = c PLr = d, Category 3

Table J.4 (continued)

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
4.9	Limited speed of the workpiece clamping device initiated by safety related parameter of workpiece clamping device in MSO 1, MSO 2 or MSO 3, e.g. speed limitation for turning operation.		<p>Monitoring of the movement is not required if the workpiece clamping device design considers the maximum speed and rotational speed of the NC-axes which cause the movements.</p>	none	
		SF 16	<p>Automatic workpiece feeding by pallet systems with different workpieces and clamping means: The selection of different safe parameters for speed and rotational speed monitoring is required if the clamping device is not suitable for the maximum speeds or rotational speeds. Incorrect input of rotational speed parameters is the most common source of error.</p>	Rotational speed parameters may be provided by a central control level of the machine.	PLr = a
			<p>Manual workpiece feeding: The speed and rotational speed monitoring shall be entered into the machine control system by a double user confirmation and verified on plausibility within the machine control system. It shall not be possible to change the speed limit by simple means.</p>	Rotational speed parameters may be provided by manual data input.	PLr = a
4.10	Limited axes speed initiated by safety related parameter in MSO 2 or MSO 3.	SF 16			See Table J.17, 17.3 and 17.4

Table J.4 (continued)

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
4.11	<p>Safety related parameter: Monitoring of workpiece proportional technology – clamping pressure in MSO 1, MSO 2 or MSO 3: If the actual pressure of the workpiece clamping device is monitored outside acceptable tolerance range, the stopping of the workpiece drive performs according to IEC 60204–1, depending on the technique applied independent on the position of the interlocked guard. Manual or automatic workpiece clamping device.</p>	SF 16	<p>Automatic workpiece feeding by pallet systems with different workpieces and clamping means: The selection of different safe parameters for proportional technology – clamping pressure is required. Incorrect input of the pressure parameters is the most common source of error.</p> <p>Manual workpiece feeding: The pressure monitoring shall be entered into the machine control system. It shall not be possible to change the speed limit by simple means.</p>	Pressure parameters may be provided by a central control of the machine.	PLr = a
4.12	<p>Safely related parameter: Monitoring of workpiece data internal and external gripping/clamping/chucking in MSO 1, MSO 2 or MSO 3 on turning application: If the wrong direction of the clamping movement is detected (positions outside the acceptable tolerance range, see 5.2.5.6 f), the stopping of the workpiece drive performs according to IEC 60204–1, depending on the technology applied independent on the position of the interlocked guard. Manual or automatic workpiece clamping device.</p>	SF 16	<p>Automatic workpiece feeding by pallet systems with different workpieces and clamping means: The required selection of the direction of the clamping movement shall be detected. Incorrect input of the parameters is the most common source of error.</p> <p>Manual workpiece feeding: The required selection of the direction of the clamping movement shall be detected. It shall not be possible to change the speed limit by simple means.</p>	Workpiece parameters may be provided by a central control of the machine.	PLr = a
4.13	<p>Prevention of unexpected unclamping movement or depressurizing initiated by rotating/moving workpiece in MSO 1, MSO 2 or MSO 3.</p>	SF 08–1	<p>Manual clamping systems Workpiece cannot be ejected, e.g. collecting device provided, mass very large or speed/rotational speed low</p> <p>Workpiece can be ejected by centrifugal force due to the speed or axis motion of the workpiece-bearing axis. Unclamping or depressurizing the workpiece shall only be done with speed $n = 0$ or axis velocity $v = 0$</p>	Workpiece parameters may be provided by manual data input.	<p>none</p> <p>none</p> <p>PLr = d Category 3</p>

Table J.5 — Tailstock

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
5.1	Safety-related stop function initiated by open interlocked guards or de-activated protective devices in MSO 1, MSO 2 or MSO 3.	SF 01			PLr = c
5.2	Safety-related stop function initiated by release — of enabling device, — two-hand-control, or — hold-to-run control device in case of open interlocked guards or other protective devices in MSO 2 or MSO 3.	SF 07-1			PLr = c
5.3	Prevention of unexpected start-up initiated with non-actuated — enabling device, — two-hand-control, or — hold-to-run control device in case of open interlocked guards or other protective devices in MSO 2 or MSO 3.	SF 07-2			PLr = d, category 3
5.4	Prevention of unexpected start-up initiated by open interlocked guards or de-activated protective devices in MSO 1, MSO 2 or MSO 3.	SF 08-1			PLr = d, category 3

Table J.5 (continued)

No.	Explanation of safety function effect, other requirements	No. of SF	Remarks	Additional explanation	PLr
5.5	<p>Safely limited speed (SLS) of linear, rotational and auxiliary axes initiated by</p> <ul style="list-style-type: none"> — in MSO 1, as far as required for safe operation, — in MSO 2 or MSO 3 with enabling device actuated, — in MSO 2 or MSO 3 with a hold-to-run control device actuated, — in MSO 1, MSO 2, MSO 3 with two-hand control or — in MSO 2 or MSO 3 with electronic handwheel. 	SF 16	<p>If the hazardous zone is not accessible in the intended use, a speed monitoring in controller, speed governor and speed controller) are sufficient in combination with an enabling device (see SF 07-1 and SF 07-2).</p> <p>If the hazardous zone is accessible in the intended use, for rotational axes, the peripheral speed has to be considered at the max. radius.</p>		None
					PLr = d Category 3

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