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Guidance on safe use of machinery

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Summary of pages

This document comprises a front cover, and inside front cover, pages i to x, pages 1 to 192, an inside back cover and a back cover.

Foreword

Publishing information

This Published Document is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2019. It was prepared by Technical Committee MCE/3, *Safeguarding of machinery*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This Published Document supersedes PD 5304:2014, which is withdrawn.

Information about this document

BS 5304:1988 was withdrawn following publication of a series of harmonized European machinery safety standards. Recognizing that BS 5304 contained valuable practical advice, PD 5304:2000, followed by PD 5304:2005 and PD 5304:2014, was published to retain the advice contained in BS 5304, with the addition of references to those relevant harmonized European machinery safety standards.

This edition takes account of the requirements of the current harmonized European machinery safety standards, to help the user maintain those safety requirements when upgrading, refurbishing or changing the use of machinery.

NOTE The bibliography provides a link to an online list of harmonized European standards relevant to machinery safety.

Ensuring that risks associated with the use of machinery are eliminated or reduced is a task that requires unremitting and careful attention at all times. It is hoped that this Published Document will make a worthwhile contribution to the prevention of harm arising from the use of machinery. It is intended to serve as a useful guide to all those with responsibility for safe use of machinery and duties under the Health and Safety at Work etc. Act 1974 and the Provision and Use of Work Equipment Regulations 1998.

Figures are used to illustrate the general application of these principles. However, solutions other than those illustrated can be equally effective.

The safeguarding of machinery is continually being improved. Users of machinery need to make themselves aware of any new codes of practice, etc., which might be published from time to time and any other relevant new developments.

This Published Document can be withdrawn, revised, partially superseded or superseded. Information regarding the status of this Published Document can be found in the Standards Catalogue on the BSI website at bsigroup.com/standards, or by contacting the Customer Services team.

Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Presentational conventions

The guidance in this Published Document is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the Clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a Published Document cannot confer immunity from legal obligations.

Section 1: General

1 Scope

This Published Document provides guidance on the safe use (see [3.21](#)) of machinery, including that supplied prior to the implementation of the Supply of Machinery (Safety) Regulations 2008 [\[1\]](#).

It provides guidance on:

- a) the basic principles of safeguarding, with reference to current harmonized European machinery safety standards; and
- b) the continuing safe use of machinery manufactured in accordance with harmonized European machinery safety standards, in conjunction with the machine supplier's instructions for use.

This Published Document is intended to promote a high standard of machinery safety. It describes and illustrates a variety of protective measures and explains methods by which it is possible to assess which measure(s) it is reasonable to adopt in particular circumstances. It is necessary, however, to consult specific legislation in applying the principles set down. Although reference is made to particular types of machine, specific recommendations are not given for every type of machine.

The guidance can be applied to machinery during its modification, refurbishment, upgrading or change of use in order to satisfy the Provision and Use of Work Equipment Regulations (PUWER) 1998 [\[2\]](#).

NOTE 1 See also HSE Approved Code of Practice L22: Safe use of work equipment [\[3\]](#).

NOTE 2 Significant modification, refurbishment, upgrading or change of use to existing machinery that results in, for example, changes in the measures used to reduce risk(s) or the introduction of a new hazard(s), can make it necessary to satisfy relevant requirements from the Supply of Machinery (Safety) Regulations 2008 [\[1\]](#), in particular Schedule 3.

NOTE 3 PD 5304 is not intended to be used as an alternative to the current harmonized European machinery safety standards for machinery supplied in accordance with the Supply of Machinery (Safety) Regulations 2008 [\[1\]](#).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions of this document.¹ For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[BS 6753](#), *Specification for shotbolts (solenoid operated) for guarding machinery*

BS EN 349, *Safety of machinery – Minimum gaps to avoid crushing of parts of the human body*

BS EN 981, *Safety of machinery – System of auditory and visual danger and information signals*

BS EN 1299, *Mechanical vibration and shock – Vibration isolation of machines – Information for the application of source isolation*

BS EN 1550, *Machine-tools safety – Safety requirements for the design and construction of work holding chucks*

BS EN 1672-2, *Food processing machinery – Basic concepts – Part 2: Hygiene requirements*

BS EN 1837, *Safety of machinery – Integral lighting of machines*

¹ Documents that are referred to solely in an informative manner are listed in the Bibliography.

- BS EN 50205, *Relays with forcibly guided (mechanically linked) contacts*
- BS EN 60204-1:2018, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*
- BS EN 60204-32:2008, *Safety of machinery – Electrical equipment of machines – Part 32: Requirements for hoisting machines*
- BS EN 60529, *Degrees of protection provided by enclosures (IP Code)*
- BS EN 60947-4-2, *Low-voltage switchgear and controlgear – Part 4-2: Contactors and motor starters – AC semiconductor motor controllers and starters*
- [BS EN 60947-5-1:2017](#), *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*
- BS EN 60947-5-5:1998+A2:2017, *Low-voltage switchgear and controlgear – Part 5-5: Control circuit devices and switching elements – Electrical emergency stop devices with mechanical latching function*
- BS EN 61310-1, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, acoustic and tactile signals*
- BS EN 61310-2, *Safety of machinery – Indication, marking and actuation – Part 2: Requirements for marking*
- BS EN 61310-3, *Safety of machinery – Indication, marking and actuation – Part 3: Requirements for the location and operation of actuators*
- BS EN 61496-1:2013, *Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests*
- BS EN 61800-5-1, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*
- BS EN 61800-5-2, *Adjustable speed electrical power drive systems – Part 5-2: Safety requirements – Functional*
- BS EN 61810 (all parts), *Electromechanical elementary relays*
- BS EN 62061:2005+A2:2015, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*
- BS EN 82079-1, *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*
- BS EN ISO 4413, *Hydraulic fluid power – General rules and safety requirements for systems and their components*
- BS EN ISO 4414, *Pneumatic fluid power – General rules and safety requirements for systems and their components*
- BS EN ISO 7731, *Ergonomics – Danger signals for public and work areas – Auditory danger signals*
- BS EN ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*
- BS EN ISO 12543 (all parts), *Glass in building – Laminated glass and laminated safety glass*
- BS EN ISO 13849-1:2015, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*
- BS EN ISO 13849-2, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*
- BS EN ISO 13850, *Safety of machinery – Emergency stop – Principles for design*

[BS EN ISO 13851](#), *Safety of machinery – Two-hand control devices – Principles for design and selection*

BS EN ISO 13855, *Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body*

BS EN ISO 13856-1, *Safety of machinery – Pressure-sensitive protective devices – Part 1: General principles for design and testing of pressure-sensitive mats and pressure-sensitive floors*

BS EN ISO 13857:2008, *Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*

[BS EN ISO 14118](#), *Safety of machinery – Prevention of unexpected start-up*

BS EN ISO 14119:2013, *Safety of machinery – Interlocking devices associated with guards – Principles for design and selection*

BS EN ISO 14120, *Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards*

BS EN ISO 14122 (all parts), *Safety of machinery – Permanent means of access to machinery*

BS EN ISO 14159, *Safety of machinery – Hygiene requirements for the design of machinery*

[BS EN ISO 20607](#), *Safety of machinery – Instruction handbook – General drafting principles*

[BS EN ISO 13854](#), *Safety of machinery – Minimum gaps to avoid crushing of parts of the human body*

[BS IEC 61496-2](#), *Safety of machinery – Electro-sensitive protective equipment – Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)*

BS EN IEC 61496-3, *Safety of machinery – Electro-sensitive protective equipment – Part 3: Particular requirements for active opto-electronic protective devices responsive to diffuse Reflection (AOPDDR)*

BS EN IEC 60204-11, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*

BS EN IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

[BS EN IEC 60947-4-1:2019](#), *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

[BS EN IEC 62046](#), *Safety of machinery – Application of protective equipment to detect the presence of persons*

PD CLC/TR 60079-32-1, *Explosive atmospheres – Part 32-1: Electrostatic hazards, guidance*

3 Terms and definitions

For the purposes of this Published Document, the following terms and definitions apply.

3.1 failure to danger

any malfunction in the machinery or its power supply that increases the risk

3.2 guard

physical barrier, designed as part of the machine, to provide physical protection to persons from hazards

NOTE 1 A guard can either act:

- a) *alone; it is then only effective when it is in the closed position for a movable guard or securely held in place as a fixed guard; or*

- b) in conjunction with an interlocking device with or without guard locking; in this case, protection is ensured whatever the position of the guard.

NOTE 2 Depending on its design, a guard might be called, for example, "casing", "shield", "cover", "screen", "door" or "enclosing guard".

NOTE 3 Further information on types of guards and their requirements are given in BS EN ISO 12100:2010, 6.3.3, and BS EN ISO 14120.

3.3 harm

physical injury or damage to the health of persons

3.4 hazard

potential source of harm to a person

NOTE 1 The term "hazard" may be qualified in order to define its origin (e.g. mechanical hazard, electrical hazard) or the nature of the potential harm (e.g. electric shock hazard, cutting hazard, fire hazard).

NOTE 2 The hazard envisaged is either:

- a) permanently present during the intended use of the machine (e.g. motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature); or
- b) might appear unexpectedly (e.g. explosion, crushing hazard as a consequence of an unintended/unexpected start-up, ejection as a consequence of a breakage, fall as a consequence of acceleration/deceleration).

3.5 hazardous area

space within and/or around machinery in which a person can be exposed to a hazard

NOTE Also known as "danger zone".

3.6 integrity

measure of the ability of a machine, components, devices, systems and procedures to perform a required function under specified conditions

3.7 intended use (of a machine)

use of a machine in accordance with the information provided in the instructions for use

3.8 interlocking device (interlock)

mechanical, electrical or other type of device, the purpose of which is to prevent the operation of hazardous machine functions under specified conditions (generally as long as a guard is not closed)

3.9 interlocking guard

guard associated with an interlocking device so that, together with the control system of the machine, the following functions are performed:

- the hazardous machine functions "covered" by the guard cannot operate until the guard is closed;
- if the guard is opened while hazardous machine functions are operating, a stop command is given; and
- when the guard is closed, the hazardous machine functions "covered" by the guard can operate (the closure of the guard does not by itself start the hazardous machine functions)

NOTE BS EN ISO 14119 gives detailed provisions.

[SOURCE: BS EN ISO 12100:2010]

3.10 machinery (machine)

assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material

NOTE The terms “machinery” and “machine” also cover an assembly of machines which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole.

3.11 protective device

safeguard other than a guard to provide physical protection to persons from hazards

NOTE Examples of protective devices are given in [Section 8](#).

3.12 protective measure

measure intended to achieve risk reduction, implemented by:

- a) the designer (inherently safe design, safeguarding and complementary protective measures, information for use); and
- b) the user (organization: safe working procedures, supervision, permit-to-work systems; provision and use of additional safeguards; use of jigs; use of personal protective equipment; training)

3.13 reasonably foreseeable misuse

use of a machine in a way not intended by the designer, but which could result from readily predictable human behaviour

3.14 risk

combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: BS EN ISO 12100:2010]

3.15 safeguard

guard or protective device to provide physical protection to persons from hazards

3.16 safeguarding

protective measure using safeguards to protect persons from the hazards which cannot reasonably be eliminated or from the risks which cannot be reduced by inherently safe design measures

NOTE BS EN ISO 12100 gives more information on safeguarding.

3.17 safety function

function of a machine whose failure can result in the immediate increase of risk(s)

3.18 safe system of work

method of working that reduces the risk of harm

3.19 scotch

mechanical restraint device placed manually or automatically between two parts of machinery and capable of preventing them closing under gravity or power

3.20 unexpected start-up (unintended start-up)

start-up of a machine which, because of its unexpected nature, generates a hazard

NOTE 1 Unexpected or unintended start-up can be caused by, for example:

- a) a start command which is the result of a failure in, or an external influence on, the control system;*
- b) a start command generated by inopportune action on a start control or other parts of the machine, e.g. a sensor or a power control element;*
- c) restoration of the power supply after an interruption;*
- d) external/internal influences (e.g. gravity, wind, self-ignition in internal combustion engines) on parts of the machine.*

NOTE 2 Machine start-up during normal sequence of an automatic cycle is intended, but could be considered to be unexpected from the point of view of the operator. For more information, see BS EN ISO 14118. Prevention of accidents in this case involves the use of safeguarding measures (see BS EN ISO 12100:2010, 6.3).

3.21 use

activity involving machinery, including starting, stopping, programming, setting, transporting, repairing, modifying, maintaining, servicing and cleaning

Section 2: Strategy for selecting protective measures

4 General

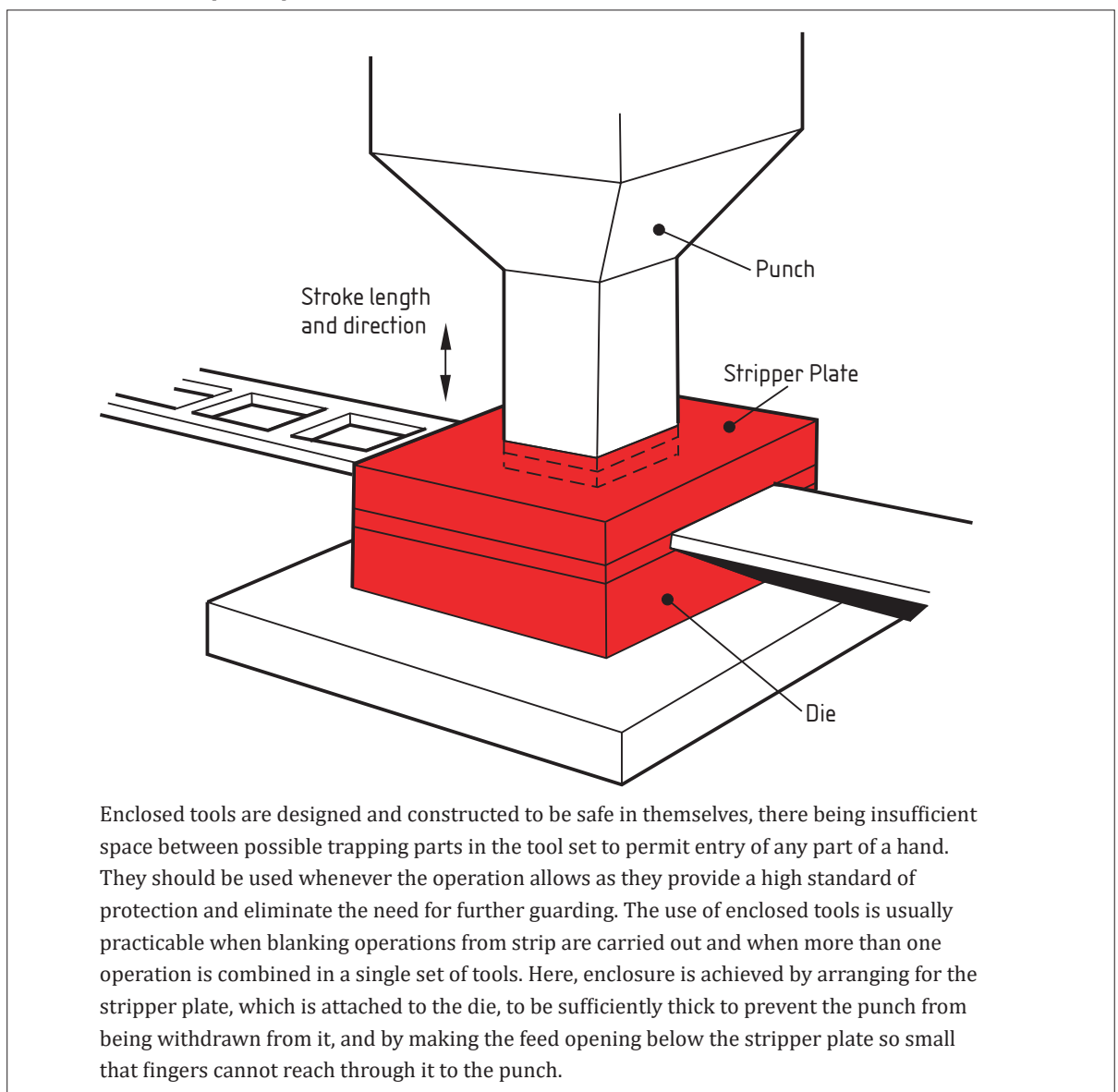
A strategy for reducing risk of harm should be applied in the following order:

- a) identify the hazards and assess the risks of injury and damage to health;
- b) eliminate the hazards by inherently safe design to the extent that it is practicable;
- c) reduce the remaining risk by use of safeguards and/or complementary protective measures to the extent that it is practicable; and
- d) use of safe systems of work, including provision of information, training and personal protective equipment.

