

Guidance on safe use of machinery

ICS 13.110

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Introduction by Dr Paul Davies

Chief Scientist and Engineer of the Health and Safety Executive

The Health and Safety Executive (HSE) welcomes the publication of PD 5304:2005 by the British Standards Institution which was developed by the Institution's relevant national technical committees with contributions and support from HSE.

PD 5304:2005 covers the safe use of machinery and provides comprehensive guidance on practical measures and techniques that may be applied to machinery so as to safeguard operators, maintenance personnel and others. The guidelines deal with issues ranging from selection of protective measures and safeguards through to practical examples of guard design and their application.

The progress made on the development of technical requirements embodied in European standards in support of the Machinery Directive (98/37/EC) is an important factor in machinery safety. This has been recognized during the development of PD 5304:2005 and the basic principles of safeguarding are described with reference to current harmonized European machinery safety standards.

HSE recognizes that guidance on these topics is required for users of machinery to satisfy duties under the Provision and Use of Work Equipment Regulations 1998. This standard will provide much of this guidance, as it is applicable to any machine during its modification, refurbishment or change of use by persons that are competent in relevant aspects of machinery safety.

We have therefore been pleased to have been able to contribute to and support the development of PD 5304:2005 as its contents form an essential part of the technical framework that should be used to improve safety of machinery in the workplace. Its recommendations on the proper application of safeguards and safe working practices may also contribute towards safety in other industry sectors.

I am pleased to introduce PD 5304:2005 and commend its guidance to you as a valuable contribution to safe use of machinery in this country.

A handwritten signature in blue ink, appearing to read 'Paul Davies', is shown within a light blue rectangular box.

Paul Davies

Foreword

This Published Document has been prepared by Technical Committees MCE/3 and GEL/44. It supersedes PD 5304:2000, which is withdrawn.

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

This edition has been updated to take account of the requirements contained in the current harmonized European machinery safety standards and to help the user to maintain those safety requirements when upgrading, refurbishing or changing the use of machinery.

NOTE The Bibliography provides a full list of available transposed harmonized European standards relevant to machinery safety current at the time of publication.

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 [1] and the Provision and Use of Work Equipment Regulations 1998 [2].

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

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

This Published Document is not to be regarded as a British Standard.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to viii, pages 1 to 207 and a back cover.

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Section 1. General

1.1 Scope

This Published Document provides guidance on the safe use of machinery supplied prior to the Supply of Machinery (Safety) Regulations 1992 [3] (normally machines supplied before 1995).

It also provides guidance for users on:

- machinery designed to and manufactured in accordance with harmonized European machinery safety standards insofar as it is necessary, when following the instructions supplied for use; and
- basic principles of safeguarding, with reference to current harmonized European machinery safety standards.

It is intended that this guidance can be applied to any particular machinery during its modification, refurbishment, upgrading or change of use in order to satisfy the Provision and Use of Work Equipment Regulations 1998 [2]. See also the approved code of practice *Safe use of work equipment* [4].

However significant modification, refurbishment, upgrading or change of use to existing machinery that results in, for example changes of the measures used to control a hazard(s) or the introduction of a new hazard(s), can make it necessary to satisfy relevant requirements from the Supply of Machinery (Safety) Regulations 1992 [3] in particular Schedule 3.

NOTE 1 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 1992 [3].

NOTE 2 Attention is drawn to the Supply of Machinery (Safety) Regulations 1992 [3] for machinery which has been subject to significant modification, refurbishment, upgrading or change of use and is intended to be made available for supply to a third party.

