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Safety of machinery — Principles of risk assessment

Sécurité des machines — Principes pour l'appréciation du risque

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Contents

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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 3.

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.

International Standard ISO 14121 was prepared by the European Committee for Standardization (CEN) (as EN 1050:1996) and was adopted, under a special “fast-track procedure”, by Technical Committee ISO/TC 199, *Safety of machinery*, in parallel with its approval by the ISO member bodies.

Annexes A and B of this International Standard are for information only.

Introduction

This International Standard has been prepared to be a harmonized standard in the sense of the Machinery Directive of the European Union and associated regulations of the European Free Trade Association (EFTA).

The function of this Type A standard is to describe principles for a consistent systematic procedure for risk assessment as introduced in clause 6 of ISO/TR 12100-1:1992.

This International Standard gives guidance for decisions during the design of machinery (see 3.11 of ISO/TR 12100-1:1992) and will assist in the preparation of consistent and appropriate Type B and Type C standards in order to comply with the essential safety and health requirements (see annex A of EN 292-2:1991/A1:1995).

By itself this International Standard will not provide presumption of conformity to the essential safety and health requirements (see annex A of ISO/TR 12100-1:1992).

It is recommended that this International Standard be incorporated in training courses and manuals to give basic instruction on design methods.

Safety of machinery — Principles of risk assessment

1 Scope

This International Standard establishes general principles for the procedure known as risk assessment, by which the knowledge and experience of the design, use, incidents, accidents and harm related to machinery is brought together in order to assess the risks during all phases of the life of the machinery [see 3.11 a) of ISO/TR 12100-1:1992].

This International Standard gives guidance on the information required to allow risk assessment to be carried out. Procedures are described for identifying hazards and estimating and evaluating risk. The purpose of the International Standard is to provide advice for decisions to be made on the safety of machinery and the type of documentation required to verify the risk assessment carried out.

This International Standard is not intended to provide a detailed account of methods for analysing hazards and estimating risk, as this is dealt with elsewhere (e.g. text books and other reference documents). A summary of some of these methods is given for information only (see annex B).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/TR 12100-1:1992, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology.*

ISO/TR 12100-2:1992, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles and specifications.*

IEC 60204-1:1992, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements.*

EN 292-2:1991/A1:1995, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles and specifications.*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO/TR 12100-1:1992 and the following apply.

3.1
harm
physical injury and/or damage to health or property

[ISO/IEC Guide 51:1990, 3.4]

3.2
hazardous event
event that can cause harm

3.3
safety measure
means that eliminates a hazard or reduces a risk

NOTE For additional information see clause 5 of ISO/TC 12100-1:1992.

3.4
residual risk
risk remaining after safety measures have been taken

4 General principles

4.1 Basic concept

Risk assessment is a series of logical steps to enable, in a systematic way, the examination of the hazards associated with machinery. Risk assessment is followed, whenever necessary, by risk reduction as described in clause 5 of ISO/TR 12100-1:1992. When this process is repeated it gives the iterative process for eliminating hazards as far as possible and for implementing safety measures.

Risk assessment includes (see Figure 1):

— risk analysis

  1) determination of the limits of the machinery (see clause 5);

  2) hazard identification (see clause 6);

  3) risk estimation (see clause 7);

— risk evaluation (see clause 8).

