

Safety of machinery — Basic concepts, general principles for design —

Part 2: Technical principles

The European Standard EN ISO 12100-2:2003 has the status of a
British Standard

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee MCE/3, Safeguarding of machinery, which has the responsibility to:

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- monitor related international and European developments and promulgate them in the UK.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN ISO title page, the EN ISO foreword page, the ISO title page, pages ii to v, a blank page, pages 1 to 32, the Annex ZA page, the Annex ZB page, an inside back cover and a back cover.

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Sécurité des machines - Notions fondamentales, principes
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(ISO 12100-2:2003)

Sicherheit von Maschinen - Grundbegriffe, allgemeine
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Foreword

This document (EN ISO 12100-2:2003) has been prepared by Technical Committee ISO/TC 199 "Safety of machinery" in collaboration with Technical Committee CEN/TC 114 "Safety of machinery", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2004, and conflicting national standards shall be withdrawn at the latest by May 2004.

This document supersedes EN 292-2:1991.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZB, which is an integral part of this document.

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Endorsement notice

The text of ISO 12100-2:2003 has been approved by CEN as EN ISO 12100-2:2003 without any modifications.

NOTE Normative references to International Standards are listed in Annex ZA (normative).

EN ISO 12100-2:2003

**INTERNATIONAL
STANDARD**

**ISO
12100-2**

First edition
2003-11-01

**Safety of machinery — Basic concepts,
general principles for design —**

**Part 2:
Technical principles**

*Sécurité des machines — Notions fondamentales, principes généraux
de conception —*

Partie 2: Principes techniques



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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 12100-2 was prepared by Technical Committee ISO/TC 199, *Safety of machinery*.

This edition cancels and replaces ISO/TR 12100-2:1992, which has been technically revised.

ISO 12100 consists of the following parts, under the general title *Safety of machinery — Basic concepts, general principles for design*:

- *Part 1: Basic terminology, methodology*, expressing the basic overall methodology to be followed when designing machinery and when producing safety standards for machinery, together with the basic terminology related to the philosophy underlying this work;
- *Part 2: Technical principles*, giving advice on how this philosophy can be applied using available techniques.

Introduction

The primary purpose of ISO 12100 is to provide designers with an overall framework and guidance to enable them to produce machines that are safe for their intended use. It also provides a strategy for standard makers.

The concept of safety of machinery considers the ability of a machine to perform its intended function(s) during its lifecycle where risk has been adequately reduced.

This standard is the basis for a set of standards which has the following structure:

- **type-A standards** (basic safety standards) giving basic concepts, principles for design, and general aspects that can be applied to all machinery;
- **type-B standards** (generic safety standards) dealing with one safety aspect or one type of safeguard that can be used across a wide range of machinery:
 - type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);
 - type-B2 standards on safeguards (e.g. two-hand controls, interlocking devices, pressure sensitive devices, guards);
- **type-C standards** (machine safety standards) dealing with detailed safety requirements for a particular machine or group of machines.

This standard is a type-A standard.

The subject of numerous clauses or subclauses of this standard is also dealt with, in a more detailed manner, in other type-A or B standards.

When a type-C standard deviates from one or more provisions dealt with by Part 2 of this standard or by a type-B standard, the type-C standard takes precedence.

It is recommended that this standard be incorporated in training courses and manuals to convey basic terminology and general design methods to designers.

Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles

1 Scope

This standard defines technical principles to help designers in achieving safety in the design of machinery.

ISO 12100-2 is intended to be used together with ISO 12100-1 when considering the solution to a specific problem. The two parts of ISO 12100 can be used independently of other documents or as a basis for the preparation of other type-A standards or type-B or -C standards.

This standard does not deal with damage to domestic animals, property or the environment.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60204-1:1997, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements.*

ISO 12100-1:2003, *Safety of machinery – Basic concepts, general principles for design – Basic terminology, methodology.*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 12100-1:2003 apply.

4 Inherently safe design measures

4.1 General

Inherently safe design measures are the first and most important step in the risk reduction process because protective measures inherent to the characteristics of the machine are likely to remain effective, whereas experience has shown that even well-designed safeguarding may fail or be violated and information for use may not be followed.

Inherently safe design measures are achieved by avoiding hazards or reducing risks by a suitable choice of design features of the machine itself and/or interaction between the exposed persons and the machine.

NOTE Clause 5 gives safeguarding and complementary measures to achieve the risk reduction objectives where inherently safe design measures are not sufficient (see 3-step method in ISO 12100-1:2003, clause 5).

4.2 Consideration of geometrical factors and physical aspects

4.2.1 Geometrical factors

Such factors can be, e.g.:

- designing the shape of machinery to maximise direct visibility of the working areas and hazard zones from the control position, e.g. reducing blind spots, and choosing and locating means of indirect vision where necessary (e.g. mirrors) so as to take into account the characteristics of human vision, particularly when safe operation requires permanent direct control by the operator, e.g.:
 - the travelling and working area of mobile machines;
 - the zone of movement of lifted loads or of the carrier of machinery for lifting persons;
 - the area of contact of the tool of a hand-held or hand-guided machine with the material being worked;

The design of the machine shall be such that, from the main control position, the operator is able to ensure that there are no exposed persons in the danger zones.

- the shape and the relative location of the mechanical component parts; for instance, crushing and shearing hazards are avoided by increasing the minimum gap between the moving parts, such that the part of the body under consideration can enter the gap safely, or by reducing the gap so that no part of the body can enter it (see ISO 13852, ISO 13853, ISO 13854);
- avoiding sharp edges and corners, protruding parts. In so far as their purpose allows, accessible parts of the machinery shall have no sharp edges, no sharp angles, no rough surfaces, no protruding parts likely to cause injury, and no openings which may "trap" parts of the body or clothing. In particular, sheet metal edges shall be deburred, flanged or trimmed, open ends of tubes which may cause a "trap" shall be capped;
- designing the shape of the machine to achieve a proper working position and accessibility of manual controls (actuators).

4.2.2 Physical aspects

Such aspects can be, e.g.:

- limiting the actuating force to a sufficiently low value so that the actuated part does not generate a mechanical hazard;
- limiting the mass and/or velocity of the movable elements, and hence their kinetic energy;
- limiting the emissions by acting on the characteristics of the source:
 - measures for reducing noise emission at source (see ISO/TR 11688-1);
 - measures for reducing the emission of vibration at source include e.g. redistribution or addition of mass and change of process parameters, e.g. frequency and/or amplitude of movements (for hand-held and hand-guided machinery, see CR 1030-1);
 - measures for reducing the emission of hazardous substances include e.g. use of less hazardous substances or use of dust reducing processes;
 - measures for reducing radiation emissions include e.g. avoiding the use of hazardous radiation sources, limiting the power of radiation to the lowest level sufficient for the proper functioning of the machine, designing the source so that the beam is concentrated on the target, increasing the distance between the source and the operator or providing for remote operation of the machinery.

- measures for the reduction of emission of non-ionizing radiation are given in 5.4.5 (see also EN 12198-1 and -3).

4.3 Taking into account the general technical knowledge regarding machine design

This general technical knowledge can be derived from technical specifications for design (e.g. standards, design codes, calculation rules). These should be used to cover:

a) mechanical stresses, e.g.:

- stress limitation by implementation of correct calculation, construction and fastening methods as regards, e.g. bolted assemblies, welded assemblies;
- stress limitation by overload prevention, (e.g. "fusible" plugs, pressure-limiting valves, breakage points, torque-limiting devices);
- avoiding fatigue in elements under variable stresses (notably cyclic stresses);
- static and dynamic balancing of rotating elements;

b) materials and their properties, e.g.:

- resistance to corrosion, ageing, abrasion and wear;
- hardness, ductility, brittleness;
- homogeneity;
- toxicity;
- flammability.
- flammability.

c) emission values for:

- noise;
- vibration;
- hazardous substances;
- radiation.

When the reliability of particular components or assemblies is critical for safety (e.g. ropes, chains, lifting accessories for lifting loads or persons), stress values shall be multiplied by appropriate working coefficients.

4.4 Choice of an appropriate technology

One or more hazards can be eliminated or risks reduced by the choice of the technology to be used in certain applications, e.g.:

a) on machines intended for use in explosive atmospheres:

- fully pneumatic or hydraulic control system and machine actuators;
- "intrinsically safe" electrical equipment (see EN 50020);

- b) for particular products to be processed such as a solvent: equipment assuring that the temperature will remain far below the flash point .
- c) alternative equipment to avoid high noise level, e.g.:
 - electrical instead of pneumatic equipment;
 - in certain conditions, water cutting instead of mechanical equipment.