Designers and suppliers ought to have applied this strategy. However the user has responsibility for continued safe use of machinery in its intended application. This is particularly important following commissioning, modification and/or change of use (see also BS EN ISO 12100 and HSE Guidance document INDG271 [4]).

NOTE 1 Examples of inherently safe design are given in [Figure 1](#) and [Figure 14](#).

NOTE 2 For existing machinery there can be less scope for elimination of hazards by inherently safe design, so it is usually necessary to apply safeguards and/or complementary protective measures.

Figure 1 — *Enclosed tools at a power press*

The greater the risk, the greater is the need to protect against it. The greater the probability or severity of harm resulting from failure of the protective measure(s), the greater should be the integrity of the measure.

This applies to safeguarding and controls in general, to interlocks, braking systems, overrun devices, workholding devices, etc. Systematic methods of assessing these devices and systems are available. Systems of work are subject to the same principle but cannot usually be assessed to the same extent.

The identification of the various hazards should be followed by a careful study of the possible failures or combination of failures of the protective measure(s) which might lead to these hazards causing harm.

In any system where a failure can adversely affect safety, each component within the system should be considered in turn. The likely types of failure and their consequences for the system as a whole should be taken into account.

Where the supplier has been unable to take every hazard into consideration, for example those arising from use, their identification and elimination should be considered by the user. Modifications might be possible which, although not capable of eliminating injury or damage to health, reduce

its scale. [Section 4](#) gives information on identification of hazards and [Section 5](#) on methods to reduce risks.

When a hazard cannot be eliminated, other measures for reducing the risk should be considered. Where the residual risks are significant, additional measures can reduce the scale of injury (e.g. by reducing speeds or forces) or exposure (e.g. provision of local exhaust ventilation). The avoidance of injury and damage to health depends on the integrity of these measures.

In considering the various measures to reduce risk, it is important to have a realistic assessment of all the risks involved. This is considered in [Section 3](#).

Certain protective measures are more effective than others. Safeguarding and complementary protective measures should be considered before safe systems of work. Safeguards and complementary protective measures are considered in [Section 6](#), [Section 7](#), [Section 8](#), [Section 9](#) and [Section 10](#), and safe systems of work in [Section 12](#).

Consideration should also be given to using a combination of hazard elimination or risk reduction, safeguarding and safe systems of work. As part of a safe system of work, personnel might require personal protective equipment and this is also considered in [Section 12](#).

In addition to measures which are taken explicitly for safety reasons, a large number of other factors influence the safe use of machinery which might not have been taken into account at the design stage. (See [Section 5](#), [Section 11](#) and [Section 12](#).)

5 Selection of protective measures

When applying the strategy for selection, it might not be possible to use some types of protective measures because they are either not technically feasible or are not suitable for the particular application.

In considering measures for all the hazards during each relevant phase of machine life, risk assessment techniques assist in choosing the best possible combination of protective measures. Further information on risk assessments is given in [Section 3](#).

6 Avoidance of reasonably foreseeable misuse of guards and protective devices

Guards, protective devices and associated (e.g. control) systems for machinery should achieve their safety function(s) with minimal downtime and the lowest reduction in productivity. Production pressures, incentive schemes or well-intentioned zeal can lead to safeguards being misused.

Safeguards should be designed and constructed such as to make deliberate or accidental defeating as difficult as is reasonably practicable. In addition, the safeguarding systems should be reliable as poor reliability encourages misuse.

See [Section 7](#) regarding the design and construction of guards intended to discourage guard misuse (defeatability).

NOTE See also BS EN ISO 14119:2013, 5.7, for designs to minimize the possibilities of misuse of interlocking devices associated with guards.

7 Phases of machine life

So far as is possible, the user should take into account hazards associated with all phases of machine life, which are likely to include:

- a) transport;
- b) installation;
- c) commissioning;
- d) operation, including starting up and shutdown;
- e) setting or process changeover;
- f) cleaning;
- g) adjustment;
- h) maintenance; and
- i) decommissioning and dismantling.

These can give rise to conflicting requirements, and priority should be given to those phases which give rise to the greatest risk. For example, for manually-operated machines on repetitious work this is likely to be the operation phase, while for fully automated and/or remote-controlled machinery, where there is no access during operation, the maintenance, tool-setting and adjustment phases might require greater emphasis.

Section 3: Risk assessment

8 General

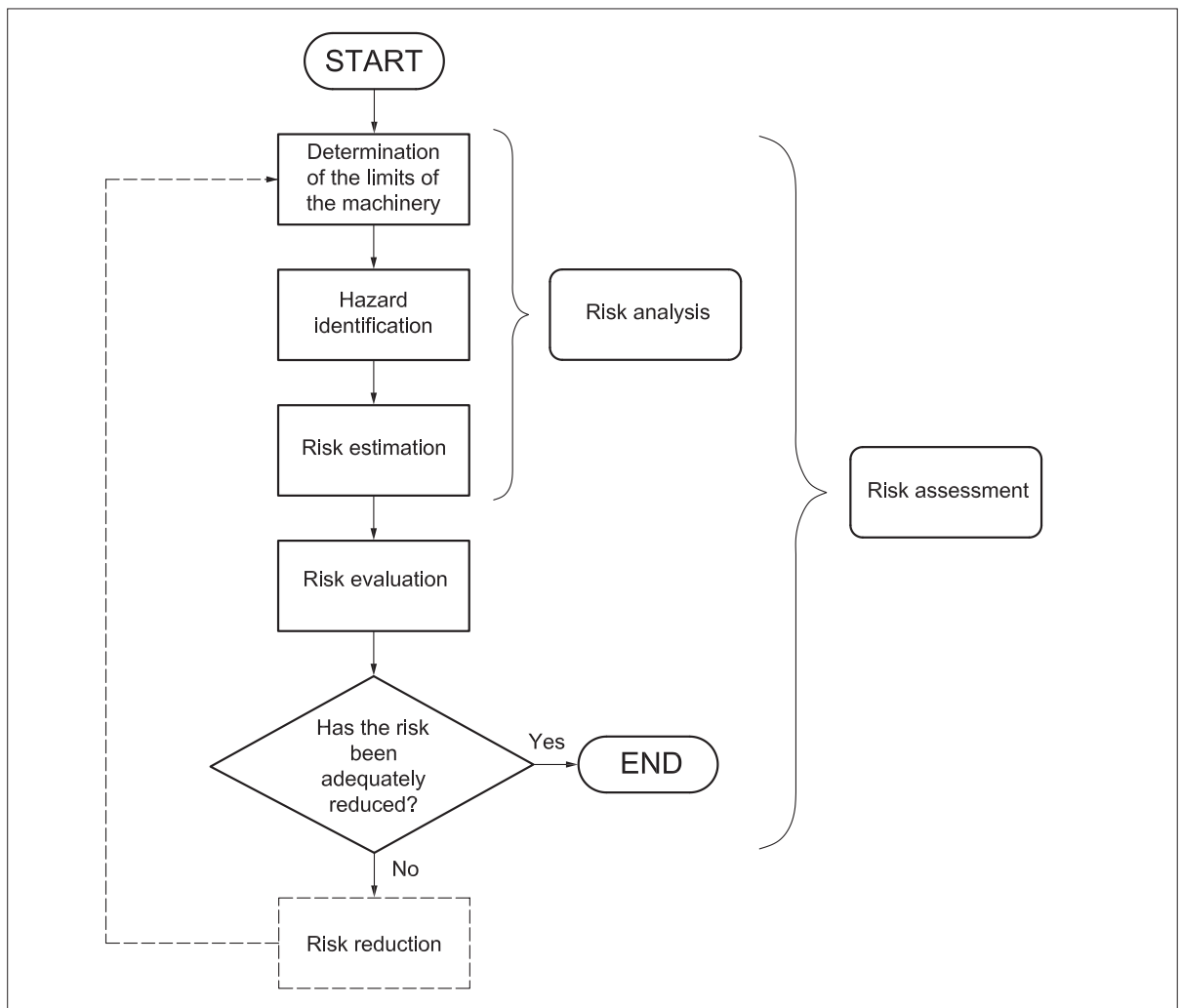
- 8.1** Risk assessment is a requirement of the Management of Health and Safety at Work Regulations 1999 [5]. The technique of risk assessment formalizes the process by which designers, suppliers and users of machinery use their experience to identify hazards, estimate the risks from each identified hazard and evaluate these to decide whether risk reduction is necessary, either by eliminating the hazard or reducing the risk(s) associated with the hazard(s) by selecting appropriate protective measures (see [Section 4](#)).
- 8.2** Risk assessments should be conducted when the machinery is first taken into service and when there are changes, such as the following:
- a) modifications to a machine;
 - b) changes to a machine as a result of repair;
 - c) an incident or dangerous occurrence;
 - d) changes to work practices, operating procedures, materials processed or methods of use;
 - e) changes to the environment or location in which a machine is used;
 - f) new information becomes available about a hazard that indicates the risks associated with it are different to what was previously thought; and
 - g) any other indications that the existing risk assessment is no longer valid.
- 8.3** Risk assessments should be reviewed at planned, regular intervals as part of standard management practice. The frequency of reviews should take into account the nature of the risks and the degree of change likely in the work activity.
- 8.4** The extent and complexity of the assessment required can only be determined after an initial appraisal of the risks and existing safety measures. The absence of an accident history, a small number of accidents or low severity of accidents should not be taken as an automatic presumption of a low risk.

Risk assessment and risk reduction should be carried out in accordance with BS EN ISO 12100:2010, Clause 4 and Clause 5 of which outline the strategy and principles for carrying out risk assessments, while Clause 6 gives a strategy for risk reduction.

Clauses [9](#), [10](#), [11](#) and [12](#) describe the underlying principles involved.

- 8.5** Risk assessment (see [Figure 2](#)) involves the following:
- a) risk analysis, comprising:
 - 1) determination of the characteristics and limits of the machinery;
 - 2) hazard identification: what can cause harm, where, when and how (see [Section 4](#)); and
 - 3) risk estimation: how severe and how likely is harm?
 - b) risk evaluation: can the risk be tolerated?

Risk analysis provides information required for the risk evaluation, which in turn allows judgements to be made about whether or not risk reduction is required. These judgments should be supported by a qualitative or, where appropriate, a quantitative, estimate of the risk associated with the hazards present at the machinery.

Figure 2 — *Iterative process to reduce risk***8.6** The risk from each identified hazard consists of:

- a) the severity of potential harm from each identified hazard (see Clause 9);
- b) the probability of occurrence of that harm (see Clause 10), which is a function of:
 - 1) the exposure of person(s) to the hazard;
 - 2) the occurrence of a hazardous event; and
 - 3) the technical and human possibilities to avoid or limit the harm.

Many formal and systematic methods of risk assessment for machinery exist and others are currently under development. In addition, there are methods that apply the principles of risk assessment to the assignment of performance criteria to safety-related electrical control systems for machinery. Examples of such methods are given in BS EN ISO 13849-1:2015, Annex A, and BS EN 62061:2005+A2:2015, Annex A.

9 Severity of harm

The severity of possible harm has an important influence on the selection of protective measures. Where two machines present the same probability of harm, but in one case the potential injury is death and in the other a bruised or broken finger, clearly the former requires a higher level of protection.

Some harmful effects, particularly those involving damage to health, only become apparent some time after exposure to a hazard, e.g. ionizing radiation, has ceased. Other hazards, e.g. noise, vibration, have a cumulative effect such that the harm is only apparent after significant exposure, whether in one continuous exposure or a number of shorter exposures (which might take place over a long period).

Deliberate or accidental access to the hazardous area should be taken into account for all phases of machine life (see Clause 7). For each phase the following questions should be asked, to determine the possible severity of harm.

- a) What type of mechanical or other hazard is involved? (See Clause 14 and Clause 15.)
- b) What type(s) of harm is foreseen? (See Clause 14.)
- c) What is the probability of each possible severity of harm, given the conditions under which access occurs?

Having completed all these assessments, the risks arising from each type of access can be determined.

10 Probability of occurrence of harm

When examining a machine, either from first principles or by making comparisons with similar machines, account should be taken of the frequency and/or duration of access to, or through, a hazardous area during each phase of machine life, e.g. machine operation and breakdown, commissioning, maintenance, setting and process changeover (see Clause 7). When carrying out this examination, the user might need to consider situations that were not foreseen by the machine manufacturer (see Clause 4).

By considering human behaviour at each phase, the total frequency and duration of each type of access to the hazardous areas can be assessed. Next, the possibility for avoidance of harm should be determined. An estimate should then be made of the likelihood that harm will arise from each type of access. The likelihood of harm can vary because of variations in the type of access.

It is emphasized that the absence of harm from machinery used without protective measures (for example safeguards) over a period of time does not in itself mean that the machine is completely safe.

11 Risk evaluation

When carrying out a risk evaluation, the risk from the most likely severity of the harm that is likely to occur from each identified hazard should be determined. However, the highest foreseeable severity from that hazard should also be taken into account, even if the probability of the occurrence is not high. For each hazard, the total risk is the sum of the risks under all the different circumstances given in Clauses 8, 9 and 10.