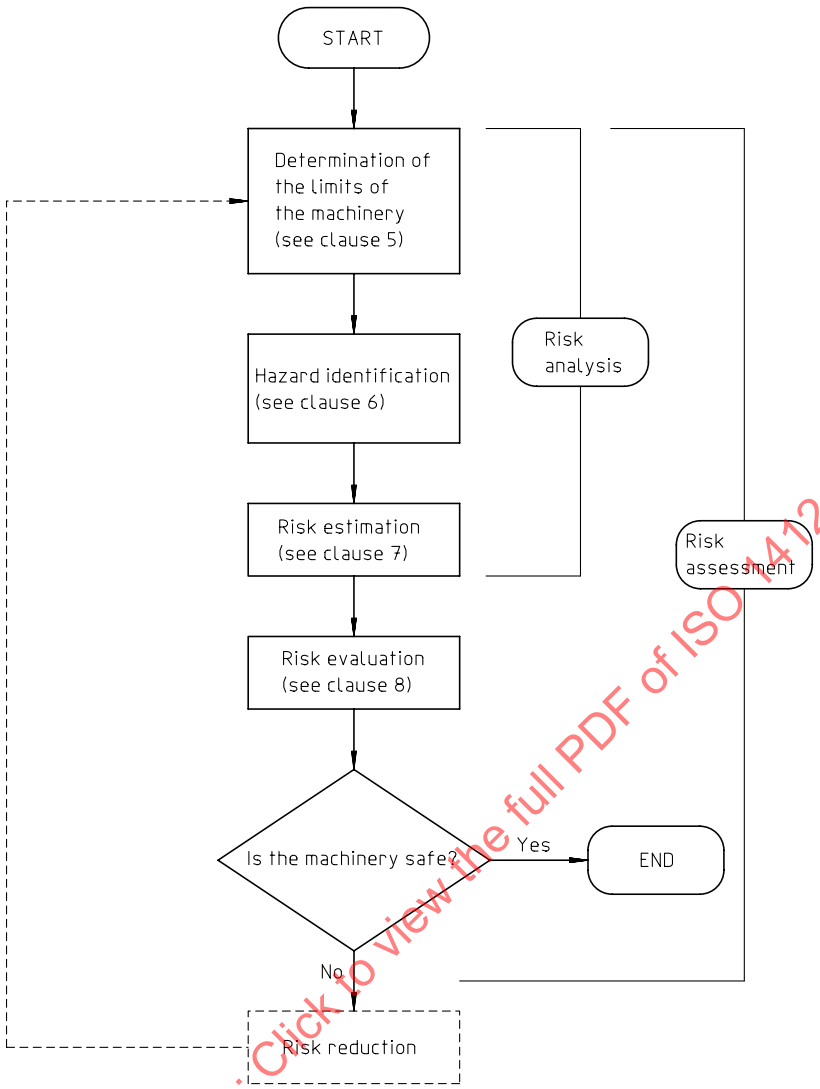
Risk analysis provides the information required for the risk evaluation, which in turn allows judgements to be made on the safety of machinery (see 3.4 of ISO/TR 12100-1:1992).

Risk assessment relies on judgemental decisions. These decisions shall be supported by qualitative methods complemented, as far as possible, by quantitative methods. Quantitative methods are particularly appropriate when the foreseeable severity and extent of harm are high.

Quantitative methods are useful to assess alternative safety measures and to determine which gives better protection.

NOTE The application of quantitative methods is restricted by the amount of useful data which is available, and in many applications only qualitative risk assessment will be possible.

The risk assessment shall be conducted so that it is possible to document the procedure which has been followed and the results which have been achieved (see clause 9).



NOTE Risk reduction and the selection of appropriate safety measures are not part of risk assessment. For further explanation, see clause 5 of ISO/TR 12100-1:1992 and ISO/TR 12100-2.

Figure 1 — The iterative process to achieve safety

4.2 Information for risk assessment

The information for risk assessment and any qualitative and quantitative analysis shall include the following as appropriate:

— limits of the machinery (see clause 5);

— requirements for the life phases of the machinery [see 3.11 a) of ISO/TR 12100-1:1992];

— design drawings or other means of establishing the nature of the machinery;

— information concerning power supply;

— any accident and incident history;

— any information about damage to health.

The information shall be updated as the design develops and when modifications are required.

Comparisons between similar hazardous situations associated with different types of machinery are often possible, provided that sufficient information about hazards and accident circumstances in those situations is available.

The absence of an accident history, a small number of accidents or low severity of accidents shall not be taken as an automatic presumption of a low risk.

For quantitative analysis, data from databases, handbooks, laboratories and manufacturers' specifications may be used provided that there is confidence in the suitability of the data. Uncertaintly associated with this data shall be indicated in the documentation (see clause 9).

Data based on the consensus of expert opinion derived from experience (e.g. DELPHI Technique — see B.8) can be used to supplement qualitative data.

