TECHNICAL REPORT

ISO/TR 22100-3

First edition
2016-10-01

Safety of machinery — Relationship with ISO 12100 —

Part 3: Implementation of ergonomic principles in safety standards

Sécurité des machines — Relation avec l'ISO 12100 —

Partie 3: Mise en oeuvre des principes ergonomiques dans les normes de sécurité

Reference number
ISO/TR 22100-3:2016(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html

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

ISO/TR 22100 consists of the following parts, under the general title *Safety of machinery — Relationship with ISO 12100*:

— *Part 1: How ISO 12100 relates to type-B and type-C standards*

— *Part 2: How ISO 12100 relates to ISO 13849-1*

— *Part 3: Implementation of ergonomic principles in safety standards*

Introduction

The primary purpose of this document is to provide designers with an overall framework and guidance for decisions about ergonomic aspects during the development of machinery, to help them design machines that are safe for their intended use. As mentioned in ISO 12100:2010, 6.2.8, failure to follow ergonomic principles in design can result in the inadequate adaptation of machines to the capacities and skills of the intended user population and hence place their health or safety at risk.

ISO 12100 describes an iterative process to reduce risks. This document describes the main ergonomic factors influencing the safety of machinery and gives a framework for incorporating them into this design process.

Mental (cognitive) aspects are also to be considered. For example, machines which are operated in an inappropriate manner or whose control devices are not clearly identifiable can lead to human error.

This document is intended to guide users to make effective use of ergonomics standards within the context of machinery design.

This document will help both ergonomics and machinery standards writers to incorporate the structure specified in ISO Guide 78.

Safety of machinery — Relationship with ISO 12100 —

Part 3: Implementation of ergonomic principles in safety standards

1 Scope

This document describes the main ergonomic risk factors influencing the safety of machinery and gives a framework for incorporating them into the design of machines by the integration of important ergonomic principles relating to:

— avoiding stressful postures and movements during use of the machine;

— designing machines, and more especially hand-held and mobile machines, which can be operated easily;

— avoiding as far as possible noise, vibration, thermal effects;

NOTE 1 The health effects of noise, vibration and adverse thermal conditions are well-known and are not addressed here. However environmental factors can interact with machine design and risks arising from such influences are addressed in this document.

— avoiding linking the operator's working rhythm to an automatic succession of cycles;

— providing local lighting on or in the machine;

NOTE 2 Lighting of the machine or of the surrounding workplace by the machine can have a significant impact on the safety of machine operation and this risk is addressed by this document.

— selecting, locating and identifying manual controls (actuators) so that they are clearly visible and identifiable and appropriately marked where necessary;

— selecting, designing and locating indicators, dials and visual display units.

The approach is based on ISO 12100 with its iterative process to identify significant hazards and reduce risks.

Relevant steps of this iterative process have been adapted to include ergonomic principles, and practical guidance is given to apply standards dealing with ergonomics which are relevant for machinery design.

This document is intended for use by standards writers and designers of machinery. It can be used when no relevant C-type standards are available.

2 Normative references

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

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

3 Terms and definitions

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

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
ergonomics
study of human factors
scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance

[SOURCE: ISO 6385:2004, 2.3]

3.2
ergonomic hazard
hazard arising from the failure to adequately consider ergonomic principles in machine design