Where higher risks are involved, more formal methods should be used, for example failure modes, effects and criticality analysis (see BS EN IEC 60812). It is also necessary to consider the reliability of operating procedures, where safety depends upon them, and this encompasses both inadvertent failure to follow procedures and deliberate failure to do so.

12 Documentation

A record of each risk assessment should be retained. Documentation should include the procedure that has been followed and the results that have been achieved, including:

- a) a description of the machine for which the assessment has been made (e.g. specifications, limits, intended use);

- b) the information/data upon which the risk assessment has been based, including any relevant assumptions that have been made (e.g. loads, strengths, safety factors); and
- c) the hazards and hazardous situations identified and the hazardous events considered in the assessment.

Section 4: Identification of hazards

13 Hazards at machinery

Examples of how a person can be injured by mechanical hazards include:

- a) contact or entanglement with the machinery including its tools;
- b) trapping between the machinery and any material or fixed structures;
- c) contact or entanglement with any material in motion;
- d) being struck by ejected parts of the machinery;
- e) being struck by material ejected from the machinery; and
- f) trapping within the machine.

Advice and safeguards applicable to identified mechanical hazards are given in Clause [14](#).

Machinery can also present non-mechanical hazards in which the dangers are less obvious or tangible. Examples of how a person can be injured by non-mechanical hazards include:

- 1) electric shock or burn from the electrical equipment or from the processing of material (e.g. in electric welding);
- 2) thermal hazards;
- 3) exposure to excessive noise and/or vibration;
- 4) exposure to excessive ionizing or non-ionizing radiation;
- 5) burns and other injuries arising from fire and explosion of materials or substances processed, used, produced, exhausted, etc., by the machinery;
- 6) harm arising from ingestion of materials or substances processed, used, produced, exhausted, etc., by the machinery;
- 7) effects of failure to observe good ergonomics principles in machine design and use;
- 8) injuries arising from slips, trips and falls occurring from failure to create and maintain safe access to and onto machinery during use; and
- 9) effects of the environment in which the machine has to be used.

Advice and safeguards applicable to non-mechanical hazards are given in Clause [15](#).

Examples of hazards, hazardous situations and hazardous events are given in BS EN ISO 12100:2010, Annex B.

All potential hazards ought to have been identified (see [Section 3](#)) and a risk reduction process performed, using the hierarchy in Clause [4](#), but for existing machinery there can be less scope for elimination of hazards by inherently safe design, so it is usually necessary to apply safeguards and/or complementary protective measures.

Many of the protective measures for eliminating or mitigating personal harm from non-mechanical hazards identified in Clause [15](#) should be considered in conjunction with the safeguards against the mechanical hazards identified in Clause [14](#), e.g. acoustic guards to prevent access and contain/absorb noise, and welding curtains to protect against radiation, spatter and burns.

Foreseeable combinations of hazards should be considered because hazards which individually present minor risk can, when combined, present a more significant risk.

14 Mechanical hazards

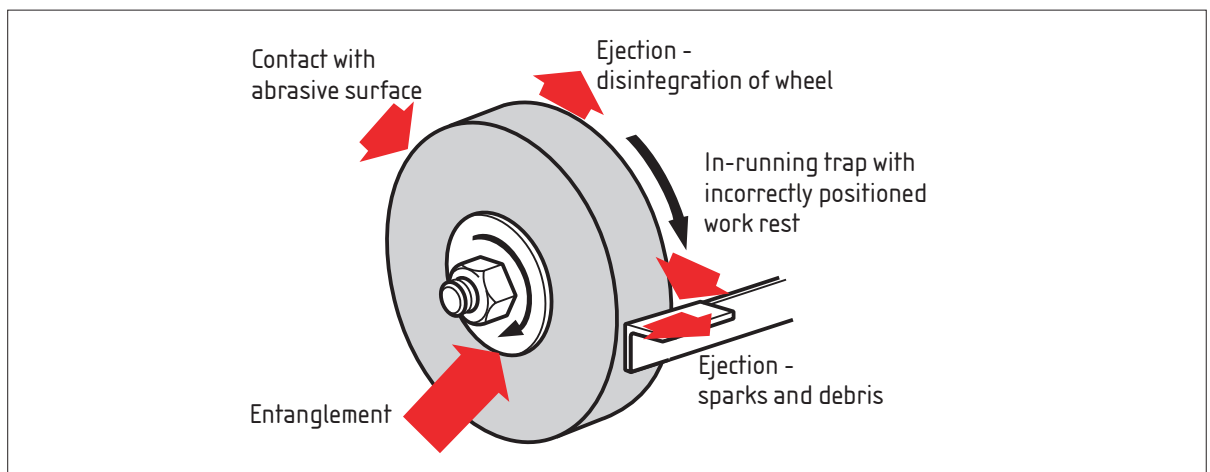
14.1 General

Movement of machinery parts can involve rotary, sliding or reciprocating motion, or a combination of these.

These movements can cause injury by entanglement, friction or abrasion, cutting, shear, stabbing or puncture, impact, crushing, or by drawing a person into a position where one or more of these types of injury can occur. The non-exhaustive list of examples in 14.2 to 14.10 is typical, and one or more of these are found on most units of machinery. Individual machines and individual parts of machines can cause one or more of these types of injury (see Figure 3). Furthermore, the shape of parts of a machine (including tools and fixtures), workpieces or loads can generate mechanical hazards even if they are motionless.

NOTE On Figure 3 and Figure 19, only the hazard(s) referred to in the associated text are shown. There might be other hazards (e.g. see note to Figure 10).

Figure 3 — Individual parts of machines causing one or more types of injury, e.g. hazards at an abrasive wheel



14.2 Entanglement

Bodily contact with the following features can lead to entanglement.

- a) Contact with a single rotating surface (see Figure 4), for example, couplings, spindles, chucks, leadscrews, mandrels, bars, or rotating workpieces. These, even when rotating slowly, can be a source of danger.

NOTE For further information on the issue of non-dangerous parts and rollers, see BS EN ISO 11111-1, Annex D.

- b) Catching on projections or in gaps (see Figure 5), for example, fan blades, spoked pulleys, chain wheels, gear wheels and flywheels, mixer and beater arms, spiked cylinders, belt fasteners, projecting keys, set screws, cotter pins on shafts or slat conveyors.
- c) Catching between two parts (see also 14.9).
 - 1) Between counter-rotating parts (see Figure 6), e.g. gear wheels, rolling mills, mixing rolls and calenders, or material being drawn between two rolls.
 - 2) Between rotating and tangentially moving parts (see Figure 7 and Figure 20), e.g. a power transmission belt and its pulley, a chain and chain wheel, a rack and pinion, metal, paper, rope, etc., and a reeling drum or shaft, batch-up, reel-up, etc., or a conveyor belt and its driving pulley or any bend pulley.

Some mechanisms contain a combination of sliding and turning movement, such as those used in certain cam gear designs, e.g. the mechanism on the side of some flatbed printing machines, or baling machines (see [Figure 7](#)).

- 3) Between rotating and fixed parts (see [Figure 8](#)), e.g. spoked handwheels or flywheels and the machinery bed, screw or worm conveyors and their casing, revolving mixer and mincing mechanisms in casings having unprotected openings, Z-blade and ribbon-blade mixers, extruder scroll and barrel, or the periphery of an abrasive wheel and an incorrectly adjusted work rest.
- d) Being caught by materials in motion (see [Figure 9](#)), e.g. in centrifuges, tumble driers, dough mixers, or swarf from machining operations.

The risk of entanglement is increased by loose clothing, gloves, neckties, jewellery, hair, cleaning brushes or rags, medical dressings or materials being handled. Entanglement hazards can be lessened by reducing speed or distance of movement, by avoiding projections and recesses, by restricting force, torque and inertia, and by aiming for smooth polished surfaces. These measures apply both to machinery and process material. It also helps if the process material and any by-product is discrete rather than continuous. Every projection, such as a setscrew, bolt or key on any exposed revolving part of machinery, should be sunk, shrouded or otherwise effectively guarded. Guards for rotating shafts should be fixed and of solid construction. However, guards of the loose tube type or of bellows construction may also be used in some applications.

The ergonomic criteria given in [Clause 48](#) and [Annex A](#) should not be regarded as giving complete protection against entanglement.