4.5 Applying the principle of the positive mechanical action of a component on another component

If a moving mechanical component inevitably moves another component along with it, either by direct contact or via rigid elements, these components are connected in the positive mode. An example of this is positive opening operation of switching devices in an electrical circuit (see IEC 60947-5-1 and ISO 14119:1998, 5.7).

NOTE Where a mechanical component moves and thus allows another one to move freely (e.g. by gravity, by spring force), there is no positive mechanical action of the first one on the other one.

4.6 Provisions for stability

Machines shall be designed to have sufficient stability to allow them to be used safely in their specified conditions of use.

Factors to be taken into account include:

- geometry of the base;
- weight distribution, including loading;
- dynamic forces due to movements of parts of the machine, of the machine itself, or of elements held by the machine which may result in an overturning moment;
- vibration;
- oscillations of the centre of gravity;
- characteristics of the supporting surface in case of travelling or installation on different sites (e.g. ground conditions, slope);
- external forces (e.g. wind pressure, manual forces).

Stability shall be considered in all phases of the life of the machine, including handling, travelling, installation, use, de-commissioning and dismantling.

Other protective measures for stability relevant to safeguarding are given in 5.2.6.

4.7 Provisions for maintainability

When designing a machine, the following maintainability factors shall be taken into account:

- accessibility, taking into account the environment and the human body measurements, including the dimensions of the working clothes and tools used;
- ease of handling, taking into account human capabilities;
- limitation of the number of special tools and equipment.

4.8 Observing ergonomic principles

4.8.1 Ergonomic principles shall be taken into account in designing machinery to reduce mental or physical stress and strain of the operator. These principles shall be considered when allocating functions to operator and machine (degree of automation) in the basic design.

NOTE It also improves the performance and reliability of the operation and hence it reduces the probability of errors at all stages of machine use.

Account shall be taken of body sizes likely to be found in the intended user population, strengths and postures, movement amplitudes, frequency of cyclic actions (see ISO 10075 and ISO 10075-2).

All elements of the "operator-machine" interface such as controls, signalling or data display elements, shall be designed to be easily understood so that clear and unambiguous interaction between the operator and the machine is possible.

(See EN 614-1, ISO 6385, EN 13861 and IEC 61310-1).

Designers' attention is especially drawn to following ergonomic aspects of machine design:

4.8.2 Avoiding stressful postures and movements during use of the machine (e.g. by providing facilities to adjust the machine to suit the various operators).

4.8.3 Designing machines, and more especially hand-held and mobile machines to enable them to be operated easily taking into account human effort, actuation of controls and hand, arm and leg anatomy.

4.8.4 Avoiding as far as possible noise, vibration, thermal effects (e.g. extreme temperatures).

4.8.5 Avoiding linking the operator's working rhythm to an automatic succession of cycles.

4.8.6 Providing local lighting on or in the machine for the illumination of the working area and of adjusting, setting-up, and frequent maintenance zones when the design features of the machine and/or its guards render the ambient lighting inadequate. Flicker, dazzling, shadows and stroboscopic effects shall be avoided if they can cause a risk. If the position of the lighting source has to be adjusted, its location shall be such that it does not cause any risk to persons making the adjustment.

4.8.7 Selecting, locating and identifying manual controls (actuators) so that:

- they are clearly visible and identifiable and appropriately marked where necessary (see 5.4);
- they can be safely operated without hesitation or loss of time and without ambiguity (e.g. a standard layout of controls reduces the possibility of error when an operator changes from a machine to another one of similar type having the same pattern of operation);
- their location (for push-buttons) and their movement (for levers and handwheels) are consistent with their effect (see IEC 61310-3);
- their operation cannot cause additional risk.

See also EN 894-3.

Where a control is designed and constructed to perform several different actions, namely where there is no one-to-one correspondence (e.g. keyboards), the action to be performed shall be clearly displayed and subject to confirmation where necessary.

Controls shall be so arranged that their layout, travel and resistance to operation are compatible with the action to be performed, taking account of ergonomic principles. Constraints due to the necessary or foreseeable use of personal protective equipment (such as footwear, gloves) shall be taken into account.

4.8.8 Selecting, designing and locating indicators, dials and visual display units so that:

- they fit within the parameters and characteristics of human perception;
- information displayed can be detected, identified and interpreted conveniently, i.e. long lasting, distinct, unambiguous and understandable with respect to the operator's requirements and the intended use;
- the operator is able to perceive them from the control position.

4.9 Preventing electrical hazard

For the design of the electrical equipment of machines IEC 60204-1:1997 gives general provisions, especially in clause 6 for protection against electric shock. For requirements related to specific machines, see corresponding IEC standards (e.g. series of IEC 61029, IEC 60745, IEC 60335).

4.10 Preventing hazards from pneumatic and hydraulic equipment

Pneumatic and hydraulic equipment of machinery shall be designed so that:

- the maximum rated pressure cannot be exceeded in the circuits (e.g. by means of pressure limiting devices);
- no hazard results from pressure surges or rises, pressure losses or drops or losses of vacuum;
- no hazardous fluid jet or sudden hazardous movement of the hose (whiplash) results from leakage or component failures;
- air receivers, air reservoirs or similar vessels (e.g. in gas loaded accumulators) comply with the design rules for these elements;
- all elements of the equipment, and especially pipes and hoses, be protected against harmful external effects;
- as far as possible, reservoirs and similar vessels (e.g. in gas loaded accumulators) are automatically depressurized when isolating the machine from its power supply (see 5.5.4) and, if it is not possible, means are provided for their isolation, local depressurizing and pressure indication (see also ISO 14118:2000, clause 5);
- all elements which remain under pressure after isolation of the machine from its power supply be provided with clearly identified exhaust devices, and a warning label drawing attention to the necessity of depressurizing those elements before any setting or maintenance activity on the machine.

See also ISO 4413 and ISO 4414.

4.11 Applying inherently safe design measures to control system

4.11.1 General

The design measures of the control system shall be chosen so that their safety-related performance provides a sufficient amount of risk reduction (see ISO 13849-1).

The correct design of machine control systems can avoid unforeseen and potentially hazardous machine behaviour.

Typical causes of hazardous machine behaviour are:

- an unsuitable design or modification (accidental or deliberate) of the control system logic;

- a temporary or permanent defect or a failure of one or several components of the control system;
- a variation or a failure in the power supply of the control system;
- inappropriate selection, design and location of the control devices;

Typical examples of hazardous machine behaviour are:

- unintended / unexpected start-up (see ISO 14118);
- uncontrolled speed change;
- failure to stop moving parts;
- dropping or ejection of a mobile part of the machine or of a workpiece clamped by the machine;
- machine action resulting from inhibition (defeating or failure) of protective devices.

In order to prevent hazardous machine behaviour and to achieve safety functions, the design of control systems shall comply with the principles and methods presented in this subclause 4.11 and in 4.12. These principles and methods shall be applied singly or in combination as appropriate to the circumstances (see ISO 13849-1 and IEC 60204-1:1997, clauses 9 to 12).

Control systems shall be designed to enable the operator to interact with the machine safely and easily; this requires one or several of the following solutions:

- systematic analysis of start and stop conditions;
- provision for specific operating modes (e.g. start-up after normal stop, restart after cycle interruption or after emergency stop, removal of the workpieces contained in the machine, operation of a part of the machine in case of a failure of a machine element);
- clear display of the faults;
- measures to prevent accidental generation of unexpected start commands (e.g. shrouded start device) likely to cause dangerous machine behaviour (see ISO 14118:2000, figure 1);
- maintained stop commands (e.g. interlock) to prevent restarting that could result in dangerous machine behaviour (see ISO 14118:2000, figure 1).

An assembly of machines may be divided into several zones for emergency stopping, for stopping as a result of protective devices and/or for isolation and energy dissipation. The different zones shall be clearly defined and it shall be obvious which parts of the machine belong to which zone. Likewise it shall be obvious which control devices (e.g. emergency stop devices, supply disconnecting devices) and/or protective devices belong to which zone. The interfaces between zones shall be designed such that no function in one zone creates hazards in another zone which has been stopped for an intervention.

Control systems shall be designed to limit the movements of parts of the machinery, the machine itself, or workpieces and/or loads held by the machinery, to the safe design parameters (e.g. range, speed, acceleration, deceleration, load capacity). Allowance shall be made for dynamic effects (e.g. the swinging of loads).

For example:

- the travelling speed of mobile pedestrian controlled machinery other than remote-controlled shall be compatible with walking speed;

- the range, speed, acceleration and deceleration of movements of the person-carrier and carrying vehicle for lifting persons shall be limited to non-hazardous values, taking into account the total reaction time of the operator and the machine;
- the range of movements of parts of machinery for lifting loads shall be kept within specified limits.