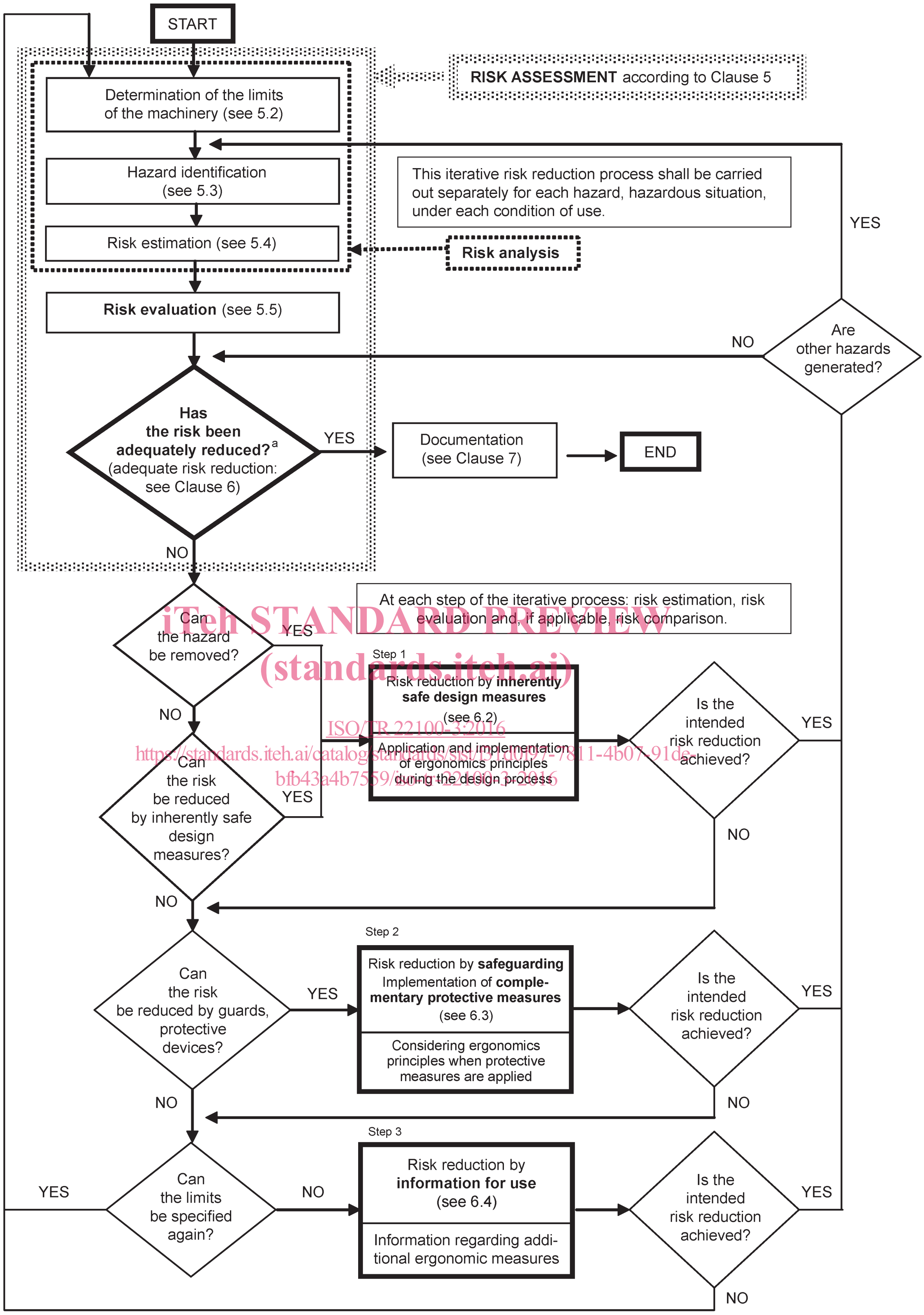
Note 1 to entry: For ergonomic hazards see also ISO 12100:2010, Table B.1, No. 8.

4 Strategy for risk assessment and risk reduction in relation to ergonomic hazards

4.1 General

The risk assessment process carried out by designers in accordance with ISO 12100:2010, Clause 5, provides information that is required for the risk evaluation through which decisions can be taken whether risk reduction is necessary. These decisions have to be supported by a qualitative or, where appropriate, a quantitative estimation of the risk identified. This is to be met by taking into account both the risks normally considered in machine design, and those arising from failing to consider the principles of ergonomics.

Figure 1 shows a schematic representation of the risk reduction process, derived from ISO 12100:2010, which illustrates how ergonomics can be integrated into the iterative three-step risk reduction process (including references to the relevant clauses in this document).



[a] The first time the question is asked, it is answered by the result of the initial risk assessment.

Figure 1 — Illustration of the integration of ergonomics into the iterative three-step design process for risk reduction (based on ISO 12100:2010, Figure 1)

4.2 Significant ergonomic hazards in relation to ISO 12100

Designs which do not take ergonomics into account can have potential consequences such as discomfort, fatigue, musculoskeletal disorders, stress and human error (see 4.3). When these are identified as being associated with the machine, they are relevant ergonomic hazards. Consequences such as discomfort and fatigue can also lead indirectly to human error. If the potential consequences require specific action, then these are significant hazards and are as important as those arising from mechanical, electrical and other hazards (see ISO 12100:2010, Table B.1).