Figure 4 — *Entanglement caused by contact with a single rotating surface*

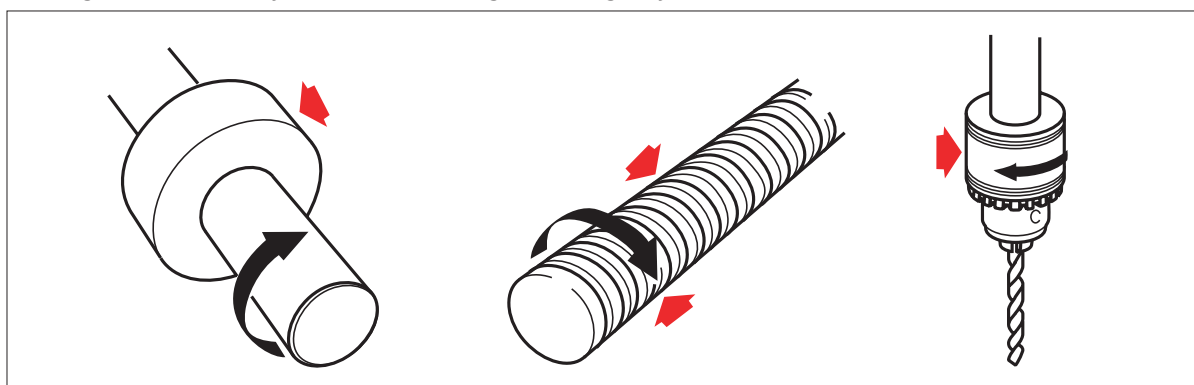


Figure 5 — *Entanglement caused by catching on projections or in gaps*

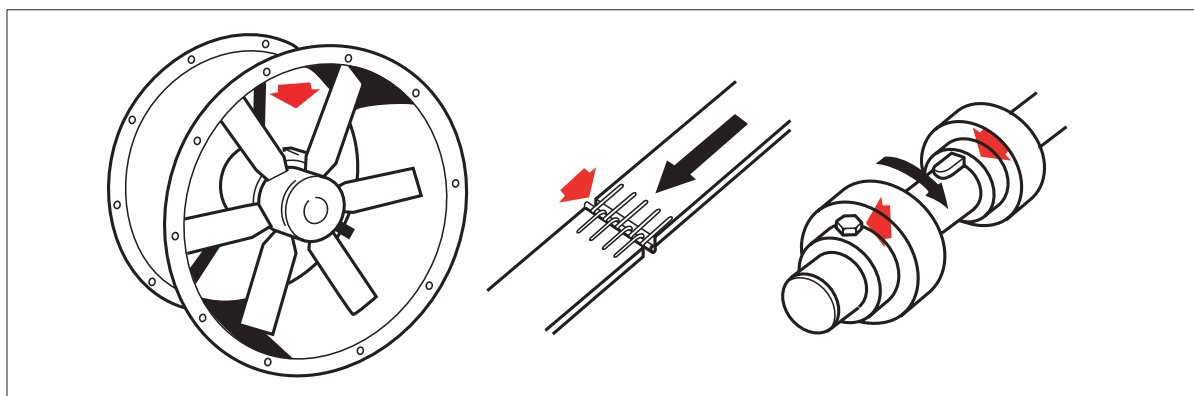


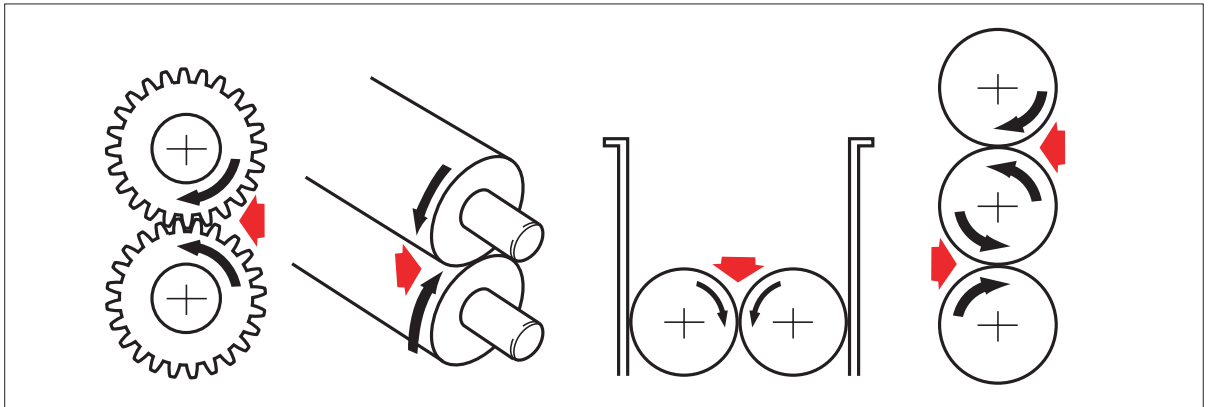
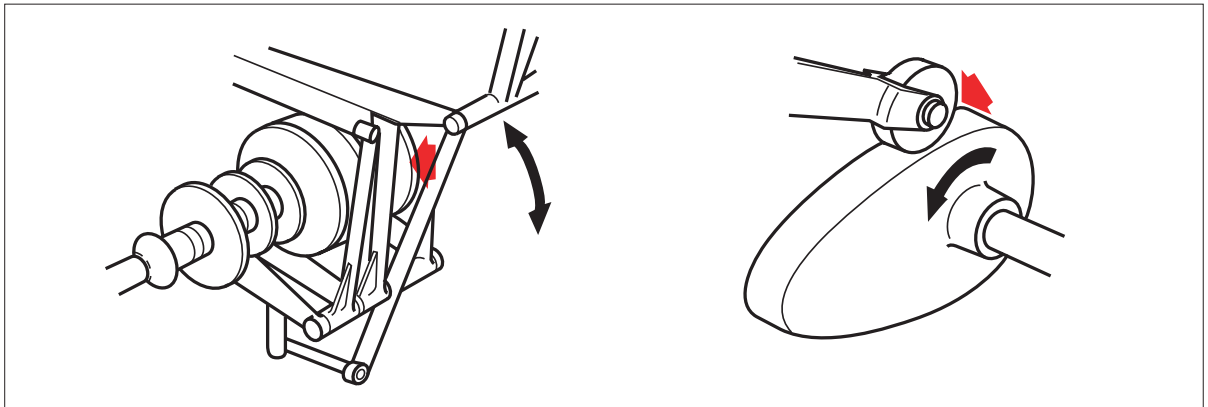
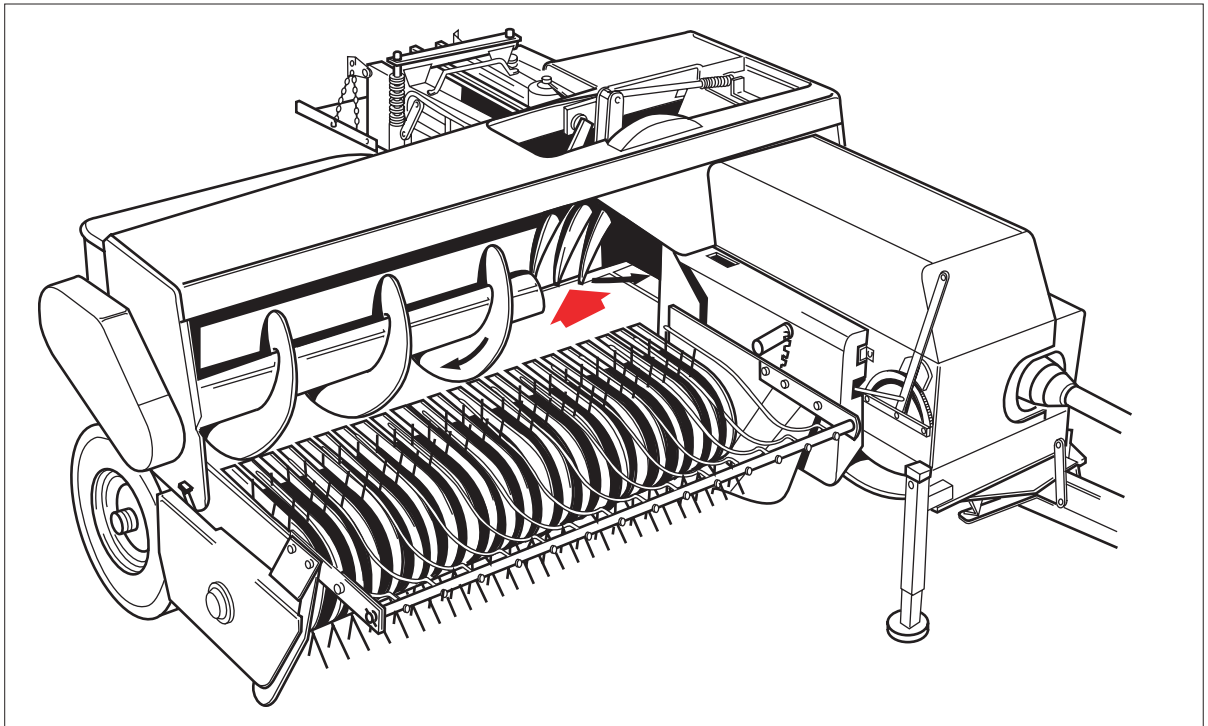
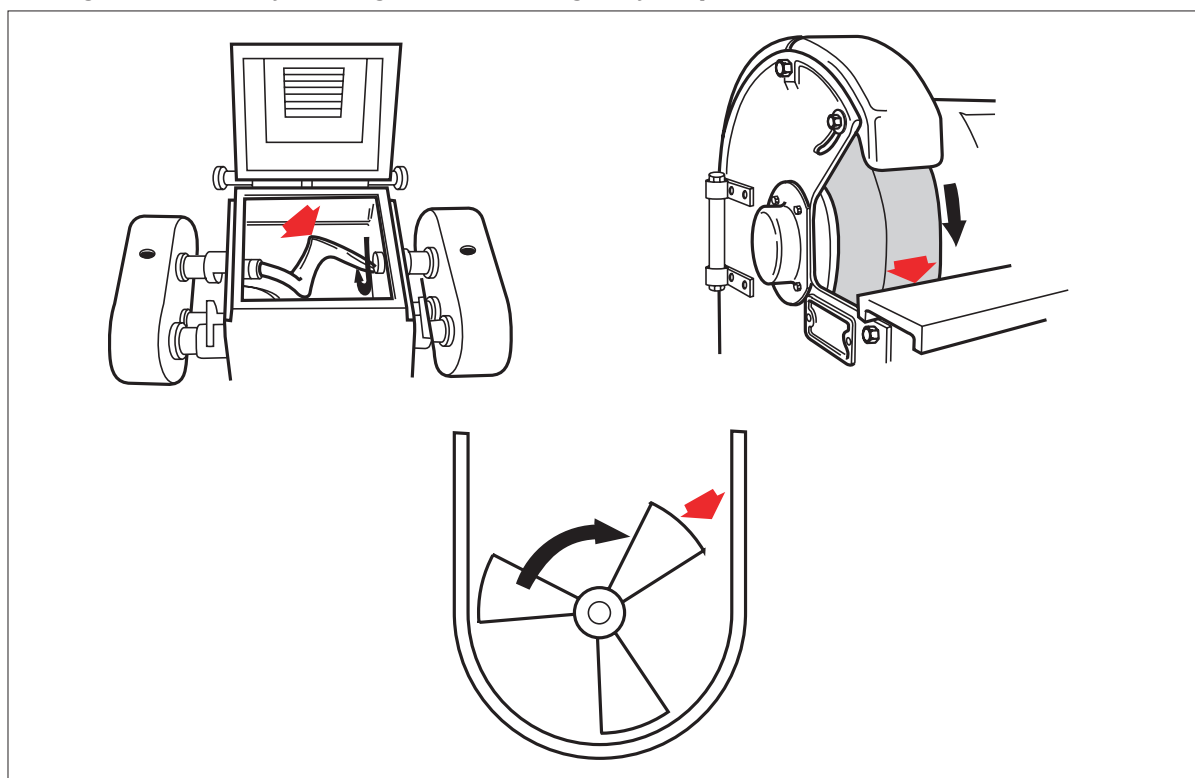
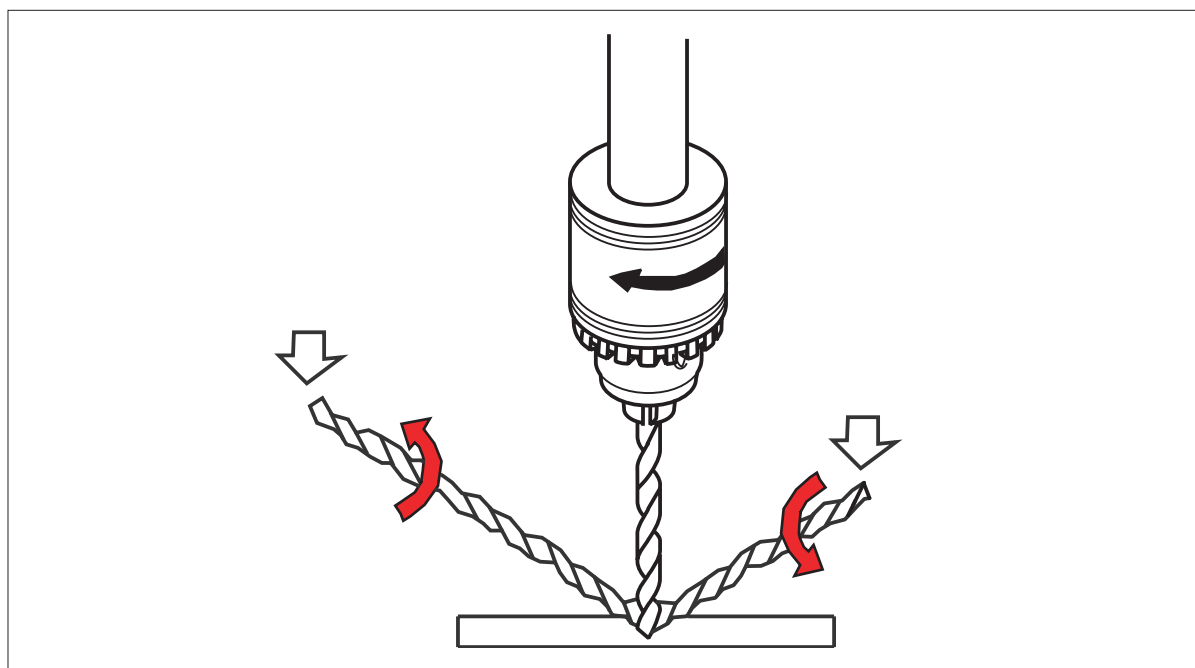
Figure 6 — Drawing-in hazards between two counter-rotating parts**Figure 7** — Entanglement caused by catching between rotating and other moving parts (1 of 2)**Figure 7** — Entanglement caused by catching between rotating and other moving parts (2 of 2)

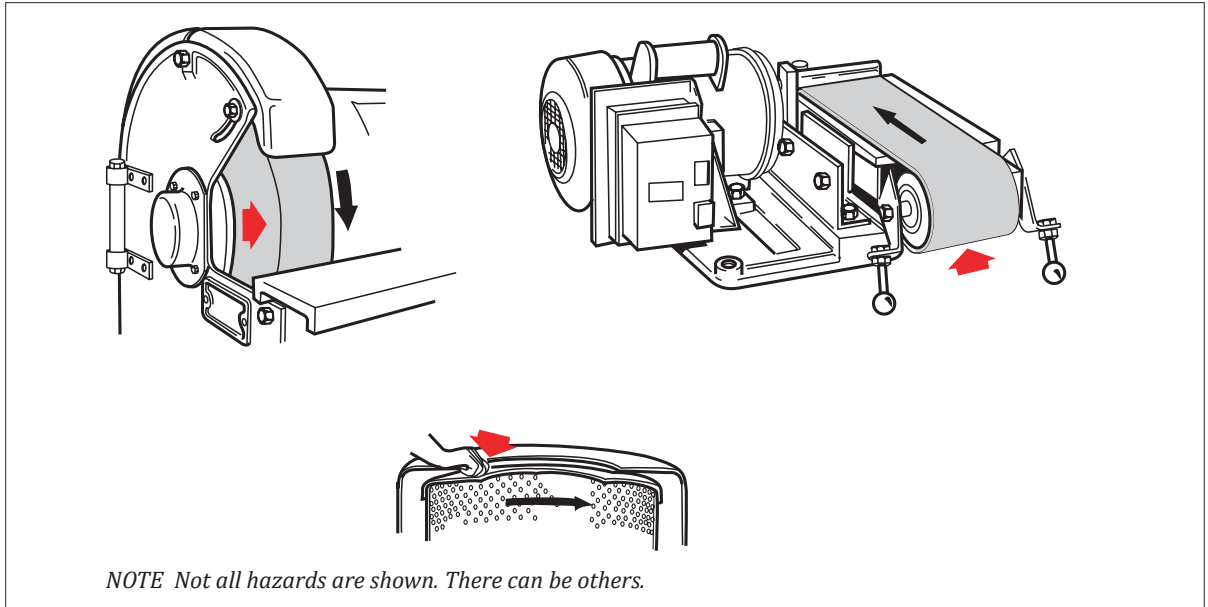
Figure 8 — Entanglement caused by catching between rotating and fixed parts**Figure 9** — Entanglement caused by catching in materials in motion (swarf)

14.3 Friction and abrasion

The distinction between abrasion and cutting by a saw, for example, is one of degree. Friction burns can be caused by relatively smooth parts operating at high speed, for example, the rim of a centrifuge basket at the edge of the casing opening. Other examples of friction or abrasion hazards include the periphery of an abrasive wheel, belt sanding machines (see [Figure 10](#)), material running onto a reel or shaft, a conveyor belt and its drums or pulleys (see [14.9](#) and [Figure 20](#)), and fast-moving ropes or belts.

Friction and abrasion hazards are reduced by reducing speed or distance of movement, force, torque and inertia, and by use of surfaces that are as smooth as possible. Damage due to any particular moving surface can be aggravated by adjacent surfaces preventing removal of the hand, etc., from the hazardous area, for example a badly adjusted work rest on an abrasive wheel.

Figure 10 — *Friction and abrasion hazards*

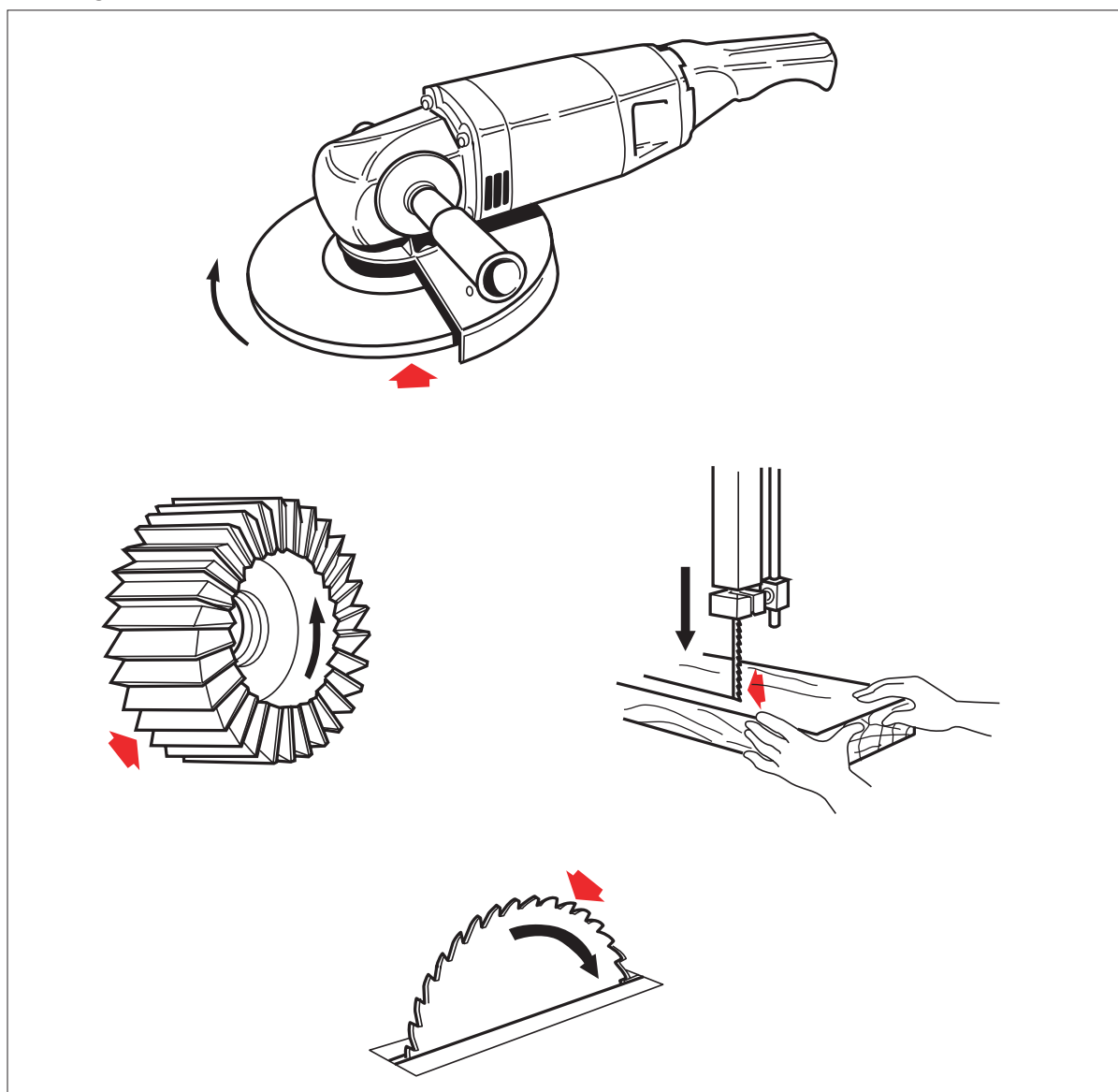


14.4 Cutting or severing

Examples of cutting or severing hazards (see [Figure 11](#)) include all kinds of cutting tool, circular saws, milling cutters, routers, spindle moulders, planing and tenoning machines, hand saw blades, rotary knives, disc blades, or the edges of moving sheet material.