1.2 Normative references

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

BS 4211, *Specification for ladders for permanent access to chimneys, other high structures, silos and bins.*

BS 6423, *Code of practice for maintenance of electrical switchgear and controlgear for voltages up to and including 1 kV.*

BS EN 294:1992, *Safety of machinery — Safety distances to prevent danger zones being reached by the upper limbs.*

BS EN 418:1992, *Safety of machinery — Emergency stop equipment, functional aspects — Principles for design.*

BS EN 982, *Safety of machinery — Safety requirements for fluid power systems and their components — Hydraulics.*

BS EN 983, *Safety of machinery — Safety requirements for fluid power systems and their components — Pneumatics.*

BS EN 999, *Safety of machinery — The positioning of protective equipment in respect of approach speeds of parts of the human body.*

BS EN 1760-1, *Safety of machinery — Pressure sensitive protective devices — General principles for the design and testing of pressure sensitive mats and pressure sensitive floors.*

BS EN 1837, *Safety of machinery — Integral lighting of machines.*

BS EN 60204-1:1998, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements.*

BS EN 60204-11, *Safety of machinery — Electrical equipment of machines — Part 11: Requirements for high voltage equipment for voltages above 1 kV AC or 1.5 kV DC and not exceeding 36 kV.*

BS EN 60947-4-1:2001, *Specification for low-voltage switchgear and controlgear — Part 4: Contactors and motor starters — Section 1: Electromechanical contactors and motor starters.*

BS EN 60947-5-3, *Specification for low-voltage switchgear and controlgear — Control circuit devices and switching elements — Requirements for proximity devices with defined behaviour under fault conditions (PDF).*

BS EN 61810-1, *Electromechanical non-specified time all or nothing relays — Part 1: General requirements*.
PD CLC/TR 50404:2003, *Electrostatics — Code of practice for the avoidance of hazards due to static electricity*.

1.3 Terms and definitions

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

1.3.1 failure to danger

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

1.3.2 guard

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

NOTE 1 A guard can either act:

- 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
- 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, enclosing guard.

NOTE 3 Further information on types of guards and their requirements are given in BS EN ISO 12100-2:2003, 5.3.2 and BS EN 953.

1.3.3 harm

physical injury or damage to the health of persons

1.3.4 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:

- 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
- 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).

1.3.5 hazard zone danger zone

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

1.3.6 integrity

ability of a machine, components, devices, systems and procedures to perform a required function under specified conditions and for a given period of time reliably and without defeat

1.3.7 intended use of a machine

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

1.3.8 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)

1.3.9**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.

1.3.10**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.

1.3.11**protective measure**

measure intended to achieve risk reduction, implemented by:

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

[BS EN ISO 12100-1:2003, 3.18]

1.3.12**reasonably foreseeable misuse**

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

1.3.13**risk**

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

1.3.14**safeguard**

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

1.3.15**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 12100-2:2003, Clause 5, gives more information on safeguarding.

1.3.16**safety function**

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

[BS EN ISO 12100-1:2003, 3.28]

1.3.17**safe working practice**

safe system of work, i.e. a method of working that eliminates or reduces the risk of harm

1.3.18**scotch**

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

1.3.19

unexpected start-up

unintended start-up

any 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 start command which is the result of a failure in, or an external influence on, the control system;
- a start command generated by inopportune action on a start control or other parts of the machine as, e.g., a sensor or a power control element;
- restoration of the power supply after an interruption;
- 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 not intended, but could be considered to be unexpected from the point of view of the operator. Prevention of accidents in this case involves the use of safeguarding measures (see BS EN ISO 12100-2:2003, Clause 5).

1.3.20

use

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

Section 2. Application and strategy for selecting protective measures

2.1 Application and objective of the guidance

2.1.1 Intended users of the published document

This Published Document is intended for those who have responsibility directly or indirectly for use [see in particular 2.2.3d), e), f), g) and h)] and refurbishment, upgrade or change of use of machinery, machinery guarding or protective devices. It is also intended to be used by those concerned with the development and implementation of safe working practices.

2.1.2 Objective and general principles

The aim of the Published Document is to promote a high standard of machinery safety during use following those other activities described in 2.1.1. It describes and illustrates a variety of protective measures and explains methods by which it is possible to assess which measure or measures 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 specific types of machine, specific recommendations are not given for every type of machine.

The Bibliography provides a list of transposed harmonized standards that are applicable to machinery, many of which are referred to in the text.

