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Safety of machinery — Emergency stop function — Principles for design

Sécurité des machines — Fonction d'arrêt d'urgence — Principes de conception

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 199, *Safety of machinery*.

This third edition cancels and replaces the second edition (ISO 13850:2006), which has been technically revised.

Introduction

The structure of safety standards in the field of machinery is as follows.

a) Type-A standards (basic safety standards) give basic concepts, principles for design, and general aspects that can be applied to machinery.

b) Type-B standards (generic safety standards) deal with one or more safety aspect(s) or one or more type(s) 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-hands controls, interlocking devices, pressure sensitive devices, guards).

c) Type-C standards (machinery safety standards) deal with detailed safety requirements for a particular machine or group of machines.

This International Standard is a type-B2 standard as stated in ISO 12100.

When provisions of a type-C standard are different from those which are stated in type-A or type-B standards, the provisions of the type-C standard take precedence.

Safety of machinery — Emergency stop function — Principles for design

1 Scope

This International Standard specifies functional requirements and design principles for the emergency stop function on machinery, independent of the type of energy used.

It does not deal with functions such as reversal or limitation of motion, deflection of emissions (e.g. radiation, fluids), shielding, braking or disconnecting, which can be part of the emergency stop function.

The requirements for this International Standard apply to all machines, with exception to:

— machines where an emergency stop would not reduce the risk;

— hand-held or hand-operated machines.

NOTE The requirements for the realization of the emergency stop function based on electrical/electronic technology are described in IEC 60204-1.

2 Normative references

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

ISO 4413, *Hydraulic fluid power — General rules and safety requirements for systems and their components*

ISO 4414, *Pneumatic fluid power — General rules and safety requirements for systems and their components*

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

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

IEC 60204-1:2005, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60947-5-5:2005, *Low-voltage switchgear and controlgear — Part 5-5: Control circuit devices and switching elements — Electrical emergency stop device with mechanical latching function*

IEC 62061, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

3 Terms and definitions

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

3.1
emergency stop (E-stop)
emergency stop function
function which is intended to

— avert arising or reduce existing hazards to persons, damage to machinery or to work in progress, and

— be initiated by a single human action

[SOURCE: ISO 12100:2010, 3.40]

3.2
emergency stop equipment
safety related parts of a control system which perform the emergency stop function

Note 1 to entry: Typically emergency stop equipment is divided into input, processing and output elements.

3.3
emergency stop device
manually actuated control device used to initiate an emergency stop function

[SOURCE: IEC 60947-5-5:2005, 3.2]

3.4
machine actuator
power mechanism of the machine used to effect motion

Note 1 to entry: Example of machine actuators are motor, solenoid, pneumatic or hydraulic cylinder.

3.5
safety function
function of a machine whose failure can result in an immediate increase of risk(s)

[SOURCE: ISO 12100:2010, 3.30]

3.6
span of control of emergency stop device(s)
predetermined section of the machinery under control of specific emergency stop device(s)

3.7
protective shroud
mechanical measure provided to reduce the possibility of unintended actuation of an emergency stop device

3.8
emergency situation
hazardous situation needing to be urgently ended or averted

Note 1 to entry: An emergency situation can arise during normal operation of the machine (for example due to human interaction or as a result of external influences) or as a consequence of a malfunction or failure of any part of the machine.

[SOURCE: ISO 12100:2010, 3.38, modified]

3.9
operator control station
assembly of one or more control actuators fixed on the same panel or located in the same enclosure

Note 1 to entry: Actuator is a part of a device to which an external manual action is to be applied (see IEC 60204-1:2005, 3.1).

[SOURCE: IEC 60204-1:2005, 3.13, modified.]

4 Safety requirements

4.1 General requirements

4.1.1 Emergency stop function

4.1.1.1 The purpose of the emergency stop function is to avert actual or impending emergency situations arising from the behaviour of persons or from an unexpected hazardous event.

The emergency stop function is to be initiated by a single human action.

4.1.1.2 The emergency stop function shall be available and operational at all times. It shall override all other functions and operations in all operating modes of the machine without impairing other protective functions (e.g. release of trapped persons, fire suppression).

When the emergency stop function is activated:

— it shall be maintained until it is manually reset;

— it shall not be possible for any start command to be effective on those operations stopped by the initiation of the emergency stop function.

The emergency stop function shall be reset by intentional human action. Resetting of the emergency stop function shall be operated by disengagement of an emergency stop device (see 4.1.4). The reset shall not initiate machine start up.

NOTE The emergency stop function cannot be considered as measure of prevention of unexpected start up as described in ISO 12100.