Each of these forms of cutter is capable of cutting by virtue of its own speed of movement when it comes into contact with the body. The effect can be aggravated by the body being held stationary, i.e. unable to move away from the cutter, by another machine part. Water jet cutting creates a similar hazard.

Cutting hazards are reduced by reducing speed or distance of movement, force, torque and inertia, and by increasing corner radii on machine parts. Adjacent abutting surfaces should be avoided. Processing materials in a way which avoids leaving raw edges also reduces the hazard.

Figure 11 — Cutting hazards

14.5 Shearing

Parts of the body can be sheared in the following ways:

- between two machine parts (see [Figure 12](#)), for example, the Table of a metal planing machine and its bed, the blade of a guillotine and the material to be cut, nip points between connecting rods or links and rotating wheels, or oscillating pendulum movements; or
- between a machinery part and a workpiece (see [Figure 13](#)), for example, transfer mechanisms, the tool of a broaching machine.

The principal measures that can be adopted to eliminate shear traps are:

- filling the gaps such that the shear trap is minimized (see [Figure 14](#) and [Figure 15](#));
- reducing the maximum clearance between the relatively moving parts so that parts of the body cannot enter the gap, e.g. by reducing the stroke of the machine; and
- increasing the minimum clearance between the shearing parts, such that parts of the body can enter the gap safely.

When the technique of increasing the clearance between the shearing parts [item 3]] is used, consideration should be given to the body parts which could be inserted in the trap. However, the technique is not effective against double shear traps. Minimum gaps to avoid crushing are given in BS EN 349 and ISO 13854, while BS EN ISO 13857 specifies safety distances (see also [Annex A](#)).

When it is not possible to avoid the creation of a shear trap, it might still be possible to restrict reach past the trap so that injury is reduced. It might also be possible to adjust speed and force of movement of parts creating the shear action.

NOTE These techniques are not generally applicable to tools whose prime purpose is to shear, e.g. guillotines and press tools.

Figure 12 — Shear hazards between two machine parts

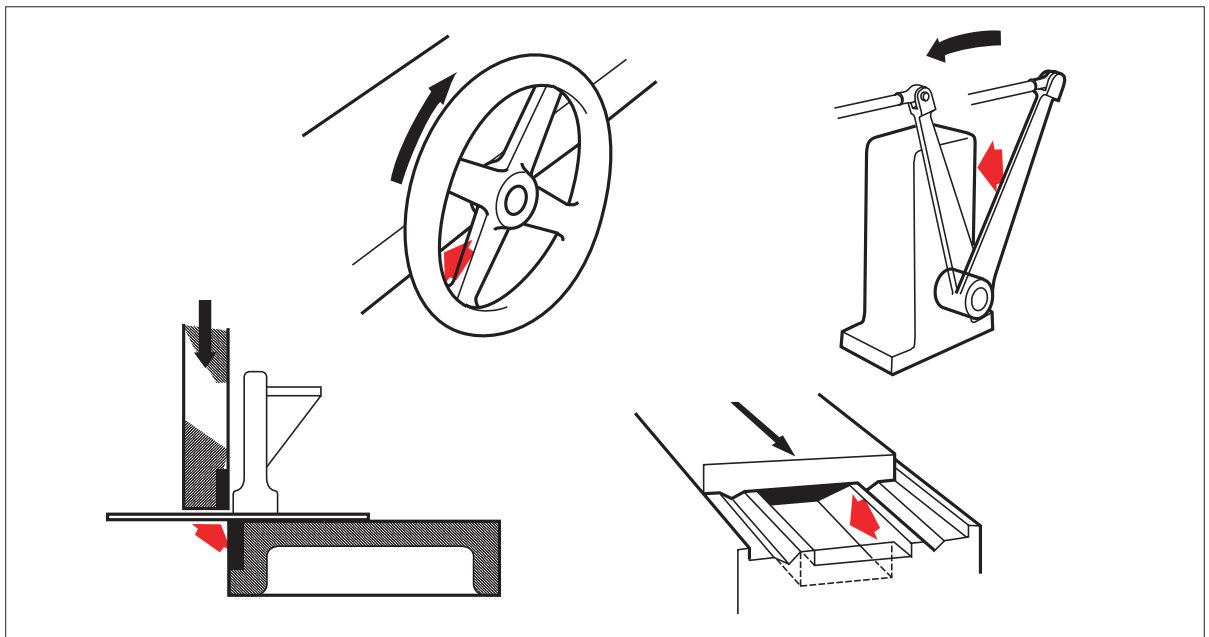


Figure 13 — Shear hazards between a machinery part and a workpiece

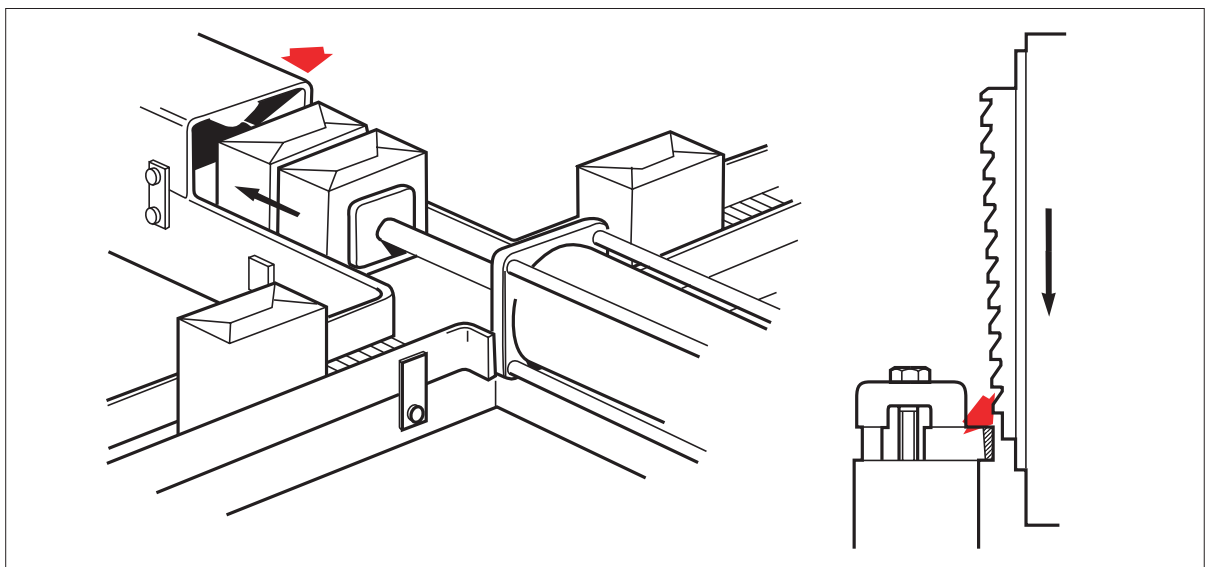
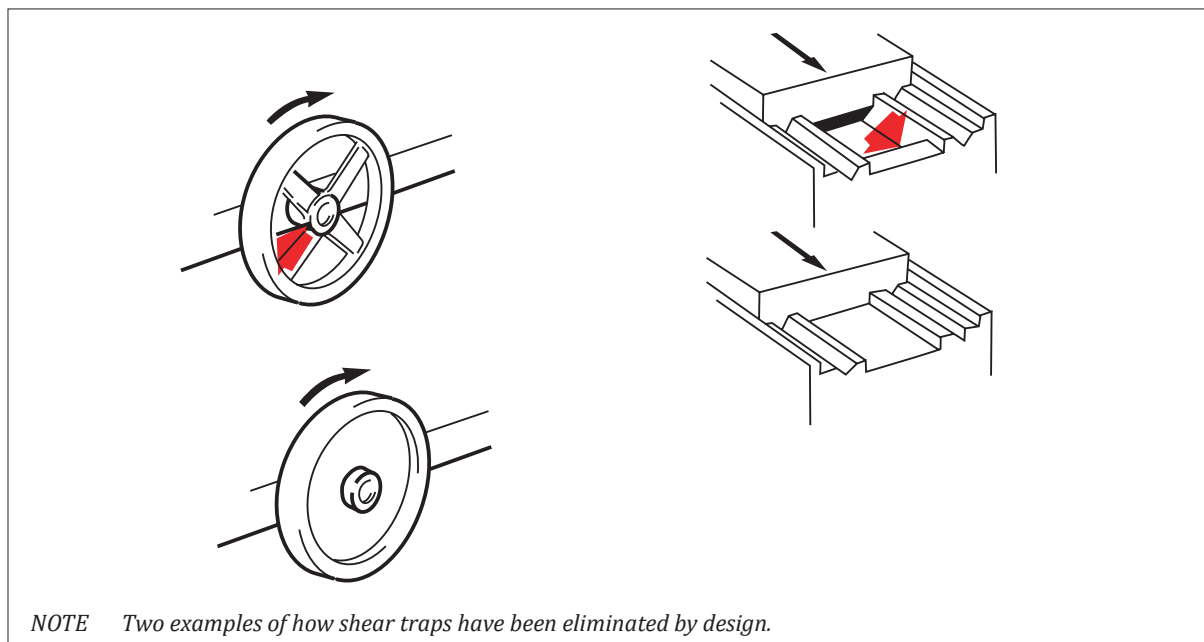
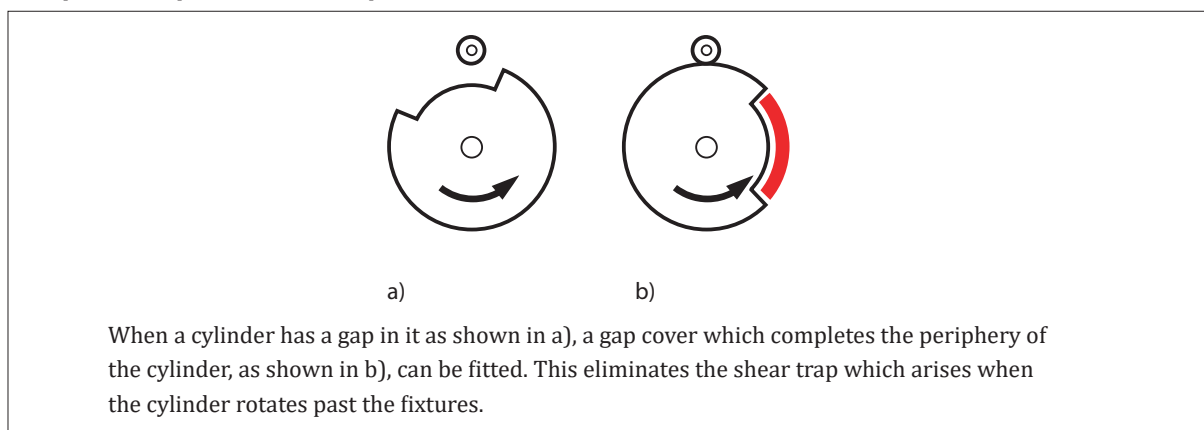


Figure 14 — Removal of shear trap by design**Figure 15** — Gap cover to prevent shear trap

14.6 Stabbing or puncture

The body can be penetrated by:

a) flying objects (see [Figure 16](#)):

- 1) ejection of parts of machinery, for example, the flying shuttle of a loom, a loose cutter on a vertical spindle moulding machine, broken tooling on a press, or the bursting of an abrasive wheel;
- 2) ejection of material, for example, flying swarf, ejection of a workpiece, molten metal ejection from a diecasting machine, sparks generated in a welding process, cartridge tools, debris from rotary mowers and hedge-cutters, or particles blown by compressed air during cleaning; and

b) rapidly moving parts of machinery or pieces of material (see [Figure 17](#)), for example, sewing machines, punching machines.

Stabbing or penetration injuries are affected by sharpness, speed, force or torque, and inertia of machine parts, process material, by-products, etc., in their normal places or on ejection from the machinery. The presence of a surface preventing the body or body part from moving away can aggravate the effect.

Where there is a risk of small or sharp ejected objects penetrating the skin, the use of sheet material instead of mesh should be considered for guards.