5 Determination of the limits of the machinery

Risk assessment shall take into account:

— the phases of machinery life (see 3.11a of ISO/TR 12100-1:1992);

— the limits of machinery (see 5.1 of ISO/TR 12100-1:1992) including the intended use (both the correct use and operation of the machinery as well as the consequences of reasonably foreseeable misuse or malfunction) in accordance with 3.12 of ISO/TR 12100-1:1992;

— the full range of foreseeable uses of the machinery (e.g. industrial, non-industrial and domestic) by persons identified by sex, age, dominant-hand usage, or limiting physical abilities (e.g. visual or hearing impairment, size, strength);

— the anticipated level of training, experience or ability of the foreseeable users such as:

  1) operators (including maintenance personnel or technicians);

  2) trainees and juniors;

  3) general public;

— exposure of other persons to the hazards associated with the machinery, where it can be reasonably foreseen.

6 Hazard identification

All hazards, hazardous situations and hazardous events associated with the machinery shall be identified. Annex A gives examples to assist in this process (see clause 4 of ISO/TR 12100-1:1992, for further information on describing hazards generated by machinery).

Several methods are available for the systematic analysis of hazards. Examples are given in annex B.

7 Risk estimation

7.1 General

After hazard identification (see clause 6), risk estimation shall be carried out for each hazard by determining the elements of risk given in 7.2. When determining these elements, it is necessary to take into account the aspects given in 7.3.

7.2 Elements of risk

7.2.1 Combination of elements of risk

The risk associated with a particular situation or technical process is derived from a combination of the following elements:

— the severity of harm;

— the probability of occurrence of that harm, which is a function of:

1) the frequency and duration of the exposure of persons to the hazard;

2) the probability of occurence of a hazardous event;

3) the technical and human possibilities to avoid or limit the harm (e.g. reduced speed, emergency stop equipment, enabling device, awareness of risks).

The elements are shown in Figure 2 and additional details are given in 7.2.2 and 7.2.3

Several methods are available for the systematic analysis of these elements. Examples are given in annex B.

NOTE In many cases these elements cannot be exactly determined, but can only be estimated. This applies especially to the probability of occurrence of possible harm. The severity of possible harm cannot be easily established in some cases (e.g. in the case of damage to health due to toxic substances or stress).

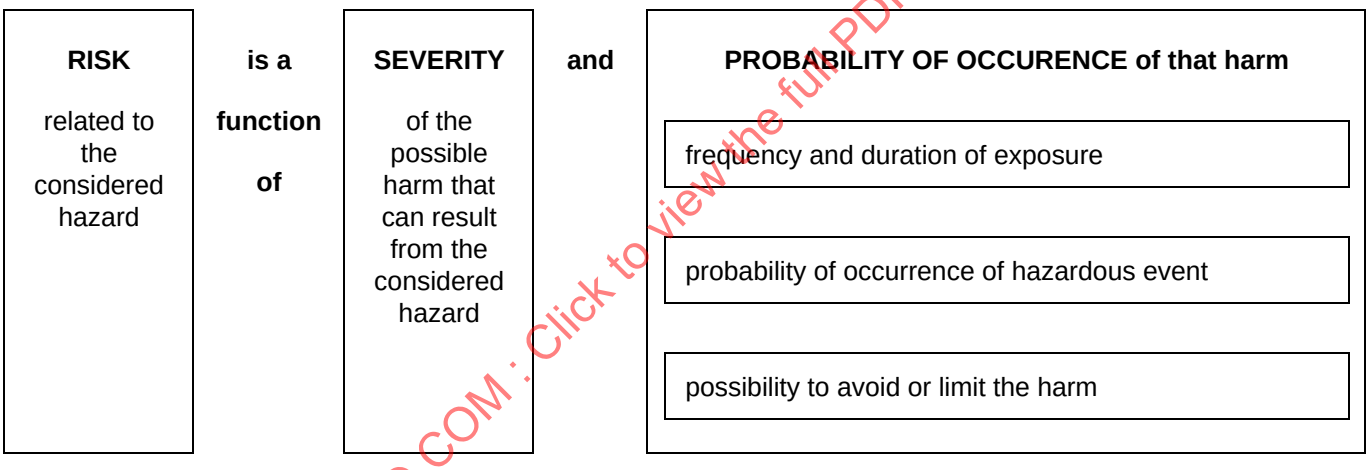


Figure 2 — Elements of risk

7.2.2 Severity (degree of possible harm)

The severity can be estimated by taking into account:

— the nature of what is to be protected:

1) persons;

2) property;

3) environment;

— the severity of injuries or damage to health:

1) slight (normally reversible);

2) serious (normally irreversible);

3) death;

— the extent of harm (for each machine):

1) one person;

2) several persons.