When machinery is designed to use synchronously different elements which can also be used independently, the control system shall be designed to prevent risks due to lack of synchronization.

4.11.2 Starting of an internal power source/switching on an external power supply

Starting of an internal power source or switching on an external power supply shall not result in starting of working parts (e.g. starting the internal combustion engine shall not lead to movement of a mobile machine, connection to mains electricity supply shall not result in starting of working parts of an electrical machine; see IEC 60204-1:1997, 7.5).

4.11.3 Starting/stopping of a mechanism

The primary action for starting or accelerating the movement of a mechanism should be performed by application or increase of voltage or fluid pressure, or, if binary logic elements are considered, by passage from state 0 to state 1 (if state 1 represents the highest energy state).

The primary action for stopping or slowing down should be performed by removal or reduction of voltage or fluid pressure, or, if binary logic elements are considered, by passage from state 1 to state 0 (if state 1 represents the highest energy state).

NOTE In certain applications (e.g. high-voltage switchgear) this principle cannot be used. Then, other measures should be applied to achieve the same level of confidence for the stopping or slowing down.

When, in order for the operator to maintain permanent control of deceleration, this principle is not observed (e.g. a hydraulic braking device of a self-propelled mobile machine), the machine shall be equipped with a means of slowing and stopping in case of failure of the main braking system.

4.11.4 Restart after power interruption

If it may generate a hazard, the spontaneous restart of a machine when it is re-energized after power interruption shall be prevented (e.g. by use of a self-maintained relay, contactor or valve).

4.11.5 Interruption of power supply

Machinery shall be designed to prevent hazardous situations resulting from interruption or excessive fluctuation of the power supply. At least the following requirements shall be met:

- the stopping function of the machinery shall remain;
- all devices whose permanent operation is required for safety shall operate in an effective way to maintain safety (e.g. locking, clamping devices, cooling or heating devices, power-assisted steering of self-propelled mobile machinery);
- parts of machinery or workpieces and/or loads held by machinery which are liable to move as a result of potential energy shall be retained for the time necessary to allow them to be safely lowered.

4.11.6 Use of automatic monitoring

Automatic monitoring is intended to ensure that a safety function(s) implemented by a protective measure do(es) not fail to be performed if the ability of a component or an element to perform its function is diminished, or if the process conditions are changed in such a way that hazards are generated.

Automatic monitoring either detects a fault immediately or carries out periodic checks so that a fault is detected before the next demand upon the safety function. In either case, the protective measure can be initiated immediately or delayed until a specific event occurs (e.g. the beginning of the machine cycle).

The protective measures may be, e.g.:

- the stopping of the hazardous process;
- preventing the re-start of this process after the first stop following the failure;
- the triggering of an alarm.

4.11.7 Safety functions implemented by programmable electronic control systems

4.11.7.1 General

A control system including programmable electronic equipment (e.g. programmable controllers) can be used to implement safety functions at machinery. Where a programmable electronic control system is used it is necessary to consider its performance requirements in relation to the requirements for the safety functions.

The design of the programmable electronic control system shall be such that the probability of random hardware failures and the likelihood of systematic failures that can adversely affect the performance of the safety-related control function(s) are sufficiently low. Where a programmable electronic control system performs a monitoring function, the system behaviour on detection of a fault shall be considered (see also IEC 61508 series for further guidance).

NOTE Both draft IEC 62061 and ISO 13849-1 rev., which are specific to machinery safety, provide guidance that is applicable to programmable electronic control systems.

The programmable electronic control system should be installed and validated to ensure that the specified performance (e.g. safety integrity level (SIL) in IEC 61508 series) for each safety function has been achieved. Validation comprises testing and analysis (e.g. static, dynamic or failure analysis) to show that all parts interact correctly to perform the safety function and that unintended functions do not occur.

4.11.7.2 Hardware aspects

The hardware (including e.g. sensors, actuators, logic solvers) shall be selected (and/or designed) and installed to meet both the functional and performance requirements of the safety function(s) to be performed, in particular, by means of:

- architectural constraints (e.g. the configuration of the system, its ability to tolerate faults, its behaviour on detection of a fault);
- selecting (and/or designing) equipment and devices with an appropriate probability of dangerous random hardware failure;

incorporating measures and techniques within the hardware to avoid systematic failures and control systematic faults.

4.11.7.3 Software aspects

The software (including internal operating software (or system software) and application software) shall be designed so as to satisfy the performance specification for the safety functions (see also IEC 61508-3).

4.11.7.4 Application software

Application software should not be re-programmable by the user. This may be achieved by use of embedded software in a non re-programmable memory (e.g. micro-controller, application specific integrated circuit (ASIC)).

When the application requires reprogramming by the user, the access to the software dealing with safety functions should be restricted e.g. by:

- locks;
- passwords for the authorized persons.

4.11.8 Principles relating to manual control

- a) Manual control devices shall be designed and located according to the relevant ergonomic principles given in 4.8.7.
- b) A stop control device shall be placed near each start control device. Where the start/stop function is performed by means of a hold-to-run control, a separate stop control device shall be provided when a risk can result from the hold-to-run control device failing to deliver a stop command when released.
- c) Manual controls shall be located out of reach of the danger zones (see IEC 61310-3:1999, clause 4), except for certain controls where, of necessity, they are located within a danger zone, such as emergency stop or teach pendant.
- d) Whenever possible, control devices and control positions shall be located so that the operator is able to observe the working area or hazard zone.

The driver of a ride-on mobile machine shall be able to actuate all control devices required to operate the machine from the driving position, except for functions which can be controlled more safely from other positions.

On machinery intended for lifting persons, controls for lifting and lowering and, if appropriate, for moving the carrier, shall generally be located in the carrier. If safe operation requires controls to be situated outside the carrier, the operator in the carrier shall be provided with the means of preventing hazardous movements.

- e) If it is possible to start the same hazardous element by means of several controls, the control circuit shall be so arranged that only one control is effective at a given time. This applies especially to machines which can be manually controlled by means among others of a portable control unit (teach pendant, for instance), with which the operator may enter danger zones.
- f) Control actuators shall be designed or guarded so that their effect, where a risk is involved, cannot occur without intentional operation (see ISO 9355-1 and ISO 447).
- g) For machine functions whose safe operation depends on permanent, direct control by the operator, measures shall be taken to ensure the presence of the operator at the control position, e. g. by the design and location of control devices.
- h) For cableless control an automatic stop shall be performed when correct control signals are not received, including loss of communication (see IEC 60204-1:1997, 9.2.7).

4.11.9 Control mode for setting, teaching, process changeover, fault-finding, cleaning or maintenance

Where, for setting, teaching, process changeover, fault-finding, cleaning or maintenance of machinery, a guard has to be displaced or removed and/or a protective device has to be disabled, and where it is necessary for the purpose of these operations for the machinery or part of the machinery to be put in operation, safety of the operator shall be achieved using a specific control mode which simultaneously:

- disables all other control modes;
- permits operation of the hazardous elements only by continuous actuation of an enabling device, a hold-to-run control device or a two-hand control device;
- permits operation of the hazardous elements only in reduced risk conditions (e.g. reduced speed, reduced power / force, step-by-step operation, e.g. with a limited movement control device).

NOTE For some special machinery other protective measures may be appropriate.

This control mode shall be associated with one or more of following measures:

- restriction of access to the danger zone as far as possible;
- emergency stop control within immediate reach of the operator;
- portable control unit (teach pendant) and/or local controls allowing sight of the controlled elements.

(See IEC 60204-1:1997, 9.2.4).

4.11.10 Selection of control and operating modes

If machinery has been designed and built to allow for its use in several control or operating modes requiring different protective measures and/or work procedures (e.g. to allow for adjustment, setting, maintenance, inspection), it shall be fitted with a mode selector which can be locked in each position. Each position of the selector shall be clearly identifiable and shall exclusively allow one control or operating mode.

The selector may be replaced by another selection means which restricts the use of certain functions of the machinery to certain categories of operators (e.g. access codes for certain numerically controlled functions).

4.11.11 Applying measures to achieve electromagnetic compatibility (EMC)

For guidance on electromagnetic compatibility, see IEC 60204-1:1997, 4.4.2 and IEC 61000-6 series.

4.11.12 Provision of diagnostic systems to aid fault-finding

Diagnostic systems to aid fault finding should be included in the control system so that there is no need to disable any protective measure.

NOTE Such systems not only improve availability and maintainability of machinery; they also reduce the exposure of maintenance staff to hazards.