Figure 16 — *Stabbing and puncture by flying objects*

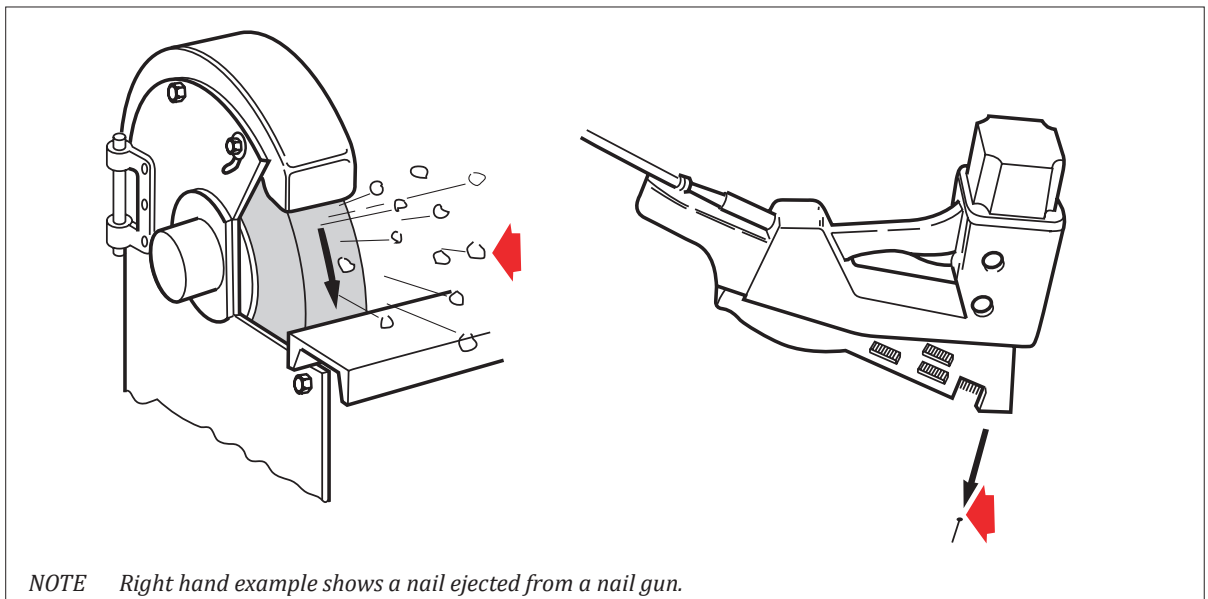
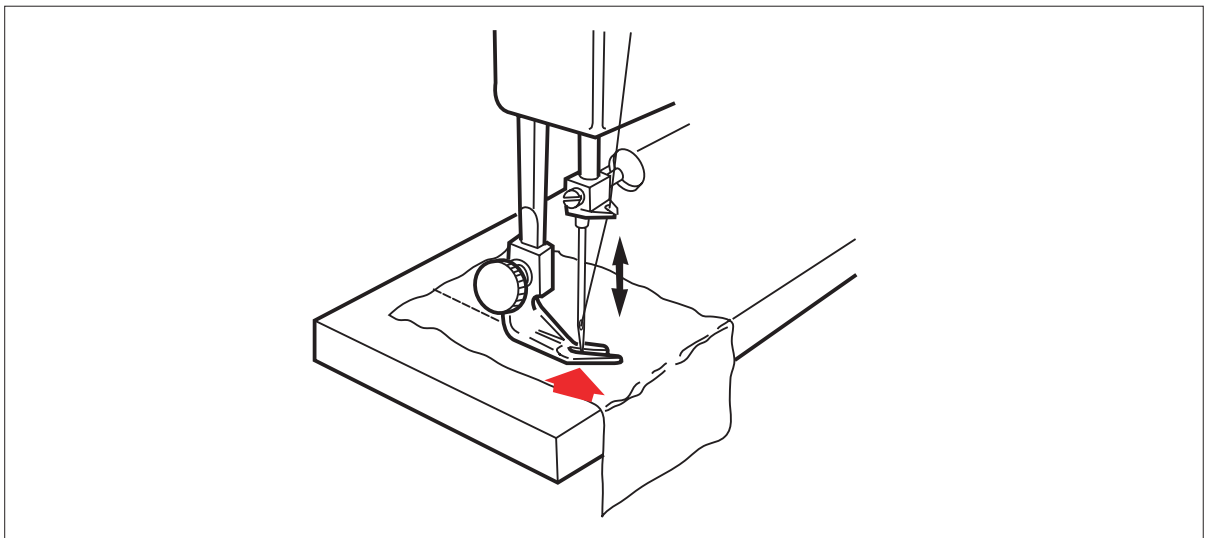
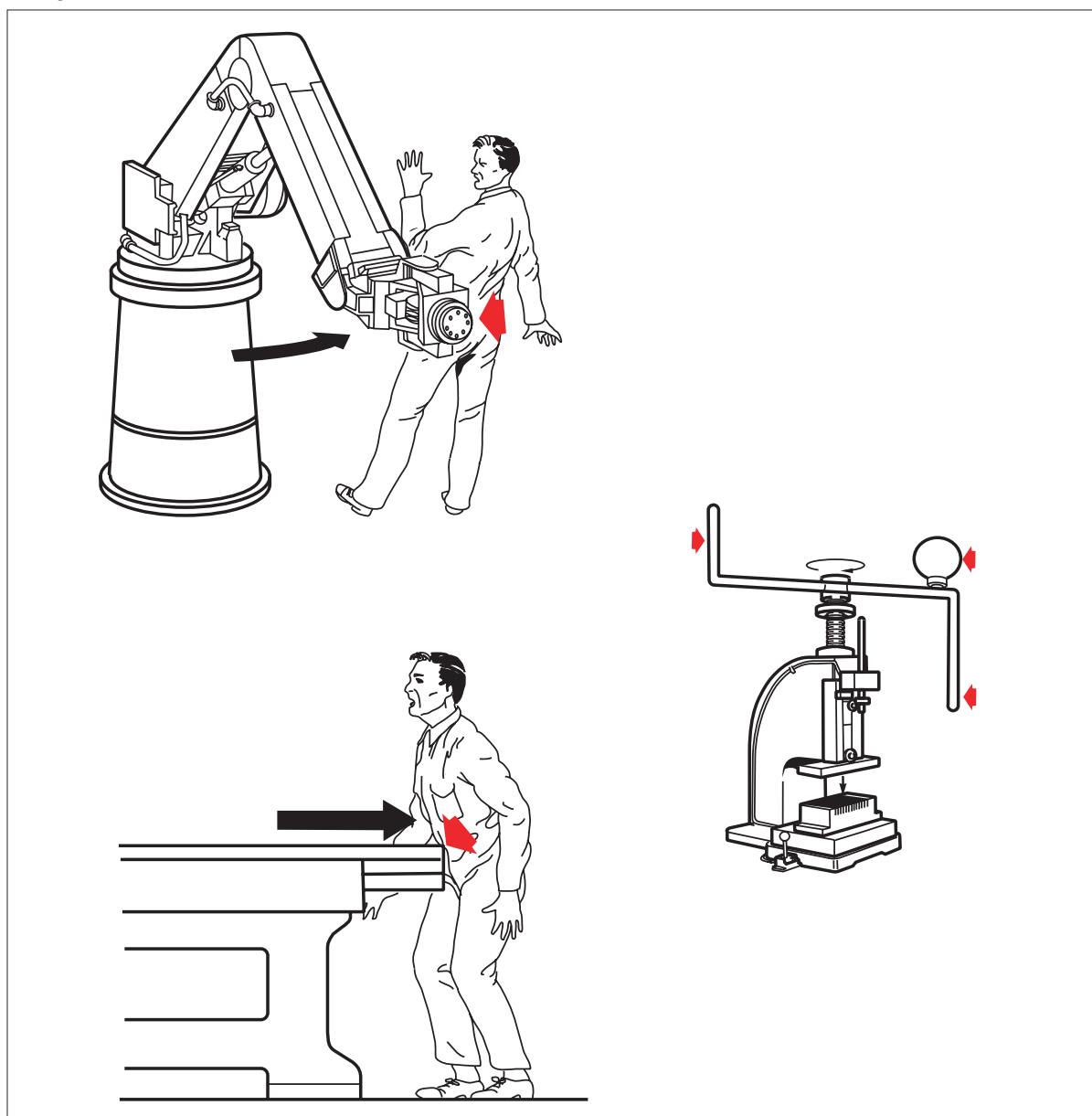


Figure 17 — *Stabbing and puncture by rapidly moving parts of machinery or pieces of material*



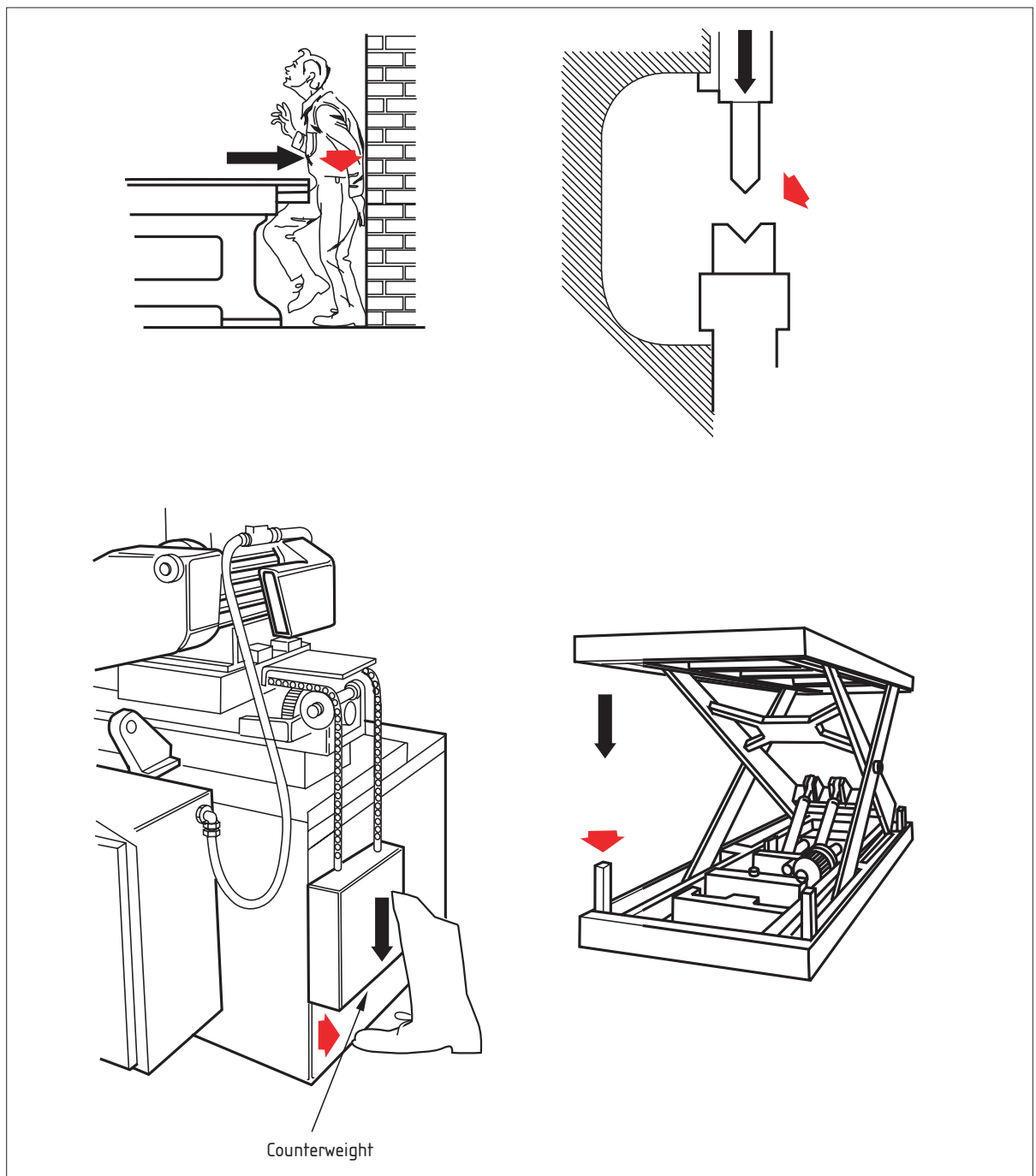
14.7 Impact

Impact hazards are caused by objects which act against the inertia of the body but do not penetrate it (see [Figure 18](#)), for example, the traversing motion of a machinery part, oscillating pendulum movements, striking by projections or moving counterweights. The considerations for impact injuries are much the same as for stabbing or penetration injuries (see [14.6](#)).

Figure 18 — *Impact hazards*

14.8 Crushing

Crushing occurs when one part of machinery moves against another with a part of the body in between (see [Figure 19](#)), for example, the ram of a forging hammer, the tools of power presses, the callipers of spot-welding machines, the closing nip between two platen motions, hand-fed platen machines, foundry moulding machines, counterweights. The traversing motion of a machinery part, for example, the Table of a machine tool, and a fixed structure not being part of the machinery can also create this type of hazard.

Figure 19 — *Crushing hazards*

14.9 Drawing-in or trapping

Shearing or crushing injuries can be caused when a part of the body is drawn into a running or in-running nip formed in the following ways:

- in-running nips between two counter-rotating parts (see [Figure 6](#)), for example, meshing gears, rolling mills, mixing rolls, press rolls, reel and carriage rolls, dough brakes and moulders or calenders;
- in-running nips between a rotating surface and a tangentially moving surface (see [Figure 20](#)), for example, power transmission belt and pulley, chain and chain wheel, rack and pinion; and
- running nips between a rotating surface and a tangentially moving surface where material, for example, metal, paper, cable and rope, runs on to a reel, drum or shaft.

Drawing-in or trapping, leading to entanglement, shear or crushing, is aggravated by speed or distance of movement, force, torque, inertia, weight or tension, for example, in a belt or in material being reeled up. Surface roughness and any tendency to adhesion have a similar effect (see [Figure 20](#)). Adjacent parts of structures can increase injuries (see [Figure 21](#)).

Figure 20 — Drawing-in hazards between rotating and tangentially moving surfaces

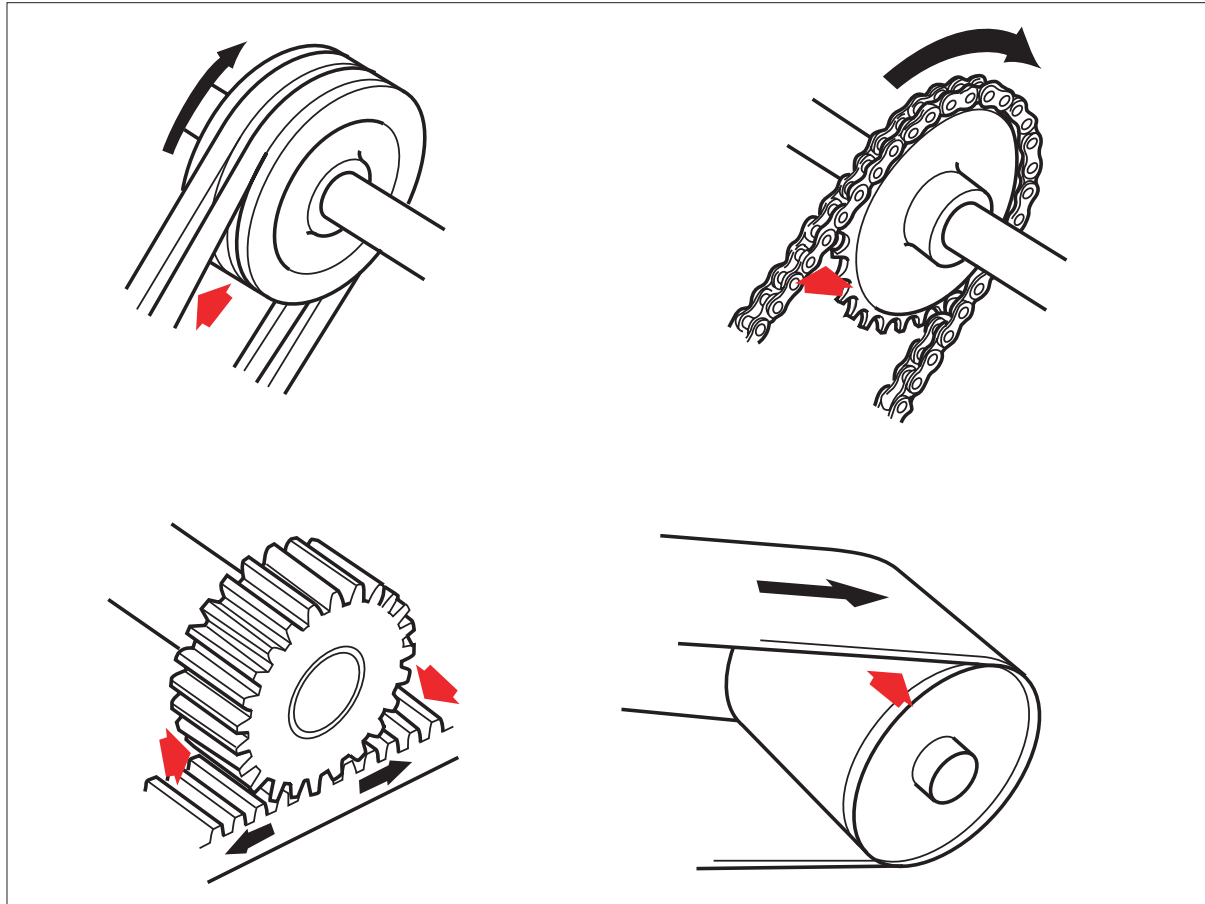
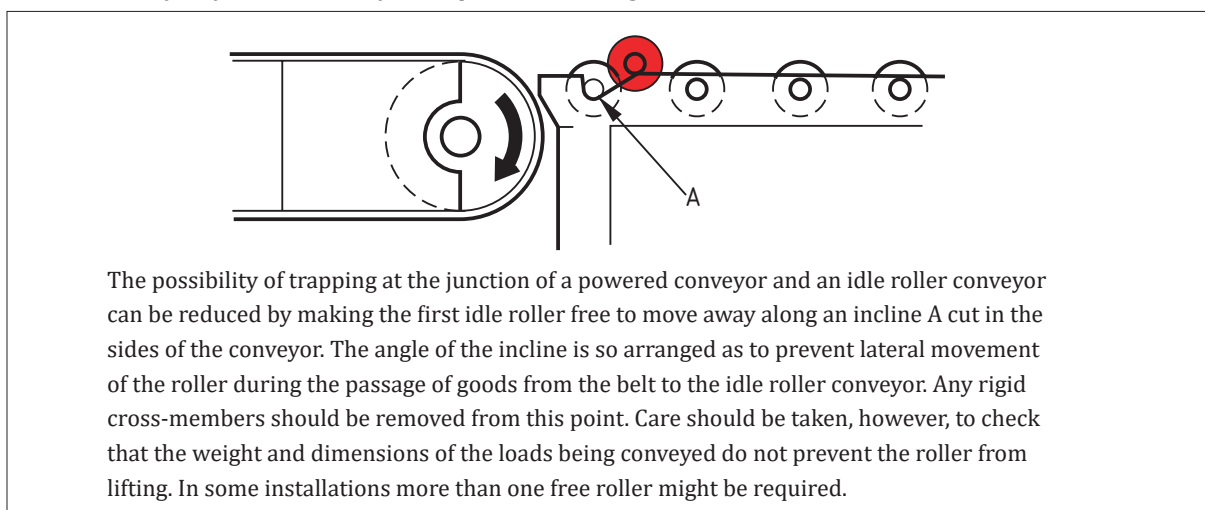