7.2.3 Probability of occurrence of harm

The probability of occurrence of harm can be estimated by taking into account 7.2.3.1 to 7.2.3.3.

7.2.3.1 Frequency and duration of exposure

— Need for access to the danger zone (e.g. for normal operation, maintenance or repair);

— nature of access (e.g. manual feed of materials);

— time spent in the danger zone;

— number of persons requiring access;

— frequency of access.

7.2.3.2 Probability of occurrence of a hazardous event

— Reliability and other statistical data;

— accident history;

— history of damage to health;

— risk comparison (see 8.3).

NOTE The occurrence of a hazardous event can be of technical or human origin.

7.2.3.3 Possibilities of avoiding or limiting harm

a) by whom the machinery is operated:
   1) by skilled persons;
   2) by unskilled persons;
   3) unmanned;
b) the speed of appearance of the hazardous event:
   1) suddenly;
   2) fast;
   3) slow;
c) any awareness of risk:
   1) by general information;
   2) by direct observation;
   3) through warning signs and indicating devices;
d) the human possibility of avoidance or limiting harm (e.g. reflex, agility, possibility of escape):
   1) possible;
   2) possible under certain conditions;
   3) impossible;
e) by practical experience and knowledge:
   1) of the machinery;
   2) of similar machinery;
   3) no experience.

7.3 Aspects to be considered when establishing elements of risk

7.3.1 Persons exposed

Risk estimation shall take into account all persons exposed to the hazards. This includes operators (see 3.21 of ISO/TR 12100-1:1992) and other persons for whom it is reasonably foreseeable that they could be affected by the machinery.

7.3.2 Type, frequency and duration of exposure

The estimation of the exposure to the hazard under consideration (including long-term damage to health) requires analysis of, and shall account for, all modes of operation of the machinery and methods of working. In particular this affects the need for access during setting, teaching, process changeover or correction, cleaning, fault-finding and maintenance (see 3.11 of ISO/TR 12100-1:1992).

The risk estimation shall account for situations when it is necessary to suspend safety functions (e.g. during maintenance).

7.3.3 Relationship between exposure and effects

The relationship between an exposure to a hazard and its effects shall be taken into account. The effects of accumulated exposure and synergistic effects shall also be considered. Risk estimation when considering these effects shall, as far as practicable, be based on appropriate recognized data.

NOTE Accident data may be available to indicate the probability and severity of injury associated with the use of a particular type of machinery with a particular type of safety measure.

7.3.4 Human factors

Human factors can affect risk and shall be taken into account in the risk estimation. This includes, for example:

— interaction of persons with the machinery;

— interaction between persons;

— psychological aspects;

— ergonomic effects;

— capacity of persons to be aware of risks in a given situation depending on their training, experience and ability.

The estimation of the ability of exposed persons shall take into account the following aspects:

— application of ergonomic principles in the design of the machinery;

— natural or developed ability to execute the required tasks;

— awareness of risks;

— level of confidence in carrying out the required tasks without intentional or unintentional deviation;

— temptations to deviate from prescribed and necessary safe working practices.

Training, experience and ability can affect the risk, but none of these factors shall be used as a substitute for hazard elimination, risk reduction by design or safeguarding where these safety measures can be implemented.

7.3.5 Reliability of safety functions

Risk estimation shall take account of the reliability of components and systems. It shall:

— identify the circumstances which can result in harm (e.g. component failure, power failure, electrical disturbances);

— when appropriate use quantitative methods to compare alternative safety measures;

— provide information to allow the selection of appropriate safety functions, components and devices.

Those components and systems identified as providing safety-critical functions (see 3.13.1 of ISO/TR 12100-1:1992) need special attention.

When more than one safety-related device contributes toward a safety function, the selection of these devices shall be consistent when considering their reliability and their performance.