4.1.1.3 The emergency stop function is a complementary protective measure and shall not be applied as a substitute for safeguarding measures and other functions or safety functions.

4.1.1.4 The emergency stop function shall not impair the effectiveness of other safety functions.

NOTE For this purpose, it can be necessary to ensure the continuing operation of auxiliary equipment such as magnetic chucks or braking devices.

4.1.1.5 The emergency stop function shall be so designed, that after actuation of the emergency stop device, hazardous movements and operations of the machine are stopped in an appropriate manner, without creating additional hazards and without any further intervention.

NOTE An "appropriate manner" can include:

— choice of an optimal deceleration rate taking into account the necessary design restraints of the machine;

— selection of the stop category (see 4.1.3);

— necessity for a predetermined shutdown sequence.

Depending on the machine and the specific risks, the emergency stop function can initiate other functions other than stopping to minimize the risk of harm (e.g. reversal or limitation of motion, rate of braking) which can be part of the emergency stop function but not dealt with in this International Standard.

4.1.1.6 The emergency stop function shall be so designed that a decision to activate the emergency stop device does not require the consideration of the resultant effects.

4.1.2 Span of control of emergency stop device(s)

The span of control of each emergency stop device shall cover the whole machine. As an exception, a single span of control may not be appropriate when, for example, stopping all linked machinery could create additional hazards or unnecessarily affect production.

Each span of control can cover section(s) of a machine, an entire machine or a group of machines (see Figure 1).

Different spans of control may overlap.

The assignment of spans of control shall be determined taking into account the following:

a) the physical layout of the machine, based on the visible area of the machine;

b) the possibility to recognize hazardous situations (e.g. visibility, noise, odour);

c) any safety implications relating to the production process;

d) the foreseeable exposure to hazards;

e) the possible adjacent hazards.

4.1.2.1 More than one span of control can be applied, if the following requirements are met:

— the spans of control shall be clearly defined and identifiable;

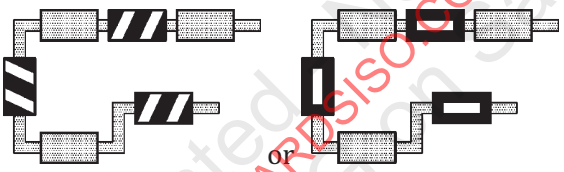
— emergency stop devices shall be readily associated with the hazard requiring an emergency stop;

— the span of control of an emergency stop device shall be identifiable at the operating position of each emergency stop device (see also 4.1.1.6).

NOTE The clear identification could be realized by pictogram or by the location itself. Reading text or instructions associated to the emergency stop device or requiring prior knowledge should be avoided.

EXAMPLE Such pictogram could be place next to an emergency stop device and would indicate the span of control of the device itself.

or  (span of control cover all sections of the entire machine)



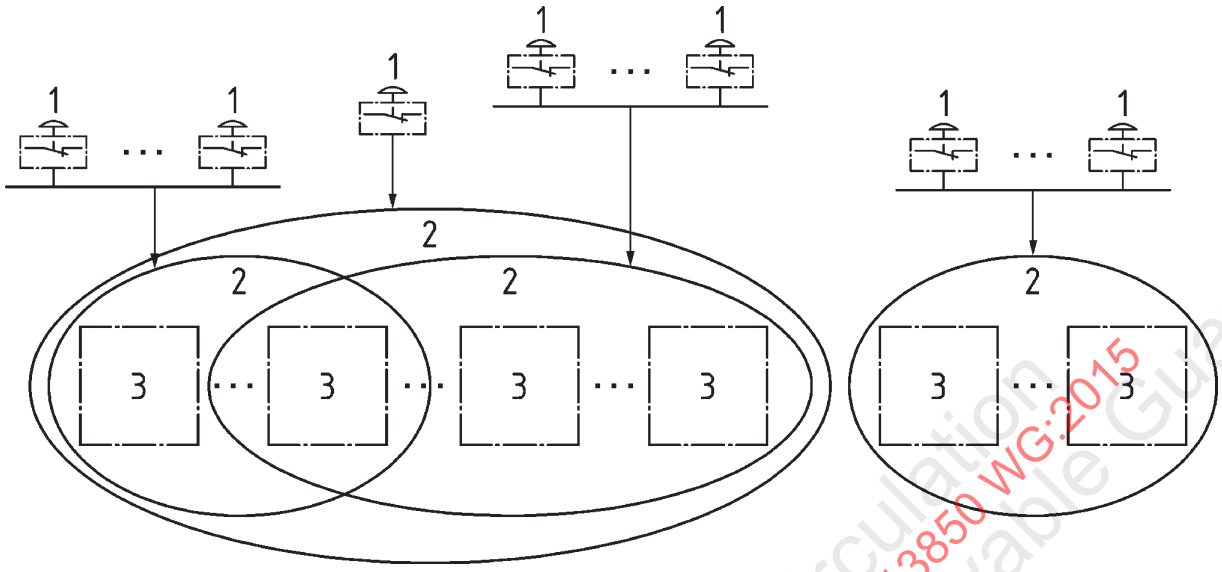
or (span of control of specific sections of the machine)