2.1.3 Future developments

Developments are constantly being introduced and experience gained to improve the safeguarding of machinery. Users of this Published Document should therefore make themselves aware of any new codes of practice, etc., which might be published from time to time and any other relevant new developments.

2.2 Strategy for selecting safety measures

2.2.1 General

A strategy for reducing risk of harm should be applied to each hazard as follows.

- a) Identify the hazards and assess the risks of injury and damage to health.
- b) Eliminate the hazards by inherently safe design or, where that is not practicable;
- c) Limit the risk by:
 - 1) use of safeguards;
 - 2) use of safe working practices;
 - 3) use of personal protective equipment.

Designers and suppliers ought to have taken account of hazards within the specified limits and intended use of the machine and taken steps to reduce the scale of harm that can be caused, for example by reducing speeds or forces, provision of local exhaust ventilation. An effective way of limiting exposure to hazards for operators is through mechanization of workpiece/material handling by use of, for example, robots, handling devices, transfer mechanisms. However there is still the possibility that persons needing to intervene to rectify faults are exposed to hazards, and this ought to have been taken into account (see also BS EN ISO 12100-2:2003, 4.14).

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, work-holding devices, emergency stop systems, etc. Systematic methods of assessing these devices and systems are available. Systems of work are subject to the same principle, but cannot 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 available 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 the risk.

When a hazard cannot be eliminated or avoided, other measures for reducing the risk should be sought. These measures might include reducing the scale of injury or exposure, providing safeguards and safe working practices, including the use of personal protective equipment. The avoidance of injury and damage to health depends on the reliability of these measures.

Unless a hazard cannot cause harm because of its position, the machinery should be provided with appropriate safety measures (e.g. safeguarding) which eliminate or, where this is not practicable, reduce the risk.

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 reliable than others. The order of priority is determined by reliability and therefore safeguarding and complementary protective measures should be considered before safe working practices. Safeguards and complementary protective measures are considered in Section 6, Section 7, Section 8, Section 9 and Section 10, and safe working practices in Section 12.

Consideration should also be given to using a combination of hazard elimination or risk reduction, safeguarding and safe working practices. As part of a safe working practice, 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 or might not have been taken at the design stage. For the benefit of the user these are considered in Section 5, Section 11 and Section 12.

2.2.2 Selection of protective measures

When applying the strategy for selection, it might not be possible to use the more effective 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. See Section 3 for more information on risk assessments.

2.2.3 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 least reduction in productivity. Production pressures, incentive schemes or well intentioned zeal can lead to safeguards being misused.

Designers and suppliers ought to have designed and constructed safeguards to make misuse of them by bypassing or defeating them, whether deliberately or by accident, as difficult as is reasonably possible. In addition, the elements of safeguarding systems should be reliable since poor reliability encourages attempts at misuse.

See Section 7 regarding the design and construction of guards intended to discourage guard misuse (defeatability). See also BS EN 1088:1996, 5.7 for designs to minimize the possibilities of misuse of interlocking devices associated with guards.

2.2.4 Phases of machine life

So far as is possible, the user should consider 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 shut down;
- e) setting or process changeover;
- f) cleaning;
- g) adjustment;
- h) maintenance;
- 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

3.1 General

The technique of risk assessment formalizes the intuitive process by which designers and safety engineers use their experience to identify hazards, evaluate the risks and decide whether risk reduction is necessary; by either eliminating the hazard or reducing the risk(s) associated with the hazard(s) by selecting appropriate protective measures.

The assessment of risk determines, to a large extent, the protective measures which it is necessary to take.

The following two factors should be taken into account when carrying out a risk assessment.

- a) The severity of potential harm from the hazard under consideration.
- b) The probabilities of occurrence of that harm.

The extent and complexity of the assessment required can only be determined after an initial appraisal of the risks and safety measures.

The guidelines in 3.2, 3.3 and 3.4 describe the underlying principles involved. ISO 14121 (BS EN 1050) outlines some principles for carrying out risk assessments and BS EN ISO 12100-1:2003, Clause 5 specifies the strategy for risk reduction.