NOTE 1 Discomfort and fatigue are relevant warning signals, as they can lead to occupational disease or to accidents and can influence performance and quality.

NOTE 2 The term ergonomic hazard is used in ISO 12100 to describe hazards resulting from the failure to adequately consider ergonomics during the design process. For consistency this term is therefore retained in this document.

Table 1 shows an example comparing mechanical hazards with ergonomic hazards.

Table 1 — Comparison of mechanical and ergonomic aspects of hazards

Work task: load/unload a machine		
Location of hazard: machine loading area		
Hazards arising from the failure to adequately consider	**Mechanical aspects**	**Ergonomic aspects**
Origin of hazard	Sharp edge	Sustained awkward posture
Factors influencing the risk	Surface characteristics	Space for movement restricted
Potential consequences	Cutting	Discomfort/Fatigue
Harm	Injury, pain, bleeding	Back pain, musculoskeletal disorders
Severity of harm	Light to serious damage to health	Light to serious damage to health (reversible or chronic)

4.3 Potential consequences

4.3.1 General

Taking ergonomic principles into account in designing machinery helps to reduce the mental or physical load on the operator. In turn this reduces strain and improves efficiency. It is important to consider these principles when allocating functions to operator and machine in the basic design.

As outlined in ISO 12100, failure to consider these principles can have potential consequences for the health, safety and performance of the operator. Table B.1 of ISO 12100:2010 lists some of these consequences, which are described below.

4.3.2 Discomfort

Discomfort refers to a lack of comfort, to a mental or physical uneasiness that is less intense and less localized than pain. On the contrary, comfort gives or brings aid, support, satisfaction. Comfort refers to a condition furnishing mental and/or physical ease. Sustained discomfort can lead to

— lack of attention or concentration (distraction),

— ill-health,

— absenteeism,

— decreased productivity — both qualitatively (with more discarded items) and quantitatively, and

— accidents.

Important aspects contributing to discomfort are

— awkward postures or sustained (static) postures,
— heavy physical work,
— repetitive movements,
— accessibility e.g. reaching distances,
— visual comfort, e.g. lines of sight, colour, visibility, light intensity and direction, viewing distances,
— surface contact e.g. shape, temperature, ease of contact,
— vibration (whole body and hand-arm),
— noise e.g. intensity, frequency, duration, pattern,
— climate/environment e.g. air temperature, wind speed (draught), relative humidity, clothing,
— odours e.g. fumes,
— inadequate cooperation or communication between operators during machine operation,
— balance between activity and inactivity; between vigilance and inattentiveness.

4.3.3 Fatigue

Fatigue is a state of impaired performance capability which can result from current or preceding physical and/or mental activities. Fatigue can be physical or mental, general or local. The extent of any fatigue depends on the intensity, duration and temporal pattern of these activities. Recovery from fatigue requires rest periods with sufficient time for recuperation.

Important aspects contributing to fatigue are:

— type of workload, e.g. mental or physical;
— intensity of the workload, e.g. weight to be moved, complexity of information to be processed;
— repetitiveness of task components (highly repetitive tasks can be more fatiguing);
— time for recovery e.g. rest breaks.

NOTE As well as variation in mental and physical capabilities between different operators, the capabilities of an individual operator and therefore their susceptibility to fatigue and other effects will vary over time.

4.3.4 Musculoskeletal disorders

Musculoskeletal disorders can be either acute or chronic. Acute disorders usually arise from some form of muscle overload, with work which is either too demanding, or with other characteristics such as sudden onset, which can tear or strain muscles or other soft tissue structures.

Chronic disorders usually arise from sustained or repeated demands which exceed the body's recovery and repair mechanisms. In some instances, unaccustomed activities create a hazard and an introductory or learning period can be beneficial.

Some disorders can be either acute or chronic in origin. For example, some tendon problems can arise from a short-term overload (acute) or a more sustained period of repeated activity.

Static loading (force application without movement) can also be problematic as muscle movement is an essential part of the recovery and repair process.