— actuation of an emergency stop device shall not create additional hazard(s) or increase the risk(s), in any span of control;

— actuation of an emergency stop device in one span of control shall not prevent the initiation of an emergency stop function in another span of control;

— information for use of the machine shall include information on the span of control of emergency stop device.

So far as practicable, emergency stop devices with different spans of control shall not be located near each other.



Key

1 emergency stop device
2 span of control
3 section of machine or machine

Figure 1 — Examples demonstrating the concept of span of control

4.1.3 Stop categories

The emergency stop shall function in accordance with either of the following stop categories (see also IEC 60204-1). The relevant stop category shall be selected by the risk assessment.

Stop category 0

Stopping by immediate removal of power to the machine actuators.

NOTE 1 Additional braking can be necessary.

Examples of stop category 0 are:

— switching off the electrical power to the electric motor(s) of the machine by electromechanical switching devices;

— mechanical disconnection (declutching) between the hazardous elements and their machine actuator(s);

— blocking the fluid power supply to the hydraulic/pneumatic machine actuators;

— removing the power needed to generate a torque or force in an electrical motor using the Safe torque off (STO) function of a power drive system in accordance with IEC 61800-5-2.

Stop category 1

Stopping movements and operations with power available to the machine actuators to achieve the stop and then removal of power when the stop is achieved.

Examples of stop category 1 are:

— deceleration of motion then removal of the electrical power to the motor(s) when motion has ceased by electromechanical switching devices;

— using the Safe stop 1 (SS1) function of a power drive system in accordance with IEC 61800-5-2.

NOTE 2 For removal of power, it can be sufficient to remove the power needed to generate a torque or force. This can be achieved by declutching, disconnecting, switching off, or by electronic means (e.g. a Power Drive System (PDS) in accordance with IEC 61800–5-2), without necessarily performing isolation.

4.1.4 Disengagement (e.g. unlatching) of the emergency stop device

The effect of an activated emergency stop device shall be sustained until the actuator of the emergency stop device has been disengaged. This disengagement shall only be possible by an intentional human action on the device where the command has been initiated. The disengagement of the device shall not restart the machinery but only permit restarting.

The instructions for use of the machine shall state that, after actuation and before disengaging the device(s), the machinery shall be inspected in order to detect the reason for actuation.

4.1.5 Emergency stop equipment

4.1.5.1 The safety related parts of the control system or subsystems which perform the emergency stop function shall comply with the relevant requirements of ISO 13849-1 and/or IEC 62061.

Determination of the Performance Level (PL) or SIL required should take into account the purpose of the emergency stop function, but the minimum required is PL_r c or SIL 1.

NOTE The emergency stop function can share safety related parts with other safety functions taking into account the requirements of ISO 13849-1 and/or IEC 62061.

4.1.5.2 Electrical equipment that implements the emergency stop function shall be in accordance with the relevant requirements of IEC 60204-1.

4.1.5.3 Hydraulic equipment that implements the emergency stop function shall be in accordance with the relevant requirements of ISO 4413 for design, construction and modification of systems and their components.

4.1.5.4 Pneumatic equipment that implements the emergency stop function shall be in accordance with the relevant requirements of ISO 4414 for design, construction and modification of systems and their components.

4.2 Operating conditions, environmental influences

The components, devices and elements used to achieve the emergency stop function shall be selected, assembled, interconnected, fixed and protected to operate correctly under the expected operating conditions and environmental influences, taking into account

— the frequency of operation and need for periodic testing, for example, in the case of infrequent operation, and

— the environmental constraints of, for example, vibration, shock, temperature, radiation (e.g. ultraviolet from the sun), rain, snow, freezing water, dust, foreign bodies, moisture, corrosive materials and fluids.

4.3 Emergency stop device

4.3.1 Emergency stop devices shall be designed to be easily identified and actuated by the operator and others who could need to actuate them. The actuator of the emergency stop device may be one of the following types:

a) pushbuttons easily activated by the palm of a hand;

b) wires, ropes, bars;

c) handles;

d) foot-pedals without a protective cover, where other solutions are not applicable.