When safety measures include work organization, correct behaviour, attention, application of personal protective equipment, skill or training, the relatively low reliability of such measures as compared to proven technical safety measures shall be taken into account in the risk estimation.

7.3.6 Possibility to defeat or circumvent safety measures

Risk estimation shall take account of the possibility to defeat or circumvent safety measures. The estimation shall also take account of the incentive to defeat or circumvent safety measures, for example:

— the safety measure slows down production, or interferes with any other activities or preferences of the user;

— the safety measure is difficult to use;

— persons other than the operator are involved;

— the safety measure is not recognized by the user or is not accepted as suitable for its function.

The possibility to defeat a safety measure depends on both the type of safety measure (e.g. adjustable guard, programmable trip device) and its design details.

The use of programmable electronic systems introduces an additonal possibility of defeat or circumvention if access to safety-related software is not properly designed and monitored. Risk estimation shall identify where safety-related functions are not separated from other machine functions, and shall determine the extent to which access is possible. This is particularly important when remote access for diagnostic or process correction purposes is required (see 12.3.5 of IEC 60204-1:1992).

7.3.7 Ability to maintain safety measures

Risk estimation shall consider whether the safety measures can be maintained in the condition necessary to provide the required level of protection.

NOTE If the safety measure cannot easily be maintained in correct working order, this may encourage the defeat or circumvention of the safety measure to allow continued use of the machinery.

7.3.8 Information for use

Risk estimation shall take account of the proper implementation of clause 5 of ISO/TR 12100-2:1992 for the information for use to be supplied with the machinery.

8 Risk evaluation

8.1 General

After risk estimation, risk evaluation shall be carried out to determine if risk reduction is required or whether safety has been achieved. If risk reduction is required, then appropriate safety measures shall be selected and applied, and the procedure repeated (see figure 1). During this iterative process, it is important for the designer to check whether additional hazards are created when new safety measures are applied. If additional hazards do occur, they shall be added to the list of identified hazards.

The achievement of the risk reduction objectives (see 8.2) and a favourable outcome of risk comparison (see 8.3) give confidence that the machinery is safe (see 3.4 of ISO/TR 12100-1:1992).

8.2 Achievement of risk reduction objectives

Achievement of the following conditions will indicate that the risk reduction process can be concluded.

a) The hazard has been eliminated or the risk reduced by:
   1) design or by the substitution for less hazardous materials and substances;
   2) safeguarding.

b) The safeguarding selected is of a type which, by experience, provides a safe situation for the intended use.

c) The type of safeguarding selected is appropriate for the application in terms of:
   1) probability of defeat or circumvention;
   2) severity of harm;
   3) hindrance to the execution of the required task.

d) The information on the intended use of the machinery is sufficiently clear.

e) The operating procedures for the use of the machinery are consistent with the ability of personnel who use the machinery or other persons who can be exposed to the hazards associated with the machinery.

f) The recommended safe working practices for the use of the machinery and the related training requirements have been adequately described.

g) The user is sufficiently informed about the residual risks in the different phases of the life of the machinery.

h) If personal protective equipment is recommended, the need for such equipment and the training requirements for its use have been adequately described.

i) Additional precautions are sufficient (see clause 6 of ISO/TR 12100-2:1992).

8.3 Comparison of risks

As part of the process of risk evaluation, the risks associated with the machinery can be compared with those of similar machinery provided the following criteria apply:

— the similar machinery is safe;

— the intended use and the way both machines are made are comparable;

— the hazards and the elements of risk are comparable;

— the technical specifications are comparable;

— the conditions for use are comparable.

The use of this comparison method does not eliminate the need to follow the risk assessment process as described in this International Standard for the specific conditions of use. For example, when a band saw used for cutting meat is compared with a band saw used for cutting wood, the risks associated with the different materials shall be assessed.

9 Documentation

For the purpose of this International Standard, documentation on risk assessment shall demonstrate the procedure which has been followed and the results which have been achieved. This documentation includes, when relevant:

a) the machinery for which the assessment has been made (e.g. specifications, limits, intended use);

b) any relevant assumptions which have been made (e.g. loads, strengths, safety factors);

c) the hazards identified;

- the hazardous situations identified;
- the hazardous events considered in the assessment;

d) the information on which risk assessment was based (see 4.2);

- the data used and the sources (e.g. accident histories, experiences gained from risk reduction applied to similar machinery);
- the uncertainty associated with the data used and its impact on the risk assessment;

e) the objectives to be achieved by safety measures;

f) the safety measures implemented to eliminate identified hazards or to reduce risk (e.g. from standards or other specifications);

g) residual risks associated with the machinery;

h) the result of the final risk evaluation (see Figure 1).