Important aspects contributing to musculoskeletal disorders:

— force requirements (are related to the size of the body part involved, with larger muscles being generally capable of higher forces);

— frequency of movements (smaller body parts such as fingers are naturally better suited to rapid movements than larger joints such as the shoulder);

— duration of force application (the greater the force, the less time it can be sustained for, especially without movement);

— position of body parts – posture - (body parts are more resilient when working close to their anatomical neutral position, such as with the arms by the side rather than raised above the shoulders);

— range of joint movement (as a rough guide, remaining within the middle 50 % of the range of movement is preferable and the more extreme a movement or posture the more strain will be experienced).

NOTE External environmental loads, such as vibration (hand-arm or whole-body) or extremes of temperature may need to be taken into account. This document does not cover noise and vibration requirements.

4.3.5 Stress

4.3.5.1 General

The terminology relating to “stress” is often both confused and confusing. In some instances, the term is used in the equivalent manner to the engineering use of the term, to reflect the loads placed on a person (with the outcome regarded as ‘strain’). In others, these are referred to as stressors, with the impact regarded as stress. Still others term the loads as pressure – again with stress as the potential outcome.

When used in the engineering sense, the term is essentially neutral and stress can be beneficial or harmful depending upon its characteristics. In other instances however, stress as an outcome is, by definition an adverse consequence.

Both fatigue and discomfort, addressed above, can be caused by physical and psychological stressors. However, although the volume of work can be a contributor to psychological stress it is more usually psychological factors which combine to give rise to the negative outcome. For this reason in some countries, to avoid any confusion, the term “psychological stress” is used instead.

NOTE 1 Psychological stressors can also aggravate existing fatigue and discomfort.

NOTE 2 Psychological stress is sometimes referred to as mental stress.

4.3.5.2 Psychological stress

In a safety of machinery context, it is likely to be issues such as the complexity and variability of the tasks required of operators and others, together with cognitive factors such as requirements for sustained attention and the probability and consequences of errors which contribute to any risk.

Important aspects contributing to psychological stress, which can be influenced by the design of the machine, include

— complexity of task,

— variability of task,

— time constraints on performance,

— cognitive resources required,

— multitasking vs. serial task performance,

— probability of errors,

— consequences of errors,

— design of interfaces (e.g. displays, signals and controls),

— requirements for sustained attention,

— repetitiveness of task performance,

— intensity of workload, and

— temporal pattern of workload.

The general factors which contribute to the overall burden of psychological stress can be grouped into six broad categories:

1) demands (not being able to cope with the demands of the job);

2) control (not having sufficient influence over how work is done);

3) support (not having sufficient support from colleagues and superiors);

4) relationships (being subjected to unacceptable behaviours);

5) role (not understanding roles and responsibilities);

6) change (not being involved and informed in organisational changes).

However, central to the concept of psychological stress, and a major mediating influence over whether the demands placed on an individual become excessive, is the idea of the individual 'coping' with the demands placed upon them. Thus, psychological stress develops when work demands of various types and combinations exceed the person's capacity and capability to cope. The consequences can be considerable including poor mental wellbeing, anxiety or depression as well as contributing to physical ill-health.

4.3.6 Human error

Human error, which can be expressed as a discrepancy between the human action taken or omitted, and that intended or required is a very complex field, with many different approaches to defining and classifying errors. In a safety of machine design context, the focus turns to the potential for human error by the designer, in failing to adequately ensure that controls or displays can be clearly and unambiguously identified and operated correctly in accordance with operator expectations (stereotypes).

In essence, errors can occur when a person does something he or she should not (e.g. operating the wrong control device) or does not do something he/she should (e.g. spot a warning signal). However, the complexities increase when the possibilities are explored further. Thus, was the wrong control device activated, the right one operated wrongly, the right one operated at the wrong time, and so on. Do the consequences arise from the failure to operate the right control device — or the operation of the wrong one? The likelihood of error is also influenced by additional factors such as work demands or pressures, sustained vigilance, monotony, etc.

Some important machine design aspects contributing to human error are

— selection of inappropriate display designs (e.g. digital or analogue displays),

— inappropriate control design (e.g. small devices to be operated by gloved hands),

— inappropriate control-response relationships (e.g. direction of control movement in relation to the movement of the machine),