4.12 Minimizing the probability of failure of safety functions

Safety of machinery is not only dependent on the reliability of the control systems but also on the reliability of all parts of the machine.

The continued operation of the safety functions is essential for the safe use of the machine. This can be achieved by:

4.12.1 Use of reliable components

"Reliable components" means components which are capable of withstanding all disturbances and stresses associated with the usage of the equipment in the conditions of intended use (including the environmental conditions), for the period of time or the number of operations fixed for the use, with a low probability of failures generating a hazardous malfunctioning of the machine. Components shall be selected taking into account all factors mentioned above (see also 4.13).

NOTE 1 "Reliable components" is not a synonym for "well-tried components" (see ISO 13849-1:1999, 6.2.2).

NOTE 2 Environmental conditions which are to be taken into consideration are, for instance: impact, vibration, cold, heat, moisture, dust, corrosive and/or abrasive substances, static electricity, magnetic and electric fields. Disturbances which can be generated by those conditions are, e.g.: insulation failures, temporary or permanent failures in the function of control system components.

4.12.2 Use of "oriented failure mode" components

"Oriented failure mode" components or systems are those in which the predominant failure mode is known in advance and which can be used so that such a failure leads to a non-hazardous alteration of the machine function.

NOTE In some cases, it will be necessary to take additional measures to limit the negative effects of such a failure.

The use of such components should always be considered, particularly in cases where redundancy is not employed.

4.12.3 Duplication (or redundancy) of components or subsystems

In the design of safety-related parts of the machine, duplication (or redundancy) of components may be used so that, if one component fails, another component (or other components) continue(s) to perform its (their) function, thereby ensuring that the safety function remains available.

In order to allow the proper action to be initiated, component failure shall be preferably detected by automatic monitoring (see 4.11.6) or in some circumstances by regular inspection, provided that the inspection interval is shorter than the expected lifetime of the components.

Diversity of design and/or technology can be used to avoid common cause failures (e.g. from electromagnetic disturbance) or common mode failures.

4.13 Limiting exposure to hazards through reliability of equipment

Increased reliability of all component parts of machinery reduces the frequency of incidents requiring rectification, thereby reducing exposure to hazards.

This applies to power systems (operative part) as well as to control systems, to safety functions as well as to other functions of machinery.

Safety-critical components (as, e.g., certain sensors) with a known reliability shall be used.

The elements of guards and of protective devices shall be particularly reliable, as their failure can expose persons to hazards, and also as poor reliability would encourage attempts to defeat them.

4.14 Limiting exposure to hazards through mechanization or automation of loading (feeding) /unloading (removal) operations

Mechanization and automation of machine loading / unloading operations and more generally of handling operations (of workpieces, materials, substances) limit the risk generated by these operations by reducing the exposure of persons to hazards at the operating points.

Automation can be achieved e.g. by robots, handling devices, transfer mechanisms, air blast equipment. Mechanization can be achieved, e.g. by feeding slides, push rods, hand-operated indexing tables.

While automatic feeding and removal devices have much to offer in preventing accidents to machine operators, they can create danger when any faults are being rectified. Care shall be taken to ensure that the use of these devices does not introduce further hazards (e. g. trapping, crushing) between the devices and parts of the machine or workpieces / materials being processed. Suitable safeguards (see clause 5) shall be provided if this cannot be ensured.

Automatic feeding and removal devices with their own control systems and the control system of the associated machine shall be interconnected after thoroughly studying how all safety functions are performed in all control and operation modes of the whole equipment.

4.15 Limiting exposure to hazards through location of the setting and maintenance points outside of danger zones

The need for access to danger zones shall be minimized by locating maintenance, lubrication and setting points outside these zones.

5 Safeguarding and complementary protective measures

5.1 General

Guards and protective devices shall be used to protect persons whenever inherently safe design does not reasonably make it possible either to remove hazards or to sufficiently reduce risks. Complementary protective measures involving additional equipment (e.g. emergency stop equipment) may have to be taken (see ISO 12100-1:2003, 5.4).

The different kinds of guards and protective devices are defined in ISO 12100-1:2003, 3.25 and 3.26.

Certain safeguards may be used to avoid exposure to more than one hazard (e.g. a fixed guard preventing access to a zone where a mechanical hazard is present being used to reduce noise level and collect toxic emissions).

5.2 Selection and implementation of guards and protective devices

5.2.1 General

This subclause gives guidelines for the selection and the implementation of guards and protective devices the primary purpose of which is to protect persons against hazards generated by moving parts, according to the nature of those parts (see figure 1) and to the need for access to the danger zone(s).

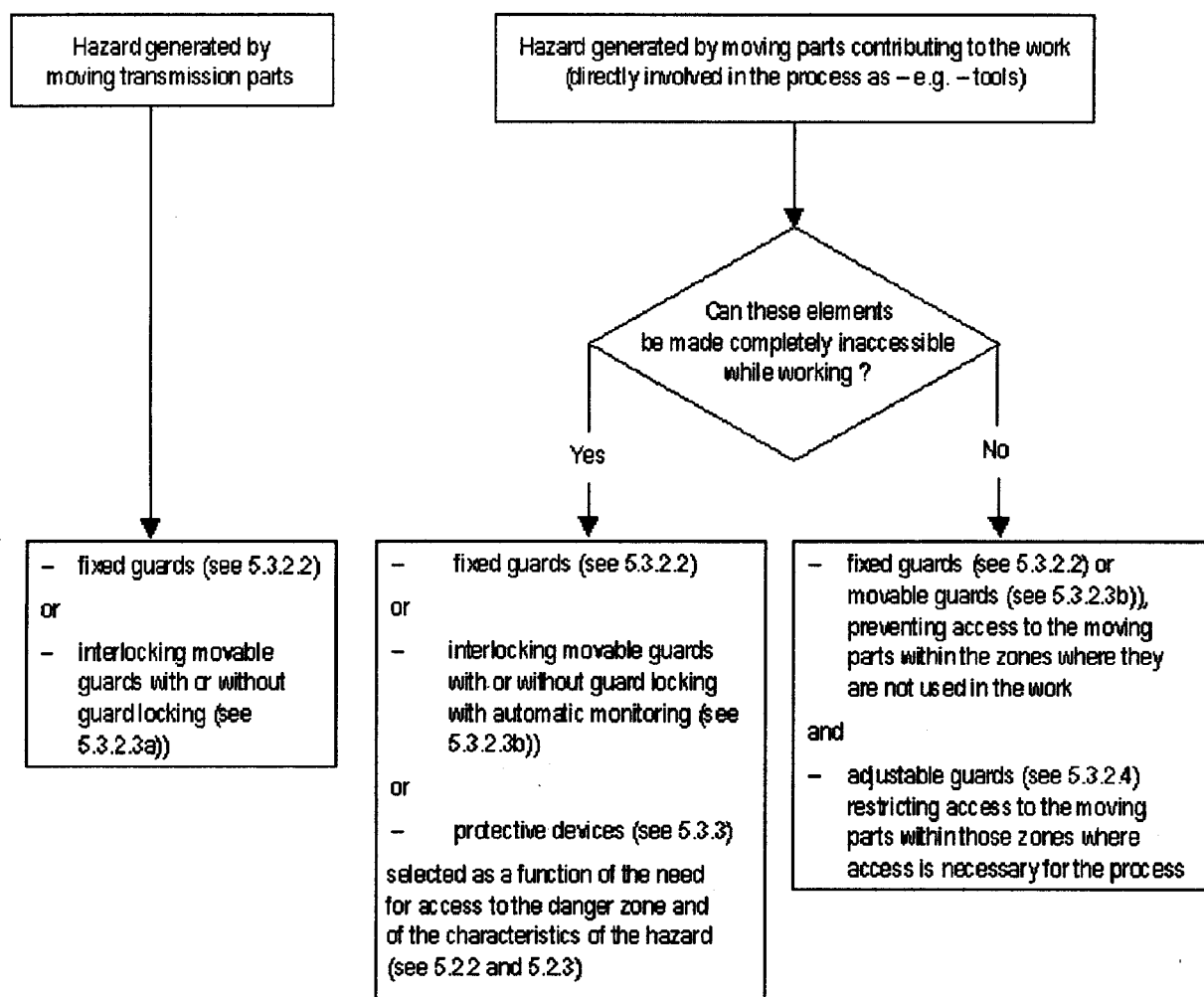


Figure 1 — Guidelines to help make the choice of safeguards against hazards generated by moving parts

The exact choice of a safeguard for a particular machine shall be made on the basis of the risk assessment for that machine.