Formal and systematic methods of risk assessment for machinery exist and others are currently under development. In particular the review of ISO 14121 will lead to the publication of recommended methods that can be used to practically apply its principles to a range of machine types.

There are methods that apply the principles of risk assessment to the assignment of performance criteria to safety-related electrical control systems for machinery. One such method is given in BS EN 62061:2005, Annex A.

Also the method provided in Annex B for the selection of interlocking systems is available for machinery within the scope of this Published Document.

3.2 Probability of occurrence of harm

When examining a machine either from first principles or by making comparisons, account should be taken of the frequency and/or duration of access to or beyond a danger zone during each phase of machine life, e.g. machine operation and breakdown, commissioning, maintenance, setting and process changeover (see 2.2.4). When carrying out this examination, the user might need to consider situations that were not foreseen by the machine manufacturer, see 2.2.1.

By considering foreseeable human behaviour at each phase, the designer can assess the probable total frequency of access to the danger zones. Next, an estimate should be made of the proportion of each type of access likely to result in harm, which might require a reliability assessment of safety or other features. However the severity of harm for each type of access can vary because of variations in the position of access for different reasons.

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. It is most unlikely that any but the very largest employers using large numbers of similar machines are able to gather sufficient accident data from within their own plant to give a statistically significant indication of the probability of harm from a given type of machine.

Limited accident statistics are available from various sources, for example large employers, employers' organizations and trade unions. The more extensive studies which have been carried out from time to time by the Health and Safety Executive generally indicate accident frequency only in terms of a rate for an industry as a whole over a specific period, without giving specific data on hours of exposure to risk.

The available data have to be interpreted with extreme care and in individual cases, particularly with new types of machinery, judgement of the level of probability of harm should still be based on individual and collective experience of other machinery with similar modes of operation, maintenance, etc.

3.3 Severity of harm

The severity of possible harm has an important influence on the level 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 carries the higher risk and requires a higher level of safety precautions.

Some types of harm, particularly those involving damage to health, are not immediately apparent and can manifest some time after exposure to a hazard has ceased. Other types of harm build up over a long period of exposure to a hazard.

Access to the hazard zone can occur during all phases of machine life (see 2.2.4) and for a variety of reasons, either deliberate or accidental. The following questions should be asked, to determine the possible severity of harm.

- a) What type of mechanical or other hazard is involved? (See 4.2 and 4.3.)
- b) What type(s) of injury are foreseen? (See 4.2.)
- c) What is the probability of each possible severity of harm, given the conditions under which access occurs?

Having carried out all these assessments, the risks for each type of access can be determined and the total risk assessed.

3.4 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 considered. 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 3.1, 3.2 and 3.3.

Where higher risks are involved, more formal methods should be used, for example failure modes, effects and criticality analysis (see BS 5760-5). 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.

Section 4. Identification of hazards

4.1 Hazards from machinery

A person might be injured by machinery as a result of:

- a) contact or entanglement with the machinery;
- b) trapping between the machine 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.

These incidences may be regarded as mechanical hazards. Advice and safeguards applicable to identified mechanical hazards are dealt with in 4.2.

Machinery can also present non-mechanical hazards in which the dangers are less obvious or tangible. These 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 levels;
- 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;
- 9) effects of the environment in which the machine has to be used.

Non-mechanical hazards are identified and dealt with in 4.3.

A machine designer ought to be aware of the hazards identified above and as many of these hazards as possible ought to have been avoided by suitable choice of design features. Where it was not possible to avoid these hazards, the designer is supposed to have examined the factors such as speed of movement, force, radiation intensity, etc. which can influence the severity of harm and selected them accordingly. Factors which can influence the frequency of exposure and hence the probability of harm occurring should also have been considered. This evaluation of the risk could, for example, have resulted in the selection and use of remote and automatic feeding and waste disposal and “sealing for life” (or remote lubrication) to reduce maintenance access.

