INTERNATIONAL STANDARD

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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;