NOTE For a supply disconnecting device to effect emergency stop, see IEC 60204–1.

4.3.2 An emergency stop device shall be located:

— at each operator control station, except where the risk assessment indicates that this is not necessary;

— at other locations, as determined by the risk assessment, e.g.:

  — at entrance and exit locations;

  — at locations where intervention to the machinery is needed, e.g. operations with a hold-to-run control function;

  — at all places where a man / machine interaction is expected by design (loading / unloading zone for example).

Emergency stop devices shall be positioned so that they are directly accessible and capable of non-hazardous actuation by the operator and others who could need to actuate them.

The actuator of emergency stop device intended to be actuated by hand should be mounted between 0,6 m and 1,7 m above the access level (e.g. floor level, platform level).

Foot-pedals should be mounted in a fixed position directly at access level (e.g. floor level).

4.3.3 An electrical emergency stop device shall apply the principle of direct opening action with mechanical latching. Electrical emergency stop devices shall be in accordance with IEC 60947-5-5.

NOTE An example of the application of the direct opening action principle is an emergency stop device employing electrical contacts that are opened by means of a direct rigid connection with the pushbutton. According to IEC 60947–5-1, direct opening action (of a contact element) is the achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (for example, not dependent upon springs).

4.3.4 Pneumatic or hydraulic emergency stop devices shall apply the principle of positive (direct) mechanical action (see ISO 12100:2010, 6.2.5) with mechanical latching.

NOTE Pneumatic and hydraulic systems typically actuate direct closing of a valve without relying on springs.

4.3.5 The actuation of the emergency stop device shall generate a stop command even if the emergency stop device actuator does not engage (latch).

4.3.6 The actuator of the emergency stop device shall be coloured RED. As far as a background exists behind the actuator and as far as it is practicable, the background shall be coloured YELLOW.

Emergency stop devices shall be designed and mounted in such a way that the actuation cannot be easily blocked by simple means.

NOTE This can happen when objects fall beneath the actuating surface or when there is an intention of defeating.

Emergency stop device requiring a key on the actuator to be disengaged (unlatched) should be avoided.

When an emergency stop actuator can only be disengaged by using a key, to avoid injuries to hands, instruction for use of the machine shall describe the correct use of the key and provide a warning that the key should only be in the actuator of the device to disengage the actuator.

4.3.7 Neither the actuator nor the background should be labelled with text or symbols. Where a symbol is needed for clarification, the symbol from IEC 60417-5638 shall be used, see Figure 2.

When it is necessary to identify the direction of unlatching of the actuator (button) then this identification shall have the same or nearly the same colour as the actuator (see also IEC 60947-5-5).

NOTE The identification of unlatching (i.e. arrows) could be misinterpreted as direction of actuation.

Figure 2 — Symbol IEC 60417-5638: Emergency stop

4.3.8 When emergency stop devices are installed on detachable or cableless operator control stations (e.g. pluggable portable teaching pendants), at least one emergency stop device shall be permanently available (e.g. in a fixed position) on the machine.

In addition, at least one of the following measures shall be applied to avoid confusion between active and inactive emergency stop devices:

— device colour changing through illumination of the active emergency stop device;

— automatic (self-actuating) covering of inactive emergency stop devices; where this is not practicable, manually-applied covering may be used, provided that the cover remains attached to the operator control stations;

— provision of proper storage for detached or cableless operator control stations.

The instructions for use of the machine shall state, which measure has been applied in order to avoid confusion between active or inactive emergency stop device(s). The correct operation of this measure shall be explained.

4.3.9 Where emergency stop devices are cableless or integrated into cableless operator control stations, the relevant requirements of IEC 60204-1 shall apply in addition to the requirements of this International Standard.

4.3.10 Measures against unintended actuation of an emergency stop device shall not create a risk of obstruction of the actuation or impair access to the emergency stop; such measures shall not impair the visibility of the emergency stop device or its actuator (see also 4.5).

4.4 Use of wires or ropes as actuators

4.4.1 When wires or ropes are used as the actuators of emergency stop devices, they shall be designed and positioned for ease of use. For this purpose, consideration shall be given to

— the amount of deflection necessary for generating the emergency stop command,

— the maximum deflection possible,

— the minimum clearance between the wire or the rope and the nearest object in the vicinity,

— making wires or ropes visible (e.g. by use of marker flags), and

— the force to be applied, and its direction in relation to the wire or rope, to actuate the emergency stop device.