Many of the protective measures which are adopted in order to eliminate or mitigate personal harm from non-mechanical hazards identified in 4.3 need to be considered in conjunction with the safeguards against the mechanical hazards identified in 4.2 in order to minimize the total risk level, e.g. acoustic guards to prevent access and contain/absorb noise, welding curtains to protect against radiation, spatter and burns. Also, it needs to be realized that some individual hazards which seem to be minor, can, when combined with each other, become equivalent to a significant hazard.

4.2 Mechanical hazards

4.2.1 General

Movement of machinery parts consists basically of 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 4.2.2 to 4.2.10 are 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 1). 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 2 to Figure 16, only the hazard(s) referred to in the associated text are shown; there might be other hazards (e.g. see reference to Figure 16 in 4.2.3).

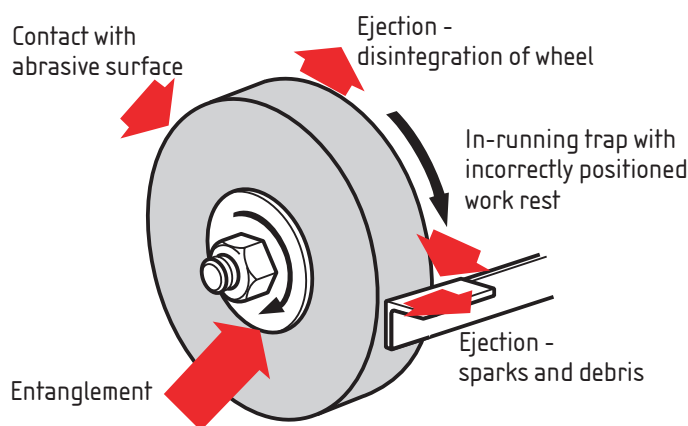


Figure 1 — Individual parts of machines causing one or more types of injury, e.g. hazards at an abrasive wheel

4.2.2 Entanglement

Bodily contact with the following features can lead to entanglement.

- a) Contact with a single rotating surface (see Figure 2), e.g. couplings, spindles, chucks, leadscrews, mandrels, bars, or rotating workpieces. These, even when rotating slowly, can be a source of danger.
- b) Catching on projections or in gaps (see Figure 3), e.g. 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 4.2.9).
 - 1) Between counter-rotating parts (see Figure 4), 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 18), 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 5).

3) Between rotating and fixed parts (see Figure 6), 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) Catching in materials in motion (see Figure 7), e.g. in centrifuges, tumble driers, dough mixers, or swarf from machining operations.

The risk of entanglement is increased by loose clothing, gloves, neck-ties, 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 helps also 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. It is preferred that guards for rotating shafts are fixed guards of solid construction. However, guards of the loose tube type or of bellows construction may also be used satisfactorily in some applications.

The ergonomic criteria given in 7.4 and Annex A should not be regarded as giving complete protection against entanglement.

4.2.3 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 8), material running on to a reel or shaft, a conveyor belt and its drums or pulleys (see 4.2.9 and Figure 18), 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 abutting surfaces preventing removal of the hand, etc. from the danger zone, for example a badly adjusted work rest on an abrasive wheel.