In selecting an appropriate safeguard for a particular type of machinery or hazard zone, it shall be borne in mind that a fixed guard is simple and shall be used where access of an operator to the danger zone is not required during normal operation (operation without any malfunction) of the machinery.

As the need for frequency of access increases this inevitably leads to the fixed guard not being replaced. This requires the use of an alternative protective measure (movable interlocking guard, sensitive protective equipment).

A combination of safeguards may sometimes be required. For example, where, in conjunction with a fixed guard, a mechanical loading (feeding) device is used to feed a workpiece into a machine, thereby removing the need for access to the primary hazard zone, a trip device may be required to protect against the secondary drawing-in or shearing hazard between the mechanical loading (feeding) device, when reachable, and the fixed guard.

Consideration shall be given to the enclosure of control positions or intervention zones to provide combined protection against several hazards which may include:

- hazards from falling or ejected objects (e.g. falling object protection structure);
- emission hazards (e.g. protection against noise, vibration, radiation, harmful substances);
- hazards due to the environment (e.g. protection against heat, cold, foul weather);
- hazards due to tipping over or rolling over of machinery (e.g. roll-over or tip-over protection structure).

The design of such enclosed work stations (e. g. cabs and cabins) shall take into account ergonomic principles concerning visibility, lighting, atmospheric conditions, access, posture.

5.2.2 Where access to the hazard zone is not required during normal operation

Where access to the hazard zone is not required during normal operation of the machinery, safeguards should be selected from the following:

- a) fixed guard (see also ISO 14120);
- b) interlocking guard with or without guard locking (see also ISO 14119, ISO 14120 and 5.3.2.3 of this standard);
- c) self-closing guard (see ISO 14120:2002, 3.3.2);
- d) sensitive protective equipment, e.g. electro-sensitive protective equipment (see IEC 61496-1, IEC 61496-2) or pressure sensitive mat (see ISO 13856-1).

5.2.3 Where access to the hazard zone is required during normal operation

Where access to the hazard zone is required during normal operation of the machinery, safeguards should be selected from the following:

- a) interlocking guard with or without guard locking (see also ISO 14119, ISO 14120 and 5.3.2.3 of this standard);
- b) sensitive protective equipment, e.g. electro-sensitive protective equipment (see IEC 61496-1, IEC 61496-2);
- c) adjustable guard;
- d) self-closing guard (see ISO 14120:2002, 3.3.2);
- e) two-hand control device (see ISO 13851);
- f) interlocking guard with a start function (control guard) (see 5.3.2.5 of this standard).

5.2.4 Where access to the hazard zone is required for machine setting, teaching, process changeover, fault finding, cleaning or maintenance

As far as possible, machines shall be designed so that the safeguards provided for the protection of the production operator may ensure also the protection of personnel in charge of setting, teaching, process changeover, fault finding, cleaning or maintenance without hindering them in performing their task. Such tasks shall be identified and considered in the risk assessment as parts of the use of the machine (see ISO 12100-1:2003, 5.3).

NOTE Isolation and energy dissipation for machine shut-down (see 5.5.4; see also ISO 14118:2000, 4.1 and clause 5) ensure the highest level of protection when carrying out tasks (especially maintenance and repair tasks) which do not require the machine to remain connected to its power supply.

5.2.5 Selection and Implementation of sensitive protective equipment¹⁾

5.2.5.1 Selection

Due to the great diversity of the technologies on which their detection function is based, all types of sensitive protective equipment are far from being equally suitable for safety applications. The following provisions are intended to provide the designer with criteria for selecting, for each application, the most suitable device(s).

Types of sensitive protective equipment include, e.g.:

- light curtains;
- scanning devices as, e.g., laser scanners;
- pressure sensitive mats;
- trip bars, trip wires.

Sensitive protective equipment can be used:

- for tripping purposes;
- for presence sensing;
- for both tripping and presence sensing;
- to re-initiate machine operation, a practice which is subject to stringent conditions.

NOTE Some types of sensitive protective equipment may be unsuitable either for presence sensing or for tripping purposes.

The following characteristics of the machinery, among others, can preclude the sole use of sensitive protective equipment

- tendency for the machinery to eject materials or component parts;
- necessity to guard against emissions (noise, radiation, dust, etc.);
- erratic or excessive machine stopping time;
- inability of a machine to stop part-way through a cycle.

5.2.5.2 Implementation

a) Consideration should be given to:

- size, characteristics and positioning of the detection zone (see ISO 13855, which deals with the positioning of some types of sensitive protective equipment);
- reaction of the device to fault conditions (see IEC 61496-1, IEC 61496-2 for electro-sensitive protective equipment);
- possibility of circumvention;

1) More details are given in draft IEC 62046

- detection capability and its variation over the course of time (e.g. as a result of its susceptibility to different environmental conditions such as the presence of reflecting surfaces, other artificial light sources, sunlight or impurities in the air).

NOTE IEC 61496-1 defines the detection capability of electro-sensitive protective equipment.

- b) Sensitive protective equipment shall be integrated in the operative part and associated with the control system of the machine so that:

- a command is given as soon as a person or part of a person is detected;
- the withdrawal of the person or part of a person detected does not, by itself, restart the hazardous machine function(s); therefore, the command given by the sensitive protective equipment shall be maintained by the control system until a new command is given;
- restarting the hazardous machine function(s) results from the voluntary actuation, by the operator, of a control device placed outside the hazard zone, where this zone can be observed by the operator;
- while the detection function of the sensitive protective equipment is interrupted the machine cannot operate, except during muting phases;

NOTE Muting is the temporary automatic suspension of a safety function(s) by safety-related parts of the control system (see ISO 13849-1).

- the position and the shape of the detection field prevents, possibly together with fixed guards, a person or part of a person from entering the hazard zone, or being present in it, without being detected.

NOTE For details, e.g. fault behaviour of active opto-electronic protective devices, IEC 61496-1, IEC 61496-2 should be taken into account.

5.2.5.3 Additional requirements for sensitive protective equipment when used for cycle initiation

In this exceptional application, starting of the machine cycle is initiated by the withdrawal of a person or of the detected part of a person from the sensing field of the sensitive protective equipment, without any additional start command, hence deviating from the general requirement given in the 2nd dash of 5.2.5.2.b). After switching on the power supply, or when the machine has been stopped by the tripping function of the sensitive protective equipment the machine cycle shall be initiated only by voluntary actuation of a start control. For cycle initiation by a sensitive protective equipment, only active opto-electronic protective devices (AOPDs) complying with IEC 61496 series shall be used, provided that:

- a) the requirements for an AOPD used as a tripping and presence-sensing device (see IEC 61496-2) are satisfied (in particular: location, minimum distance (see ISO 13855), detection capability, reliability and monitoring of control and braking systems);
- b) the cycle time of the machine is short and the facility to re-initiate the machine upon clearing of the sensing field is limited to a period commensurate with a single normal cycle;
- c) entering the sensing field of the AOPD(s) or opening interlocking guards is the only way to enter the hazard zone;

NOTE The hazard zone considered above is any zone where the operation of hazardous elements (including ancillary equipment and transmission elements) is initiated by clearing of the sensing field.

- d) if there are more than one AOPD safeguarding the machine, only one of them is capable of cycle re-initiation;
- e) with regard to the higher risk resulting from automatic cycle initiation, the AOPD and the associated part of the control system comply with a higher safety-related performance than under normal conditions.

5.2.6 Protective measures for stability

If stability cannot be achieved by inherently safe design measures such as weight distribution (see 4.6), it will be necessary to maintain it by protective measures such as the use of:

- anchorage bolts;
- locking devices;
- movement limiters or mechanical stops;
- acceleration or deceleration limiters;
- load limiters;
- alarms warning of the approach to stability or tipping limits.

5.2.7 Other protective devices

When a machine requires continuous control by the operator (e.g. mobile machines, cranes) and an error of the operator can generate a hazardous situation, this machine shall be equipped with the necessary devices to enable the operation to remain within specified limits, in particular:

- when the operator has insufficient visibility of the hazard zone;
- when the operator lacks knowledge of the actual value of a safety-related parameter (e.g. a distance, a speed, the mass of a load, the angle of a slope);
- when hazards may result from operations other than those controlled by the operator.

The necessary devices include, e.g. :

- devices for limiting parameters of movement (distance, angle, velocity, acceleration);
- overloading and moment limiting devices;
- devices to prevent collisions or interference with other machines;
- devices for preventing hazards to pedestrian operators of mobile machinery or other pedestrians;
- torque limiting devices, breakage points to prevent excessive stress of components and assemblies;
- devices for limiting pressure, temperature;
- devices for monitoring emissions;
- devices to prevent operation in the absence of the operator at the control position;
- devices to prevent lifting operations unless stabilizers are in place;
- devices to limit inclination of the machine on a slope;
- devices to ensure that components are in a safe position before travelling.