Figure 21 — Roller conveyor: first idle roller free to prevent drawing-in



14.10 Injury by compressed air or high-pressure fluid injection

Injection of fluids through the skin can cause serious tissue damage. Examples of equipment and processes that can cause this type of injury include compressed air jets, diesel injectors, paint sprayers, high-pressure water jetting and high-pressure hydraulic systems (see also [14.6](#)).

15 Non-mechanical hazards

15.1 General

Machinery can present other, non-mechanical hazards that require protective measures to be taken to prevent harm. The nature of these measure depends on the type of hazard. Where measures taken for one hazard could conflict with those taken for another, the aim should be to minimize possible risk. This normally means that precedence is given to dealing with the hazard creating the greatest risk, irrespective of the nature of the hazard. Designers and suppliers ought to have considered all hazards in accordance with BS EN ISO 12100. The nature of these hazards and examples of the availability of advice, together with examples of protective measures and safeguards that could be adopted, are given in [15.2](#) to [15.11](#), but more generally in Clause [16](#).

15.2 Electricity, including static electricity

Electrical hazards include:

- a) injury or death arising from shock and burn as a result of contact of persons with (or approach to, in the case of high voltage equipment) (normally) live parts or parts which have become live under fault conditions or have become charged with static electricity;
- b) thermal radiation and projection of arc products (including chemical effects) arising from short circuits, or overloading, or processes such as electric arc welding; and
- c) risk of ignition of flammable substances due to use of unsuitable electrical equipment or the generation of static electricity by the machine or the process.

General requirements for the electrical equipment of machines are specified in BS EN 60204-1 (and BS EN 60204-11 in the case of high voltage). Hazards due to static electricity are discussed in PD CLC/TR 60079-32-1. Modifications arising, for example, from change of use, should be in accordance with BS EN 60204-1 and PD CLC/TR 60079-32-1.

Other injuries, for example, those arising from a fall, can result from someone reacting to an electric shock.

15.3 Thermal

Thermal hazards include:

- a) contact with parts or materials operating at extremes of temperature (hot or cold);
- b) flames or explosions and radiation from heat sources; and
- c) hot or cold working environment, including trapping within a hot (e.g. oven) or cold (e.g. freezer) compartment.

Designers and suppliers ought to have used protective measures, together with the information necessary, to adequately reduce the risk arising from these hazards. Protective measures include the use of enclosures, insulation, radiation shields, splash guards, barriers to prevent contact, warning signs and notices, personal protective equipment and safe systems of work.

15.4 Noise

Exposure to excessive noise can result in:

- a) permanent hearing loss;
- b) tinnitus;
- c) tiredness;

- d) stress;
- e) loss of balance and loss of awareness; or
- f) interference with speech communication and awareness of auditory signals.

Noise reduction should be taken into account when designing protective measures for mechanical hazards. It is often possible for guard enclosures to be designed to serve the dual purpose of protection from mechanical hazards and reducing noise emissions. Guard panels should not add to the machinery noise levels due to poor design or fixing. Additional protective measures include screens fitted to the machine and silencers. Consideration should also be given to the overall noise levels where machinery is installed. Whilst a new machine might not by itself give rise to excessive noise levels the effect of its addition should be measured.

NOTE Attention is drawn to the Control of Noise at Work Regulations 2005 [6], particularly relating to the limits of levels of exposure to noise. Further information is given at www.hse.gov.uk.

Where noise reduction at source is not practicable, persons can be protected against the effects of excessive noise by the use of personal protective equipment (see 77.5).

15.5 Radiation

Exposure to excessive non-ionizing or ionizing radiation can result in immediate harm (e.g. burn injury) or give rise to long-term effects (e.g. genetic mutations).

Types of non-ionizing radiation include:

- a) electromagnetic radiation (for example, in the frequency ranges from low frequency through radio frequencies up into microwave); and
- b) light, including infra-red, visible, ultra-violet and laser light radiation.

Sources of non-ionizing radiation include electrical equipment and equipment specifically designed to generate radiation (for example, radio frequency transmitter, cavity magnetron, laser, light source) and other non-electrical equipment (for example, hot billet in a steel rolling mill, glass bottle-making machine).

Types of ionizing radiation include alpha, beta and gamma rays, X-rays, electron or ion beams and neutrons. Typical sources of ionizing radiation are X-ray, electron and ion beam generators, and sealed radioactive sources. A typical application is on semiconductor device manufacturing machines.

Protective measures include the use of, for example:

- 1) filtering and absorption; and
- 2) attenuating screens or guards.

NOTE Attention is drawn to the Ionising Radiation Regulations 2019 [7] and BS EN 12198 (all parts) for non-ionizing radiation.

15.6 Use of harmful materials and substances

Certain materials and substances processed, used, produced or exhausted by machinery, and materials used to construct the machinery, can give rise to hazards such as:

- a) fire and explosion;
- b) harm arising from ingestion, contact with the skin, eyes and mucous membranes or inhalation of fluids, gases, mists, fumes, fibres, dusts or aerosols (e.g. toxic, corrosive, teratogenic, carcinogenic, mutagenic, irritant or sensitizing effect); and
- c) biological (mould) and micro-biological (viral or bacterial).

Protective measures include:

- 1) complete enclosure with means to maintain a negative pressure differential with the surroundings;
- 2) local exhaust ventilation with filtration;
- 3) wetting with liquids; and
- 4) special ventilation in the area of the machine (air curtains, cabins for operators).

15.7 Vibration

Vibration can be transmitted to the hands and arms (use of hand-held and hand-guided machines) or to the whole body (use of mobile equipment). Serious disorders (such as low-back morbidity and trauma of the spine) and serious discomfort resulting from whole body vibration and vascular disorders (for example, white finger disease, neurological, osteo-articular disorders) from hand-arm vibration result from the most severe vibration or lower levels over a long period of time.

Protective measures include damping devices to isolate the exposed person from the source of vibration, such as resilient mounting or suspended seats. Measures for vibration isolation of stationary industrial machinery are given in BS EN 1299.

15.8 Poor ergonomics

Failure to apply good ergonomic principles in machine design can result in:

- a) physiological effects (e.g. musculo-skeletal disorders) resulting, for example, from unhealthy postures, excessive or repetitive efforts;
- b) psycho-physiological effects generated by, for example, mental overload or underload, or stress arising from the operation, supervision or maintenance of the machine; or
- c) human errors.

Advice on ergonomic principles is given in BS EN ISO 12100 (see also Clause [48](#) and [Annex A](#)).

15.9 Inadequate access

Inadequate (e.g. poorly designed or maintained) access can give rise to injuries from slips, trips and falls (protective measures are discussed in [38.3](#) and [72.3](#)).

15.10 Environment

Machines are designed for use in particular environments and the necessary protective measures should be put in place in accordance with the instructions provided with the machine. Where a machine is used in an environment outside its original range of intended use, any additional hazards should be taken into account and the necessary protective measures implemented.

15.11 Hygiene

Hygiene issues are associated with the ability of machines to be freed from product debris and microorganisms, and thus prevent product contamination, rather than the dangers of moving parts or electrical hazards to the operator (see BS EN ISO 14159). Machinery used in certain industries, notably for the processing of food and pharmaceuticals, should be designed so that it can be readily cleaned without risk of harm.

Where guarding is added at a later stage, it should allow adequate facilities for the cleaning of both the machine and the guard.

Section 5: Aspects of machine design to eliminate or reduce risks

16 Design for safe use

Designers of machinery ought to have followed the general principles given in BS EN ISO 12100, in particular the three-step method of risk reduction:

- 1) inherently safe design measures;
- 2) safeguarding and/or complementary protective measures; and
- 3) information for use,

and taken account of the relevant type-B and type-C standards. However, certain checks by the user remain necessary.

17 Checks by user

Under the Provision and Use of Work Equipment Regulations 1998 [2] (see HSE Approved Code of Practice L22, *Safe use of work equipment* [3]) users have a duty to ensure that machinery is safe for use. The guidance given in HSE guidance document INDG271, *Buying new machinery* [4] on the checks to be carried out on new machinery might be useful when assessing the safety of an existing machine.

The following non-exhaustive list can be used as a basic guide for checking the safety of a machine as part of a documented risk assessment (see [Section 3](#)).

- Do any parts look dangerous, e.g. exposed gear wheels, cutters?
- Are there guards? If so, are they securely in place?
- Do the guards prevent access to all the dangerous parts?
- Can the machine operate with the guards removed?
- Are there other protective devices, e.g. electro-sensitive protective equipment?
- Are the protective devices effective, e.g. in terms of coverage and stopping reaction time?
- Are the controls understood?
- Can dust, fumes or other hazardous emissions escape from the machine?
- Is the machinery excessively noisy?
- Is there excessive vibration?
- Are any exposed parts likely to be extremely hot or cold?
- Are any live electrical parts exposed or easy to get at?
- Can all necessary parts be safely accessed for adjustment, maintenance and/or inspection, etc., especially those at height?
- Are there any special features, e.g. slow running speed for use when setting, jigs or push sticks?
- Are the manufacturer's instructions available and, if so, are they clear and comprehensive?
- Has the machine been modified since manufacture?
- Is appropriate safeguarding provided for all the reasonably foreseeable uses?

- Have ergonomic principles been taken into account, e.g. can controls be easily operated, indicators easily read?
 - Is visibility sufficient from the control positions?
 - Is access safe, including when at height?
 - Can persons get trapped with the machine or machine compartments or enclosure?
-

18 Further considerations for safeguards

18.1 General

The selection of a safeguard should take into consideration the environment in which it is to be used. It should be capable of withstanding the conditions likely to be experienced and should not of itself create a hazard as a result of the environment.

18.2 Corrosion

If a safeguard is likely to be exposed to a corrosion risk, special measures should be taken, such as the use of corrosion-resistant materials or corrosion-resistant surface coatings.

18.3 Coolant and swarf

Machinery should be designed as far as is reasonably practicable to contain coolant and/or swarf so as not to expose persons to additional hazards.

18.4 Waste and spillage removal

Attention should be paid to safety in the area surrounding the machine, for example, protecting persons from hazards caused by leaking oil, coolant, etc. Safe means should be provided for the removal of swarf, trade waste or spilled materials.

18.5 Mist, fumes and dust

Where machinery gives rise to hazardous or objectionable levels of mist, fumes or dust, containment or suitable extraction equipment should be provided (see also [15.6](#)). Biological hazards from any fluids associated with the machine, and how exposure to these might be realized, should also be included.

NOTE Attention is drawn to the Control of Substances Hazardous to Health Regulations 2002 [\[8\]](#) regarding acceptable levels of exposure to mist, fumes and dust and occupational exposure limits and occupational exposure standards. These are given in HSE Guidance Note EH40/2005 [\[9\]](#).

19 Controls

19.1 Position

The controls should be positioned so that the operator has adequate visibility for control of the process being undertaken and any person in the hazardous area is visible. Where this is not practicable, other means, for example, presence-sensing devices or safe systems of work, should be used to prevent persons from remaining undetected within the hazardous area.

The controls should be positioned and spaced for safe and easy (i.e. ergonomic) operation. There should be sufficient clearance between each control and also between controls and other parts of the machinery such that their operation does not cause additional risk [see BS EN ISO 12100:2010, [6.2.8f](#)]. Controls should be placed so that the operator can reach them easily without stretching or moving from the normal working position.

The controls most frequently used should be placed in the most accessible positions. To reduce the possibility of error when an operator changes from one unit of machinery to another of similar type, a standard layout should, where practicable, be adopted for machinery and work situations having the same pattern of operation.

Start controls should be shrouded, gated or so positioned that the possibility of inadvertent operation is minimized.

A stop control should be positioned near to each start control.