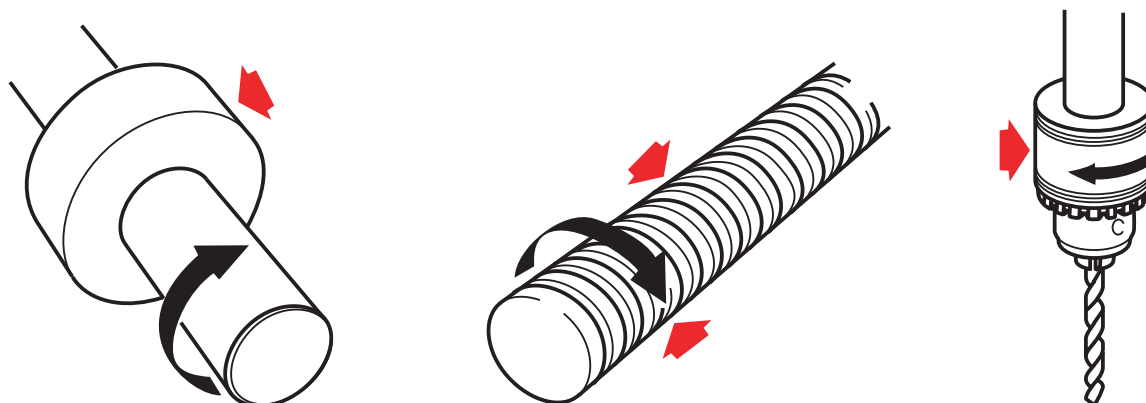
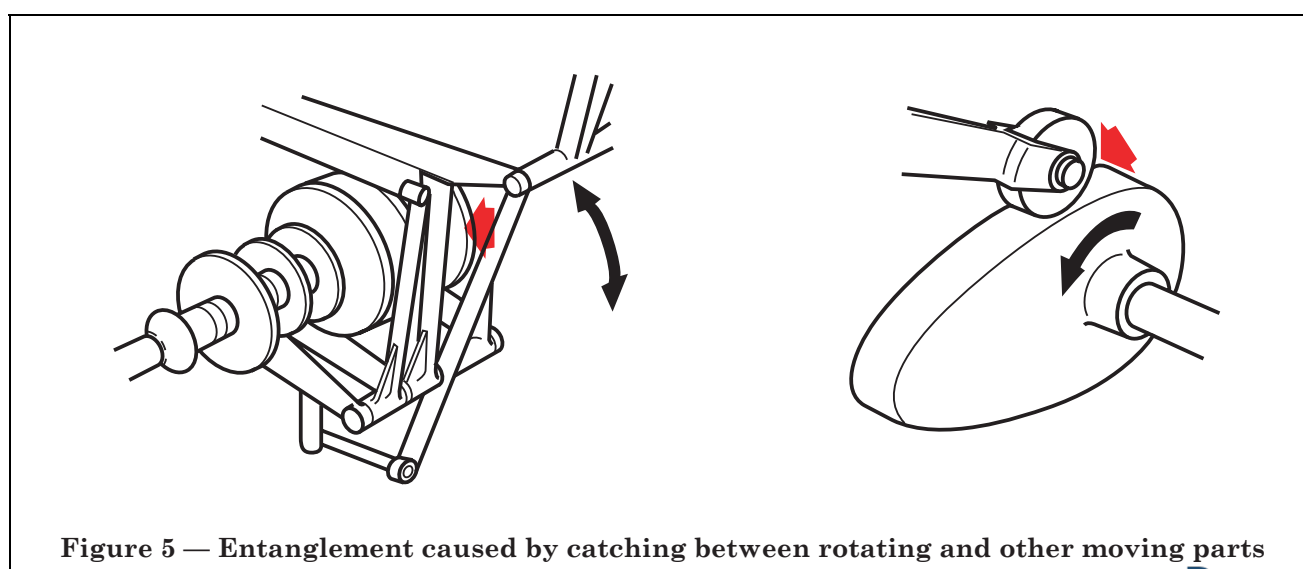