Automatic protective measures triggered by such devices which take operation of the machinery out of the control of the operator (e.g. automatic stop of hazardous movement) should be preceded or accompanied by a warning signal to enable the operator to take appropriate action (see 6.3).

5.3 Requirements for the design of guards and protective devices

5.3.1 General requirements

Guards and protective devices shall be designed to be suitable for the intended use, taking into account mechanical and other hazards involved. Guards and protective devices shall be compatible with the working environment of the machine and designed so that they cannot be easily defeated. They shall provide the minimum possible interference with activities during operation and other phases of machine life, in order to reduce any incentive to defeat them.

NOTE For additional information, see ISO 14120, ISO 13849-1, ISO 13851, ISO 14119, ISO 13856-1, IEC 61496-1, IEC 61496-2.

Guards and protective devices shall:

- be of robust construction;
- not give rise to any additional hazard;
- not be easy to by-pass or render non-operational;
- be located at an adequate distance from the danger zone (see ISO 13852, ISO 13853 and ISO 13855);
- cause minimum obstruction to the view of the production process;
- enable essential work to be carried out on installation and/or replacement of tools and also for maintenance by allowing access only to the area where the work has to be done, if possible without the guard or protective device having to be moved.

For openings in the guards see ISO 13852 and ISO 13853.

5.3.2 Requirements of guards

5.3.2.1 Functions of guards

Guards may have to achieve following functions:

- prevention of access to the space enclosed by the guard and/or
- containment / capture of materials, workpieces, chips, liquids which may be ejected or dropped by the machine and reduction of emissions (noise, radiation, hazardous substances such as dust, fumes, gases) which may be generated by the machine.

Additionally, they may need to have particular properties relating to electricity, temperature, fire, explosion, vibration, visibility (see ISO 14120) and operator position ergonomics (e.g. usability, operator's movements, postures, repetitive movements).

5.3.2.2 Requirements for fixed guards

Fixed guards shall be securely held in place:

- either permanently (e.g. by welding);
- or by means of fasteners (screws, nuts) making removal / opening impossible without using tools; they should not remain closed without their fasteners (see ISO 14120).

NOTE A fixed guard can be hinged to assist in its opening.

5.3.2.3 Requirements for movable guards

- a) Movable guards which provide protection against hazards generated by moving transmission parts shall:
- as far as possible remain fixed to the machinery or other structure (generally by means of hinges or guides) when open;
 - be interlocking guards (with guard locking when necessary) (see ISO 14119).

See figure 1.

- b) Movable guards against hazards generated by non-transmission moving parts shall be designed and associated with the machine control system so that:
- moving parts cannot start up while they are within the operator's reach and the operator cannot reach moving parts once they have started up; this can be achieved by interlocking guards, with guard locking when necessary;
 - they can be adjusted only by an intentional action, such as the use of a tool or a key;
 - the absence or failure of one of their components prevents starting of the moving parts or stops them; this can be achieved by automatic monitoring (see 4.11.6).

See figure 1 and ISO 14119.

5.3.2.4 Requirements for adjustable guards

Adjustable guards may only be used where the hazard zone cannot for operational reasons be completely enclosed.

They shall:

- be designed so that the adjustment remains fixed during a given operation;
- be readily adjustable without the use of tools.

5.3.2.5 Requirements for interlocking guards with a start function (control guards)

An interlocking guard with a start function may be used only when all the following requirements are met:

- all requirements for interlocking guards are satisfied (see ISO 14119);
- the cycle time of the machine is short;
- the maximum opening time of the guard is preset to a low value (e.g. equal to the cycle time). When this time is exceeded, the hazardous function(s) cannot be initiated by the closing of the interlocking guard with a start function and resetting is necessary before restarting the machine;
- the dimensions or shape of the machine do not allow a person, or part of a person, to stay in the hazard zone or between the hazard zone and the guard while the guard is closed (see ISO 14120);
- all other guards whether fixed (removable type) or movable are interlocking guards;

- the interlocking device associated with the interlocking guard with a start function is designed in such a way – e.g. by duplication of position detectors and use of automatic monitoring (see 4.11.6) – that its failure cannot lead to an unintended / unexpected start-up;
- the guard is securely held open (e.g. by a spring or counterweight) such that it cannot initiate a start while falling by its own weight.

5.3.2.6 Hazards from guards

Care shall be taken to prevent hazards which might be generated by:

- the guard construction (e.g. sharp edges or corners, material);
- the movements of the guards (shearing or crushing zones generated by power-operated guards and by heavy guards which are liable to fall).

5.3.3 Technical characteristics of protective devices

Protective devices shall be selected or designed and connected to the control system so as to ensure correct implementation of their safety function(s).

Protective devices shall be either selected as meeting the appropriate product standard (e.g. for active opto-electronic protective devices see IEC 61496-2) or designed according to one or several of the principles formulated in ISO 13849-1.

Protective devices shall be installed and connected to the control system so that they cannot be easily defeated.

5.3.4 Provisions for alternative types of safeguards

Provisions should be made to facilitate the fitting of alternative types of safeguards on machinery where it is known that this fitting will be necessary because the work to be done on it will vary.

5.4 Safeguarding for reducing emissions

5.4.1 General

If the measures for the reduction of emissions at source mentioned in 4.2.2 are not adequate, the machine shall be provided with additional protective measures.

5.4.2 Noise

Additional protective measures include, for example:

- enclosures (see ISO 15667);
- screens fitted to the machine;
- silencers (see ISO 14163).

5.4.3 Vibration

Additional protective measures include, for example, damping devices for vibration isolation between the source and the exposed person such as resilient mounting or suspended seats.

For measures for vibration isolation of stationary industrial machinery see EN 1299.

5.4.4 Hazardous substances

Additional protective measures include, for example:

- encapsulation of the machine (enclosure with negative pressure);
- local exhaust ventilation with filtration;
- wetting with liquids;
- special ventilation in the area of the machine (air curtains, cabins for operators).

See ISO 14123-1.

5.4.5 Radiation

Additional protective measures include, for example:

- use of filtering and absorption;
- use of attenuating screens or guards.

5.5 Complementary protective measures

5.5.1 General

Protective measures which are neither inherently safe design measures, nor safeguarding (implementation of guards and/or protective devices), nor information for use may have to be implemented as required by the intended use and the reasonably foreseeable misuse of the machine. Such measures include, but are not limited to, the ones dealt with in 5.5.2 to 5.5.6.

5.5.2 Components and elements to achieve the emergency stop function

If following a risk assessment, a machine needs to be fitted with components and elements to achieve an emergency stop function to enable actual or impending emergency situations to be averted, the following requirements apply:

- the actuators shall be clearly identifiable, clearly visible and readily accessible;
- the hazardous process shall be stopped as quickly as possible without creating additional hazards. If this is not possible or the risk cannot be reduced, it should be questioned whether implementation of an emergency stop function is the best solution;
- the emergency stop control shall trigger or permit the triggering of certain safeguard movements where necessary.

NOTE For more detailed provisions, see ISO 13850.

Once active operation of the emergency stop device has ceased following an emergency stop command, the effect of this command shall be sustained until it is reset. This reset shall be possible only at that location where the emergency stop command has been initiated. The reset of the device shall not restart the machinery, but only permit restarting.

More details for the design and selection of electrical components and elements to achieve the emergency stop function are provided in IEC 60204 series.

5.5.3 Measures for the escape and rescue of trapped persons

Measures for the escape and rescue of trapped persons may consist, e.g. of:

- escape routes and shelters in installations generating operator-trapping hazards;
- arrangements for moving some elements by hand, after an emergency stop;
- arrangements for reversing the movement of some elements;
- anchorage points for descender devices;
- means of communication to enable trapped operators to call for help.

5.5.4 Measures for isolation and energy dissipation

Especially with regard to their maintenance and repair, machines shall be equipped with the technical means to achieve the isolation from power supply(ies) and dissipation of stored energy as a result of following actions:

- a) isolating (disconnecting, separating) the machine (or defined parts of the machine) from all power supplies;
- b) locking (or otherwise securing) all the isolating units in the isolating position;
- c) dissipating or, if this is not possible or practicable, restraining (containing) any stored energy which may give rise to a hazard;
- d) verifying, by means of a safe working procedure, that the actions taken according to a), b) and c) above have produced the desired effect.

See ISO 14118:2000, clause 5 and IEC 60204-1:1997, 5.5 and 5.6.