Annex A
(informative)

Examples of hazards, hazardous situations and hazardous events

Table A.1

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/TR 12100 Part 1: 1992	ISO/TR 12100 Part 2: 1992
Hazards, hazardous situations and hazardous events				
1	**Mechanical hazards** due to: — machine parts or workpieces, e.g.: a) shape; b) relative location; c) mass and stability (potential energy of elements which may move under the effect of gravity); d) mass and velocity (kinetic energy of elements in controlled or uncontrolled motion); e) inadequacy of mechanical strength.	1.3	4.2	3.1, 3.2, 4
	— accumulation of energy inside the machinery, e.g.: f) elastic elements (springs); g) liquids and gases under pressure; h) the effect of vacuum.	1.5.3, 1.6.3	4.2	3.8, 6.2.2
1.1	Crushing hazard	1.3	4.2.1	
1.2	Shearing hazard			
1.3	Cutting or severing hazard			
1.4	Entanglement hazard			
1.5	Drawing-in or trapping hazard			
1.6	Impact hazard			
1.7	Stabbing or puncture hazard			
1.8	Friction or abrasion hazard			
1.9	High pressure fluid injection or ejection hazard	1.3.2	4.2.1	3.8
2	**Electrical hazards** due to:			
2.1	contact of persons with live parts (direct contact)	1.5.1,1.6.3	4.3	3.9, 6.2.2
2.2	contact of persons with parts which have become live under faulty conditions (indirect contact)	1.5.1	4.3	3.9
2.3	approach to live parts under high voltage	1.5.1, 1.6.3	4.3	3.9, 6.2.2
2.4	electrostatic phenomena	1.5.2	4.3	3.9
2.5	thermal radiation or other phenomena such as the projection of molten particles and chemical effects from short circuits, overloads, etc.	1.5.1, 1.5.5	4.3	3.9
3	**Thermal hazards,** resulting in:			
3.1	burns, scalds and other injuries by a possible contact of persons with objects or materials with an extreme high or low temperature, by flames or explosions and also by the radiation of heat sources	1.5.5,1.5.6, 1.5.7	4.4	
3.2	damage to health by hot or cold working environment	1.5.5	4.4	

Table A.1 *(continued)*

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/TR 12100 Part 1: 1992	ISO/TR 12100 Part 2: 1992
4	**Hazards generated by noise**, resulting in:			
4.1	hearing loss (deafness), other physiological disorders (e.g. loss of balance, loss of awareness)	1.5.8	4.5	3.2, 4
4.2	interference with speech communication, acoustic signals, etc.			
5	**Hazards generated by vibration**			
5.1	Use of hand-held machines resulting in a variety of neurological and vascular disorders	1.5.9	4.6	3.2
5.2	Whole-body vibration, particularly when combined with poor posture			
6	**Hazards generated by radiation**			
6.1	Low-frequency, radio-frequency radiation; microwaves	1.5.10	4.7	
6.2	Infrared, visible and ultraviolet radiation			
6.3	X- and gamma rays			
6.4	Alpha, beta rays, electron or ion beams, neutrons	1.5.10, 1.5.11	4.7	3.7.3, 3.7.11
6.5	Lasers	1.5.12	4.7	
7	**Hazards generated by materials and substances** (and their constituent elements) processed or used by the machinery			
7.1	Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes, and dusts	1.1.3, 1.5.13, 1.6.5	4.8	3.3 b), 3.4
7.2	Fire or explosion hazard	1.5.6, 1.5.7	4.8	3.4
7.3	Biological or microbiological (viral or bacterial) hazards	1.1.3, 1.6.5, 2.1	4.8	
8	**Hazards generated by neglecting ergonomic principles in machinery design,** as e.g. hazards from:			
8.1	unhealthy postures or excessive effort	1.1.2 d), 1.1.5, 1.6.2, 1.6.4	4.9	3.6.1, 6.2.1, 6.2.3, 6.2.4, 6.2.6
8.2	inadequate consideration of hand-arm or foot-leg anatomy	1.1.2 d), 2.2	4.9	3.6.2
8.3	neglected use of personal protection equipment	1.1.2 e)		3.6.6
8.4	inadequate local lighting	1.1.4		3.6.5
8.5	mental overload and underload, stress	1.1.2 d)	4.9	3.6.4
8.6	human error, human behavior	1.1.2 d), 1.2.2, 1.2.5, 1.2.8, 1.5.4, 1.7	4.9	3.6, 3.7.8, 3.7.9, 5, 6.1.1
8.7	inadequate design, location or identification of manual controls	1.2.2		3.6.6, 3.7.8
8.8	inadequate design or location of visual display units	1.7.1		3.6.7, 5.2