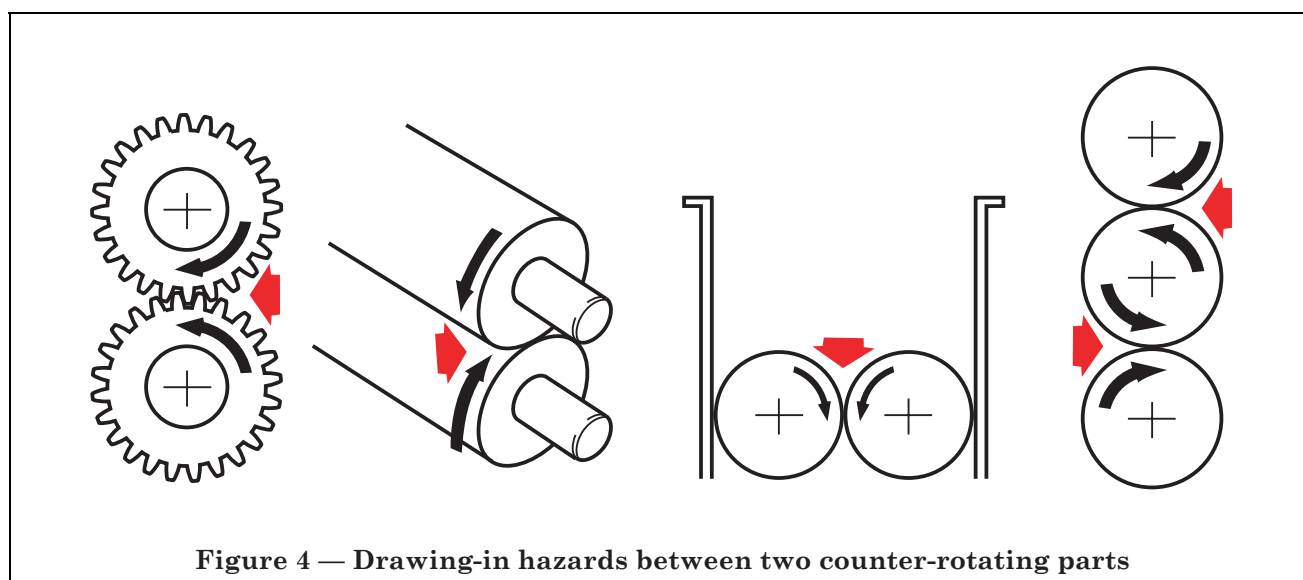
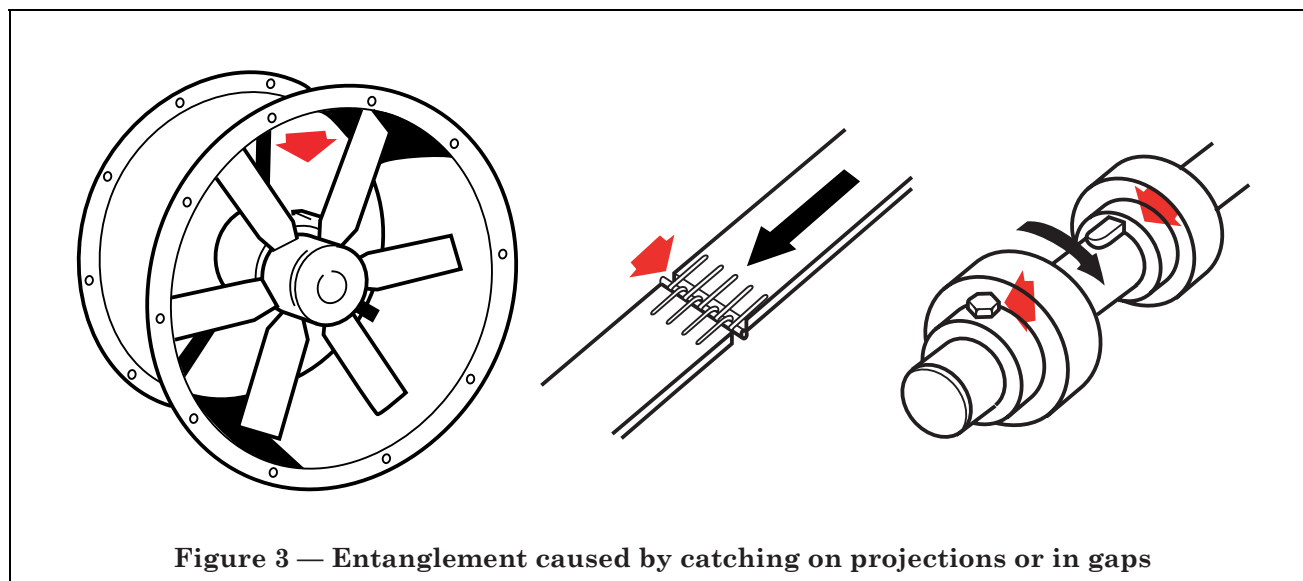