5.5.5 Provisions for easy and safe handling of machines and their heavy component parts

Machines and their component parts which cannot be moved or transported by hand shall be provided or capable of being provided with suitable attachment devices for transport by means of lifting gear.

These attachments may be, e.g.:

- standardized lifting appliances with slings, hooks, eyebolts, or tapped holes for appliance fixing;
- appliances for automatic grabbing with a lifting hook when attachment is not possible from the ground;
- guiding grooves for machines to be transported by a fork truck;
- lifting gear and appliances integrated into the machine.

Parts of machinery which can be removed manually in operation shall be provided with means for their safe removal and replacement.

See also 6.4.c) (3rd dash).

5.5.6 Measures for safe access to machinery

Machinery shall be so designed as to enable operation and all routine tasks relating to setting and/or maintenance, to be carried out, as far as possible, by a person remaining at ground level.

Where this is not possible, machines shall have built-in platforms, stairs or other facilities to provide safe access for those tasks, but care should be taken to ensure that such platforms or stairs do not give access to danger zones of machinery.

The walking areas shall be made from materials which remain as slip resistant as practicable under working conditions and, depending on the height from the ground, suitable guard-rails (see ISO 14122-3) shall be provided.

In large automated installations, particular attention shall be given to safe means of access such as walkways, conveyor bridges or crossover points.

Means of access to parts of machinery located at a height shall be provided with collective means of protection against falls (e.g. guard-rails for stairways, stepladders and platforms and/or safety cages for ladders). As necessary, anchorage points for personal protective equipment against falls from a height shall also be provided (e.g. in carriers of machinery for lifting persons or with elevating control stations).

Openings shall whenever possible open towards a safe position. They shall be designed to prevent hazards due to unintended opening.

The necessary aids for access shall be provided (e.g. steps, handholds). Control devices shall be designed and located to prevent their being used as aids for access.

When machinery for lifting goods and/or persons includes landings at fixed levels, these shall be equipped with interlocking guards preventing falls when the platform is not present at the level. Movement of the lifting platform shall be prevented while the guards are open.

For detailed provisions see ISO 14122-1, ISO 14122-2, ISO 14122-3 and ISO 14122-4.

6 Information for use

6.1 General requirements

Drafting information for use is an integral part of the design of a machine (see ISO 12100-1:2003, figure 1). Information for use consists of communication links, such as texts, words, signs, signals, symbols or diagrams, used separately or in combination to convey information to the user. It is directed to professional and/or non-professional users.

NOTE See also IEC 62079 for structuring and presentation of information for use.

6.1.1 Information shall be provided to the user about the intended use of the machine, taking into account, notably, all its operating modes.

It shall contain all directions required to ensure safe and correct use of the machine.

With this in view, it shall inform and warn the user about residual risk.

The information shall indicate:

- if training is needed;
- if personal protective equipment is needed;
- the possible need for additional guards or protective devices (see ISO 12100-1:2003, figure 1, note 4).

It shall not exclude uses of the machine that can reasonably be expected from its designation and description and shall also warn about the risk which would result from using the machine in other ways than the ones described in the information, especially considering its reasonably foreseeable misuse.

6.1.2 Information for use shall cover, separately or in combination, transport, assembly and installation, commissioning, use (setting, teaching / programming or process changeover, operation, cleaning, fault finding and maintenance) of the machine, and, if necessary, de-commissioning, dismantling and disposal.

6.2 Location and nature of the information for use

Depending on the risk, the time when the information is needed by the user and the machine design, it shall be decided whether the information – or parts thereof – are to be given:

- in/on the machine itself (see 6.3 and 6.4);
- in accompanying documents (in particular instruction handbook, see 6.5);
- on the packaging;
- by other means such as signals and warnings outside the machine.

Standardized phrases shall be considered where important messages such as warnings need to be given (see also IEC 62079).

6.3 Signals and warning devices

Visual signals (e.g. flashing lights) and audible signals (e.g. sirens) may be used to warn of an impending hazardous event such as machine start-up or overspeed.

Such signals may also be used to warn the operator before the triggering of automatic protective measures (see last paragraph of 5.2.7).

It is essential that these signals:

- are emitted before the occurrence of the hazardous event;
- are unambiguous;
- can be clearly perceived and differentiated from all other signals used;
- can be clearly recognized by the operator and other persons.

The warning devices shall be designed and located such that checking is easy. The information for use shall prescribe regular checking of warning devices.

The attention of designers is drawn to the risks from "sensorial saturation" which results from too many visual and/or acoustic signals, which may also lead to defeating the warning devices.

NOTE Consultation of the user on that subject is often necessary.

6.4 Markings, signs (pictograms), written warnings

Machinery shall bear all markings which are necessary:

a) for its unambiguous identification, at least:

- name and address of the manufacturer;
- designation of series or type;
- serial number, if any;

b) in order to indicate its compliance with mandatory requirements:

- marking;
- written indications (e.g. for machines intended for use in potentially explosive atmosphere);

c) for its safe use, e.g.:

- maximum speed of rotating parts;
- maximum diameter of tools;
- mass (expressed in kilograms) of the machine itself and/or of removable parts;
- maximum working load ;
- necessity of wearing personal protective equipment;
- guard adjustment data;
- frequency of inspection.

Information printed directly on the machine should be permanent and remain legible throughout the expected life of the machine.

Signs or written warnings only saying "danger" shall not be used.

Markings, signs and written warnings shall be readily understandable and unambiguous, especially as regards the part of the function(s) of the machine which they are related to. Readily understandable signs (pictograms) should be used in preference to written warnings.

Signs and pictograms should only be used if they are understood in the culture in which the machinery is to be used.

Written warnings shall be drawn up in the language(s) of the country in which the machine will be used for the first time and, on request, in the language(s) understood by operators.

NOTE In some countries the requirement to use specific language(s) is covered by legal requirements.

Markings shall comply with recognized standards (see ISO 2972, ISO 7000, particularly for pictograms, symbols, colours).

See IEC 60204 series as regards marking of electrical equipment.

6.5 Accompanying documents (In particular, instruction handbook)

6.5.1 Contents

The instruction handbook or other written instructions (e.g. on the packaging) shall contain among others:

- a) information relating to transport, handling and storage of the machine, e.g.:
 - storage conditions for the machine;
 - dimensions, mass value(s), position of the centre(s) of gravity;
 - indications for handling (e.g. drawings indicating application points for lifting equipment);
- b) information relating to installation and commissioning of the machine, e.g.:
 - fixing / anchoring and vibration dampening requirements;
 - assembly and mounting conditions;
 - space needed for use and maintenance;
 - permissible environmental conditions (e.g. temperature, moisture, vibration, electromagnetic radiation);
 - instructions for connecting the machine to power supply (particularly about protection against electrical overloading);
 - advice about waste removal / disposal;
 - if necessary, recommendations about protective measures which have to be taken by the user; e.g. additional safeguards (see ISO 12100-1:2003, figure 1, NOTE 4), safety distances, safety signs and signals;
- c) information relating to the machine itself, e.g.:
 - detailed description of the machine, its fittings, its guards and/or protective devices;
 - comprehensive range of applications for which the machine is intended, including prohibited usages, if any, taking into account variations of the original machine if appropriate;

- diagrams (especially schematic representation of safety functions);
 - data about noise and vibration generated by the machine, about radiation, gases, vapours, dust emitted by it, with reference to the measuring methods used;
 - technical documentation about electrical equipment (see IEC 60204 series);
 - documents attesting that the machine complies with mandatory requirements;
- d) information relating to the use of the machine, e.g. about:
- intended use;
 - description of manual controls (actuators);
 - setting and adjustment;
 - modes and means for stopping (especially emergency stop);
 - risks which could not be eliminated by the protective measures taken by the designer;
 - particular risks which may be generated by certain applications, by the use of certain fittings, and about specific safeguards which are necessary for such applications;
 - reasonably foreseeable misuse and prohibited usages;
 - fault identification and location, repair, and re-starting after an intervention;
 - personal protective equipment which need to be used and training required;
- e) information for maintenance, e.g.:
- nature and frequency of inspections for safety functions;
 - instructions relating to maintenance operations which require a definite technical knowledge or particular skills and hence should be carried out exclusively by skilled persons (e.g. maintenance staff, specialists);
 - instructions relating to maintenance actions (e.g. replacement of parts) which do not require specific skills and hence may be carried out by users (e.g. operators);
 - drawings and diagrams enabling maintenance personnel to carry out their task rationally (especially fault-finding tasks);
- f) information relating to de-commissioning, dismantling and disposal;
- g) information for emergency situations, e.g.:
- type of fire-fighting equipment to be used;
 - warning about possible emission or leakage of harmful substance(s), and if possible, indication of means to fight their effects;
- h) maintenance instructions provided for skilled persons (second dash in e)) and maintenance instructions provided for unskilled persons (third dash in e)), that should appear clearly separated from each other.