Table A.1 *(continued)*

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/TR 12100 Part 1: 1992	ISO/TR 12100 Part 2: 1992
9	**Combination of hazards**		4.10	
10	**Unexpected start-up, unexpected overrun/ overspeed** (or any similar malfunction) from:			
10.1	failure/disorder of the control system	1.2.7, 1.6.3		3.7, 6.2.2
10.2	restoration of energy supply after an interruption	1.2.6		3.7.2
10.3	external influences on electrical equipment	1.2.1, 1.5.11, 4.1.2.8		3.7.11
10.4	other external influences (gravity, wind, etc.)	1.2.1		3.7.3
10.5	errors in the software	1.2.1		3.7.7
10.6	errors made by the operator (due to mismatch of machinery with human characteristics and abilities, see 8.6)	1.1.2 d), 1.2.2, 1.2.5, 1.2.8, 1.5.4, 1.7	4.9	3.6, 3.7.8, 3.7.9, 5, 6.1.1
11	**Impossibility of stopping the machine in the best possible conditions**	1.2.4, 1.2.6, 1.2.7		3.7, 3.7.1, 6.1.1
12	**Variations in the rotational speed of tools**	1.3.6		3.2, 3.3
13	**Failure of the power supply**	1.2.6		3.7, 3.7.2
14	**Failure of the control circuit**	1.2.1, 1.2.3, 1.2.4, 1.2.5, 1.2.7, 1.6.3		3.7, 6.2.2
15	**Errors of fitting**	1.5.4	4.9	5.5, 6.2.1
16	**Break-up during operation**	1.3.2	4.2.2	3.3
17	**Falling or ejected objects or fluids**	1.3.3	4.2.2	3.3, 3.8
18	**Loss of stability / overturning of machinery**	1.3.1	4.2.2	6.2.5
19	**Slip, trip and fall of persons** (related to machinery)	1.5.15	4.2.3	6.2.4
Additonal hazards, hazardous situations and hazardous events due to mobility				
20	**Relating to the travelling function**			
20.1	Movement when starting the engine	3.3.2, 3.3.4		
20.2	Movement without a driver at the driving position	3.3.2		
20.3	Movement without all parts in a safe position	3.3.2		
20.4	Excessive speed of pedestrian-controlled machinery	3.3.4		
20.5	Excessive oscillations when moving	3.4.1		
20.6	Insufficient ability of machinery to be slowed down, stopped and immobilized	3.3.3, 3.3.5		
21	**Linked to the work position** (including driving station) on the machine			
21.1	Fall of persons during access to (or at/from) the work position	3.2.1, 3.2.3, 3.4.5, 3.4.7		
21.2	Exhaust gases/lack of oxygen at the work position	3.2.1		
21.3	Fire (flammability of the cab, lack of extinguishing means)	3.2.1, 3.5.2		