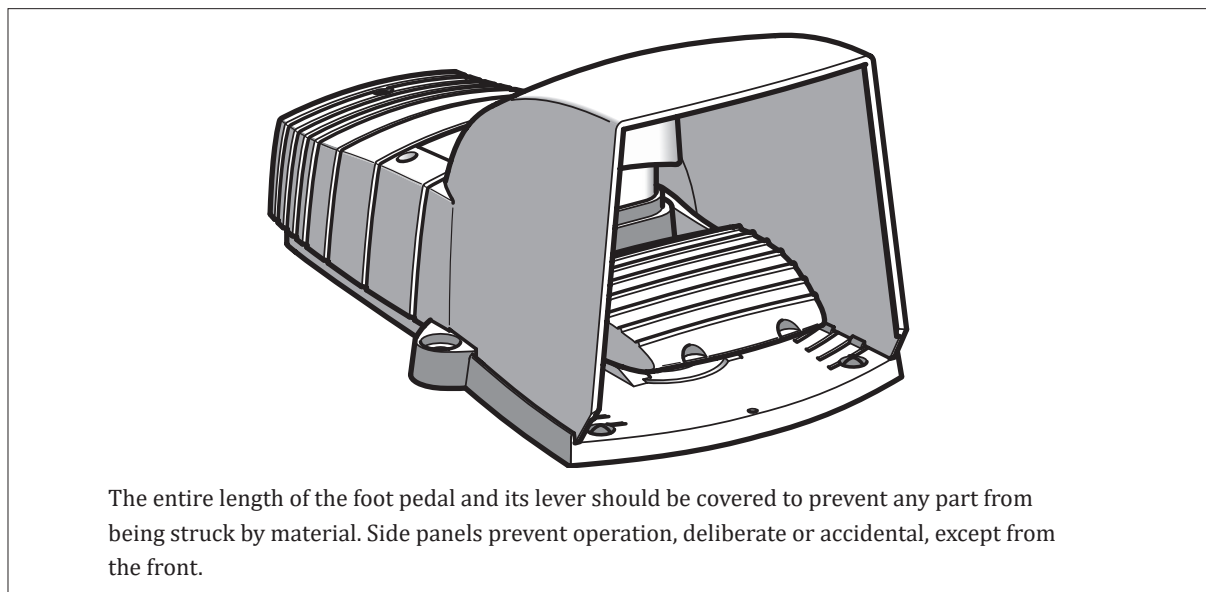
Where a machine has more than one control station (including remote or service control), measures should be provided to ensure that commands from different control stations do not lead to a hazardous situation. This can be achieved by providing unambiguous control circuit selection at a master control station overriding all other controls, so that the start control can be transferred from one position to another. These and other methods are discussed in further detail in BS EN 60204-1 and BS EN 61310-3 (see also Clause 29).

Handles, hand-wheels and levers should be positioned so that, when they are operated, the possibility of inadvertently operating other controls is minimized.

Two-hand controls should be placed, separated and protected as to prevent them from being operated by any means other than with two hands (see Clause 53 and BS EN ISO 13851).

Foot-operated controls, other than for emergency stop, should be adequately shrouded or otherwise arranged to prevent, as far as possible, accidental operation from any cause. Pedals should not be of greater width than that required for foot operation. Movable pedals should be shrouded to permit access from one direction only (see Figure 22 and also 19.4 for permissive controls).

Figure 22 — *Foot pedal protected from accidental operation by means of a cover*



19.2 Identification

Controls should be clearly identifiable and readily distinguishable from each other by their separation, size, shape, colour or feel, and by labelling with either words or symbols to identify the function or consequence of their use [see BS EN ISO 12100:2010, 6.2.8f), BS EN 60204-1, BS EN 61310-1 and BS EN 61310-2].

Controls for starting or stopping a machine should be clearly marked (see also BS EN 60204-1 and BS EN 61310-2).

Emergency stop and emergency switching off controls should be coloured red, with a yellow background where one exists, in accordance with BS EN 60204-1:2018, **10.7**, and BS EN ISO 13850:2015, **4.3.6** (see also [56.2](#)).

19.3 Operation

The direction of movement of a control should correspond with the direction of motion being controlled. For example, where a handle or hand-wheel controls a sliding part, clockwise rotation should direct movement of the part away from the operator, to their right or in an upward direction. A lever requiring movement towards, or away from, the operator should result in corresponding movement of the moving part (see also BS EN 61310-3).

Where practicable, the type of control and direction of movement of control should be varied so as to minimize the possibility of operating the wrong control.

19.4 Controls for machinery setting or adjustment and for feeding material

Generic terms for controls for machinery setting or adjustment and for feeding material include inch, jog, slow crawl, etc. The definitions and usage of these terms can vary in accordance with the type of machine and industry.

As far as practicable, tasks requiring manual intervention should be performed from outside the safeguarded space.

Where a guard needs to be displaced or removed for setting or adjustment of machinery or the feeding of material while the machinery is in motion, other protective measures should provide an adequate level of protection. Examples of other protective measures include:

- a) a protective device requiring sustained action [e.g. hold-to-run control (see Clause [51](#)), enabling device (see Clause [52](#))];
- b) reducing speed;
- c) reducing torque;
- d) limited movement device (inch or jog); and
- e) identifying and providing safe position(s) and safe access to perform troubleshooting tasks.

The enabling device should be of three-position-type (see BS EN 60204-1:2018, **10.9**).

NOTE Examples of reduced speeds from published standards are less than 10 mm/s for presses, less than 250 mm/s for robots, less than 250 mm/s for non-shearing hazards, and less than 33 mm/s for shearing hazards.

19.5 Handles and hand-wheels

Where a handle or hand-wheel is provided to operate a mechanism that can also be driven by mechanical power, the handle or hand-wheel should not rotate when the power drive is operating. Where this cannot be achieved, hand-wheels should be of the solid type without spokes or projections.

19.6 Warning signals

Where people can be exposed to hazards when the machine starts (for example, when persons can be undetected in hazardous locations not clearly visible from a start control), audible and visual warning devices might be necessary. These should operate for a predetermined time before the machinery starts to operate. The audible signals should be easily distinguishable from those at other machines.

Where malfunction of the machinery creates a hazardous situation, suitable warning signals, audio and visual, should be given, preferably automatically.

While audible and visual warnings might be provided in addition to physical safeguards, they cannot be provided as substitutes.

Further information on warning signals is given in BS EN ISO 12100:2010, **6.4.3**, BS EN ISO 7731 and BS EN 61310-1.

19.7 Program or sequence control

Where machinery is program- or sequence-controlled, parts that might not normally be considered as potentially harmful could become so in the event of program or sequence error, failure or malfunction, resulting in, for example, over-speeding of normally slow-moving parts or unexpected movement during setting-up. Therefore, a risk assessment ought to have been carried out by designers (see [Section 3](#) and [Section 4](#)). This ought to have considered risks arising from program or sequence malfunctions in all phases of machine life, for example, unexpected operation of a workpiece clamp.

Assurance of the integrity of control systems, including programmable electronic systems, is described in Clause [68](#). Programmable systems are described in Clause [39](#).

20 Indicators

Where necessary, one of the following reading indicators should be provided to warn of a potentially hazardous situation [see BS EN ISO 12100:2010, **6.2.8g**].

- a) Qualitative: shows a satisfactory or unsatisfactory state, e.g. a temperature gauge which indicates cold-normal-hot.
- b) Quantitative: provides numerical data and, as such, requires precision in reading, e.g. a pressure gauge. A quantitative indicator should not be used if a qualitative one would suffice, except where it has been combined with a qualitative indicator.
- c) Check reading: gives information automatically or when demanded about the state of the equipment, e.g. an indicator light and/or audible alarm. See BS EN 60204-1 and BS EN 61310-1 for recommended colours of indicator lamps.

Indicators designed to minimize the risk of their failing to indicate a potentially dangerous situation should be selected.

21 Unexpected/unintended start-up

Unexpected/unintended start-up (see [3.20](#)) is one of the most common causes of accidents at machinery. Therefore, preventing unexpected/unintended start-up whilst persons are present in hazardous areas is one of the most important requirements for the safe use of machinery. Machinery should have adequate means to prevent unexpected/unintended start-up (see also BS EN ISO 14118 and BS EN 60204-1:2018, **5.4**).

Means for isolation and energy dissipation are recognized ways of preventing unexpected/unintended start-up. Activities that require, for example, the dismantling of machine parts or alterations to, or testing of, power circuits, generally require this (for electrical equipment, see [75.3](#) and BS EN 60204-1:2018, **5.5** and **5.6**). The user should ensure by a safe system of work that the means provided are properly used.

However, for some tasks, isolation and energy dissipation might not be practicable. For example, although it does not achieve isolation and energy dissipation, it might be appropriate to use means such as control interlocking to maintain the stopped condition whenever a person is carrying out a particular task.

When designing such an interlocking system, the level of risk to which a person will be exposed during a particular task should be assessed and the interlocking system designed to an appropriate level of integrity to mitigate that risk.

Means that do not fulfil the isolation function (for example a contactor or solenoid valve switched off by a control circuit) may only be used for prevention of unexpected start-up during tasks such as:

- a) inspections;
- b) adjustments;
- c) work on electrical equipment where:
 - 1) there is no hazard arising from electric shock and burn;
 - 2) the means for switching off remains effective throughout the work; and
 - 3) the work is of a minor nature (for example, replacement of plug-in devices without disturbing existing wiring); and
- d) work on fluid power systems where:
 - 1) there is no hazard arising from release of pressurized fluid;
 - 2) the means of switching off remains effective throughout the work; and
 - 3) the work is of a minor nature.

The selection of means is dependent on the risk assessment, taking into account the skill required for their proper use. Some means can be inappropriate for use by unskilled persons, e.g. where disconnection under load can be hazardous.

If, in the course of carrying out the task, the situation changes (for example, increased duration, nature of the intervention, consequences of any unexpected start-up) such that the risk increases, then reliance on the means selected for preventing an unexpected start-up might no longer be appropriate.

Emergency stop systems are not intended to prevent an unexpected start-up of a machine, nor are they designed to mitigate the risk associated with any particular task. Therefore, emergency stop devices should not be used for these purposes.

22 Measures for the escape and rescue of trapped persons

Measures for the escape and rescue of trapped persons should be provided where necessary, for example:

- a) escape routes and shelters in installations generating operator trapping hazards;
- b) escape doors in guards or enclosures;
- c) arrangements for operating some machine elements by hand;
- d) arrangements for reversing the direction of operation or stopping of the appropriate machine elements;
- e) anchorage points for descender devices; and
- f) means to enable trapped persons to call for help, stop the machine or elements posing the hazard; or to effect their own escape.

The user should ensure that the means provided are properly used and maintained.

23 Clutches

Clutches are mechanical engagement and disengagement devices which, in mechanical interlocking systems, interrupt transmission of the motive force. Whether actuated by mechanical or other means, disengagement of the clutch should not depend on the availability of the power supply. This is commonly achieved by using compression type springs. The springs should be adequately rated and be of sufficient strength to secure prompt and effective clutch disengagement. Any set of springs used on a clutch should be closely uniform in dimension, quality and rating. A single spring should not be relied upon unless equivalent safety is provided by other means. The means for loading the springs should be such that, when correctly adjusted, the spring anchorages can be locked to prevent risk of slackening-back.

24 Braking systems

24.1 General

Braking systems should bring hazardous moving parts to rest with a consistent performance and as quickly as possible without generating other hazards, such as ejection of parts or material due to shock loading effects. Where necessary, the stopped position should be maintained.

As the braking capacity required is related to the momentum of the moving parts, their momentum should be kept as low as the application permits. A clutch mechanism can be used as a means of limiting the momentum to be dealt with by the brake.

Rotating parts and equipment fastened to rotating parts should be secured to prevent their dislodgement as a consequence of the brake action. Adequate precautions should be taken to prevent disengagement of screwed components (for example, retaining nuts for circular saw blades) due to reversed torque following brake application.

All braking systems should be designed to minimize the risk of failure to danger.

24.2 Mechanical (friction) braking systems

Mechanical (friction) brakes, for example, drum, disc or external calliper, rely for their effect on the action of friction material on a moving surface, usually of smooth metal.

Interruption of the power supply should not prevent application of the brake and, in many cases, their design is such that they are spring-applied and power released.

Brakes should be of such capacity as to perform satisfactorily under conditions of maximum sustained use. The design should provide for adequate dispersal of heat to prevent excessive temperature rise of the working parts.

To prevent overheating or premature wear of the friction material, the risk of binding should be minimized, for example, by regular maintenance.

Where the effectiveness of braking could be adversely affected by contamination, or by the ingress of moisture or oil, consideration should be given to:

- a) selecting an appropriate friction material;
- b) providing an effective housing to prevent ingress; and
- c) monitoring braking efficiency and supplying control systems that prevent motion when efficiency is below the acceptable level.

When springs are used, they should be of the compression type, adequately rated and of sufficient strength to secure prompt and effective brake application. Any set of springs used on a brake should

be closely uniform in dimension, quality and rating. A single spring should not be relied upon unless equivalent safety is assured by other means. The means for loading the springs should be such that, when correctly adjusted, the spring anchorages can be locked to prevent risk of slackening-back.

Adequate instructions for the setting of the brake should be available and include:

- 1) the length to which the spring(s) can be compressed; and
- 2) the setting of the operating mechanism.

In certain applications it is essential that the brake is released only when torque is available at the driving motor, for example, the hoist motion of a crane. The electrical circuit should be designed so that failure of part of the circuit cannot cause loss of control of the motor while leaving the brake disengaged. Precautions should also be taken against the possibility of a similar danger being caused by failure of one phase of a three-phase supply. It is also essential that the motor torque is sustained until the brake has taken effect (see BS EN 60204-32:2008, **9.3.4** and **9.4.4**).

Care should be taken that brakes designed for holding purposes are not unduly stressed as a result of being used to dynamically brake the load (e.g. premature application when the load has not stopped).

When hydraulic or pneumatic means are used to apply mechanical brakes, an accumulator/reservoir should be connected as close as possible to the brake to ensure a sufficient supply of fluid in the event of failure of the main supply. The accumulator/reservoir should have a low-pressure device to switch off the machinery if the pressure in the accumulator/reservoir falls below a safe limit and the feed should be fitted with a non-return valve. Further safety requirements for hydraulic and pneumatic systems are specified in BS EN ISO 4413 and BS EN ISO 4414, respectively.

24.3 Electrodynamic braking systems

24.3.1 General

Electrodynamic braking systems are arrangements by which electromagnetic forces are used directly to bring the moving part(s) to rest, for example, within the drive motor itself. Such systems have widespread application but they can fail to danger in the event of supply failure. When required, they can be connected in such a way that their function is performed when emergency stop controls are used.

24.3.2 Reverse plugging

Reverse plugging is a method of braking by which the electrical connections to a motor are changed so that a reverse torque is applied and the machine is brought rapidly to rest. The contactor should open when the motor stops, to prevent the machine restarting in the reverse direction.

24.3.3 d.c. injection

d.c. injection consists of disconnecting the motor stator windings from the a.c. supply and reconnecting them to a d.c. supply. This has a powerful braking effect and has an advantage over reverse plugging (see [24.3.2](#)) in that there is no tendency to restart in the reverse direction.

NOTE Frequent use of d.c. injection braking can give rise to increased motor temperatures.

24.3.4 Capacitor regenerative braking for a.c. motors

Capacitor braking for a.c. motors consists of the following.

- a) Disconnecting the motor from the a.c. supply and reconnecting it to a capacitor bank. The capacitor helps to maintain the self-excitation of the motor and there is an induced braking effect.