6.5.2 Production of the instruction handbook

- a) Type and size of print shall ensure the best possible legibility. Safety warnings and/or cautions should be emphasized by the use of colours, symbols and/or large print.
- b) Information for use shall be given in the language(s) of the country in which the machine will be used for the first time and in the original version. If more than one language are to be used, each language should be readily distinguished from the other(s), and efforts should be made to keep the translated text and the relevant illustration together.

NOTE In some countries the requirement to use specific language(s) is covered by legal requirements.

- c) Whenever helpful to the understanding, text should be supported by illustrations. Illustrations should be supplemented with written details enabling, for instance, manual controls (actuators) to be located and identified; they should not be separated from the accompanying text and should follow sequential operations.
- d) Consideration should be given to presenting information in tabular form where this will aid understanding. Tables should be adjacent to the relevant text.
- e) The use of colours should be considered, particularly in relation to components requiring quick identification.
- f) When information for use is lengthy, a table of contents and/or an index should be given.
- g) Safety-relevant instructions which involve immediate action should be provided in a form readily available to the operator.

6.5.3 Advice for drafting and editing information for use

- a) Relationship to model: the information shall clearly relate to the specific model of machine.
- b) Communication principles: when information for use is being prepared, the communication process "see – think – use" should be followed in order to achieve the maximum effect and should follow sequential operations. The questions "how?" and "why?" should be anticipated and the answers provided.
- c) Information for use shall be as simple and as brief as possible, and should be expressed in consistent terms and units with a clear explanation of unusual technical terms.
- d) When it is foreseen that a machine will be put to non-professional use, the instructions should be written in a form that is readily understood by the non-professional users. If personal protective equipment is required for the safe use of the machine, clear advice should be given, e.g. on the packaging as well as on the machine, so that this information is prominently displayed at the point of sale.
- e) Durability and availability of the documents: documents giving instructions for use should be produced in durable form (i.e. they should be able to survive frequent handling by the user). It may be useful to mark them "keep for future reference". Where information for use is kept in electronic form (e.g. CD, DVD, tape) information on safety-related issues that need immediate action shall always be backed up with a hard copy that is readily available.

Bibliography

- [1] CR 1030-1, *Hand-arm vibration – Guidelines for vibration hazards reduction – Part 1: Engineering methods by design of machinery*
- [2] EN 614-1, *Safety of machinery – Ergonomic design principles - Part 1: Terminology and general principles*
- [3] EN 894-3, *Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 3: Control actuators*
- [4] EN 1299, *Mechanical vibration and shock – Vibration isolation of machines – Information for the application of source isolation*
- [5] EN 12198-1, *Safety of machinery – Assessment and reduction of risks arising from radiation emitted by machinery – Part 1: General principles*
- [6] EN 12198-3, *Safety of machinery – Assessment and reduction of risks arising from radiation emitted by machinery – Part 3: Reduction of radiation by attenuation or screening*
- [7] EN 13861, *Safety of machinery - Guidance for the application of ergonomics standards in the design of machinery*
- [8] EN 50020, *Electrical apparatus for potentially explosive atmospheres – Intrinsic safety 'i'*
- [9] EN 61029, *Safety of transportable motor-operated electric tools*
- [10] IEC 60204 series, *Safety of machinery – Electrical equipment of machines*
- [11] IEC 60335-1, *Household and similar electrical appliances – Safety - Part 1: General requirements*
- [12] IEC 60745-1, *Hand-held motor operated tools – Safety – Part 1: General requirements (EN 50144-1)*
- [13] IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*
- [14] IEC 61000-6 series, *Electromagnetic compatibility (EMC) – Part 6: Generic standards*
- [15] IEC 61310-1, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, auditory and tactile signals*
- [16] IEC 61310-3:1999, *Safety of machinery – Indication, marking and actuation – Part 3: Requirements for the location and operation of actuators*
- [17] IEC 61496-1, *Safety of machinery – Electrosensitive protective equipment – Part 1: General requirements and tests*
- [18] IEC 61496-2, *Safety of machinery – Electro-sensitive protective equipment – Part 2: Particular requirements for equipment using active opto-electronic protective devices (EN 61496-2)*
- [19] IEC 61508 series, *Functional safety of electrical/electronic/programmable electronic safety-related systems*
- [20] IEC 62046 draft, *Safety of machinery – Application of personnel sensing protection equipment to machinery (PSPE)*

- [21] IEC 62061 draft, *Safety machinery – Functional safety of electrical, electronic and programmable control systems for machinery*
- [22] IEC 62079, *Preparation of instructions – Structuring, content and presentation*
- [23] ISO 447, *Machine tools – Direction of operation of controls*
- [24] ISO 2972, *Numerical control of machines – Symbols*
- [25] ISO 4413, *Hydraulic fluid power - General rules relating to systems*
- [26] ISO 4414, *Pneumatic fluid power – General rules relating to systems*
- [27] ISO 6385, *Ergonomic principles in the design of work systems*
- [28] ISO 7000, *Graphical symbols for use on equipment - Index and synopsis*
- [29] ISO 9355-1, *Ergonomic requirements for the design of displays and control actuators – Part 1: Human interactions with displays and control actuators*
- [30] ISO 10075, *Ergonomic principles related to mental work-load - General terms and definitions*
- [31] ISO 10075-2, *Ergonomic principles related to mental workload - Part 2: Design principles*
- [32] ISO/TR 11688-1, *Acoustics – Recommended practice for the design of low noise machinery and equipment - Part 1: Planning (EN ISO 11688-1)*
- [33] ISO 13849-1:1999, *Safety of machinery – Safety-related parts of control systems - Part 1: General principles for design (EN 954-1)*
- [34] ISO 13850, *Safety of machinery – Emergency stop – Principles for design design (EN 418:1992²⁾)*
- [35] ISO 13851, *Safety of machinery – Two-hand control devices – Functional aspects and design principles (EN 574)*
- [36] ISO 13852, *Safety of machinery – Safety distances to prevent danger zones being reached by the upper limbs (EN 294)*
- [37] ISO 13853, *Safety of machinery – Safety distances to prevent danger zones being reached by the lower limbs (EN 811)*
- [38] ISO 13854, *Safety of machinery – Minimum gaps to avoid crushing of parts of the human body (EN 349)*
- [39] ISO 13855, *Safety of machinery – Positioning of protective equipment with respect to the approach speeds of parts of the human body (EN 999)*
- [40] 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 (EN 1760-1)*
- [41] ISO 14118, *Safety of machinery – Prevention of unexpected start-up (EN 1037)*
- [42] ISO 14119, *Safety of machinery – Interlocking devices associated with guards - Principles for design and selection (EN 1088)*

2) The European standard and the International standard are not strictly identical.

- [43] ISO 14120:2002, *Safety of machinery – Guards - General requirements for the design and construction of fixed and movable guards* (EN 953)
- [44] ISO 14122-1, *Safety of machinery – Permanent means of access to machinery – Part 1: Choice of fixed means of access between two levels* (EN ISO 14122-1)
- [45] ISO 14122-2, *Safety of machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways* (EN ISO 14122-2)
- [46] ISO 14122-3, *Safety of machinery – Permanent means of access to machinery – Part 3: Stairs, stepadders and guard-rails* (EN ISO 14122-3)
- [47] ISO 14122-4, *Safety of machinery – Permanent means of access to machinery – Part 4: Fixed ladders* (prEN ISO 14122-4)
- [48] ISO 14123-1, *Safety of machinery – Reduction of risks to health from hazardous substances emitted by machinery - Part 1: Principles and specifications for machinery manufacturers* (EN 626-1)
- [49] ISO 14163, *Acoustics – Guidelines for noise control by silencers*
- [50] ISO 15667, *Acoustics – Guidelines for noise control by enclosures and cabins*

Annex ZA
(normative)

**Normative references to international publications
with their relevant European publications**

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE Where an International Publication has been modified by common modifications, indicated by (mod.), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN</u>	<u>Year</u>
ISO 12100-1	2003	Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology	EN ISO 12100-1	2003

Annex ZB
(informative)

Relationship of this document with EC Directives

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of EC Directive(s) :

Machinery Directive 98/37/EC, amended by Directive 98/79/EC.

Compliance with this document provides one means of conforming with the specific essential requirements of the Directive concerned and associated EFTA regulations.

WARNING: Other requirements and other EC Directives may be applicable to the product(s) falling within the scope of this document.

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