Table A.1 *(continued)*

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/TR 12100 Part 1: 1992	ISO/TR 12100 Part 2: 1992
21.4	Mechanical hazards at the work position: a) contact with the wheels; b) rollover; c) fall of objects, penetration by objects; d) break-up of parts rotating at high speed; e) contact of persons with machine parts or tools (pedestrian controlled machines).	 3.2.1 3.2.1, 3.4.3 3.2.1, 3.4.4 3.4.2 3.3.4		
21.5	Insufficient visibility from the work positions	3.2.1		
21.6	Inadequate lighting	3.1.2		
21.7	Inadequate seating	3.2.2		
21.8	Noise at the work position	3.2.1		
21.9	Vibration at the work position	3.2.1, 3.2.2, 3.6.3		
21.10	Insufficient means for evacuation/emergency exit	3.2.1		
22	**Due to the control system**			
22.1	Inadequate location of manual controls	3.2.1, 3.3.1, 3.4.5		
22.2	Inadequate design of manual controls and their mode of operation	3.2.1, 3.3.1, 3.3.3		
23	**From handling the machine** (lack of stability)	3.1.3		
24	**Due to the power source and to the transmission of power**			
24.1	Hazards from the engine and the batteries	3.4.8, 3.5.1		
24.2	Hazards from transmission of power between machines	3.4.7		
24.3	Hazards from coupling and towing	3.4.6		
25	**From/to third persons**			
25.1	Unauthorized start-up/use	3.3.2		
25.2	Drift of a part away from its stopping position	3.4.1		
25.3	Lack or inadequacy of visual or acoustic warning means	1.7.4, 3.6.1		
26	**Insufficient instructions for the driver/operator**	3.6		
Additional hazards, hazardous situations and hazardous events due to lifting				
27	**Mechanical hazards and hazardous events**			
27.1	from load falls, collisions, machine tipping caused by:			
27.1.1	lack of stability	4.1.2.1		
27.1.2	uncontrolled loading — overloading — overturning moments exceeded	4.2.1.4, 4.3.3, 4.4.2 a)		
27.1.3	uncontrolled amplitude of movements	4.1.2.6 a), 4.2.1.3		
27.1.4	unexpected/unintended movement of loads	4.1.2.6 c)		
27.1.5	inadequate holding devices/accessories	4.1.2.6 e), 4.4.1		

Table A.1 *(concluded)*

No.	Hazards	Annex A of EN 292-2:1991/A1:1995	ISO/TR 12100 Part 1: 1992	ISO/TR 12100 Part 2: 1992
27.1.6	collision of more than one machine	4.1.2.6 b)		
27.2	from access of persons to load support	4.3.3		
27.3	from derailment	4.1.2.2		
27.4	from insufficient mechanical strength of parts	4.1.2.3		
27.5	from inadequate design of pulleys, drums	4.1.2.4		
27.6	from inadequate selection of chains, ropes, lifting and accessories and their inadequate integration into the machine	4.1.2.4, 4.1.2.5, 4.3.1, 4.3.2		
27.7	from lowering of the load under the control of friction brake	4.1.2.6 d)		
27.8	from abnormal conditions of assembly/testing/use/maintenance	4.4.1, 4.4.2 d)		
27.9	from the effect of load on persons (impact by load or counterweight)	4.1.2.6 b), 4.1.2.7, 4.2.3		
28	**Electrical hazards**			
28.1	from lightning	4.1.2.8		
29	**Hazards generated by neglecting ergonomic principles**			
29.1	insufficient visiblity from the driving position	4.1.2.7, 4.4.2 c)		
Additional hazards, hazardous situations and hazardous events due to underground work				
30	**Mechanical hazards and hazardous events** due to:			
30.1	lack of stability of powered roof supports	5.1		
30.2	failure of accelerator or brake control of machinery running on rails	5.4		
30.3	failure or lack of deadman's control of machinery running on rails	5.4, 5.5		
31	**Restricted movement of persons**	5.2		
32	**Fire and explosion**	5.6		
33	**Emission of dust, gases etc.**	5.7		
Additional hazards, hazardous situations and hazardous events due to the lifting or moving of persons				
34	**Mechanical hazards and hazardous events** due to:			
34.1	inadequate mechanical strength; inadequate working coefficients	6.1.2		
34.2	failure of loading control	6.1.3		
34.3	failure of controls in personnel carrier (function, priority)	6.2.1		
34.4	overspeed of personnel carrier	6.2.3		
35	**Falling of person from personnel carrier**	1.5.15, 6.3.1, 6.3.2, 6.3.3,		
36	**Falling or overturning of personnel carrier**	6.4.1, 6.4.2		
37	**Human error, human behaviour**	6.5		