Figure 2 — Entanglement caused by contact with a single rotating surface



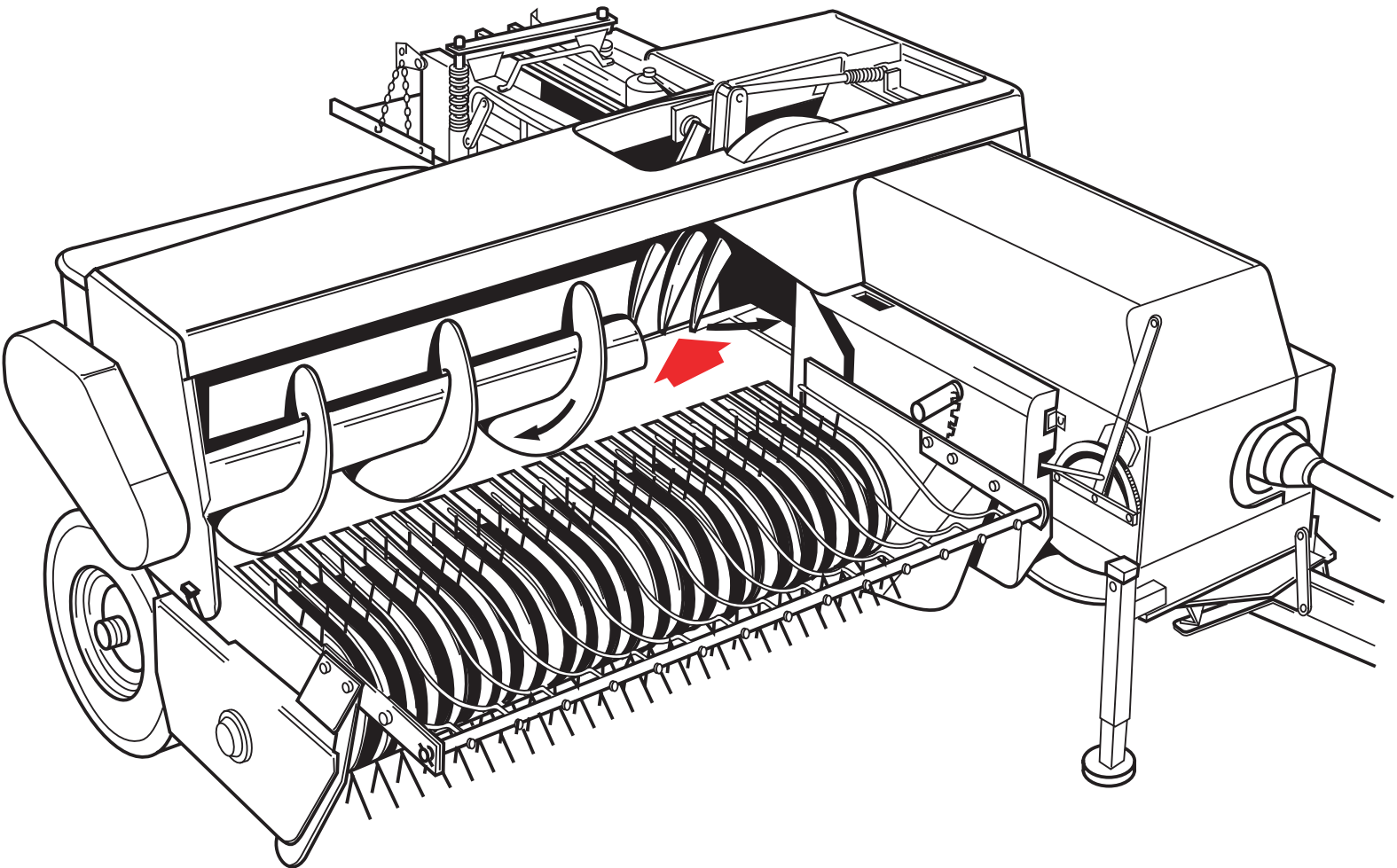


Figure 5 — Entanglement caused by catching between rotating and other moving parts (*continued*)

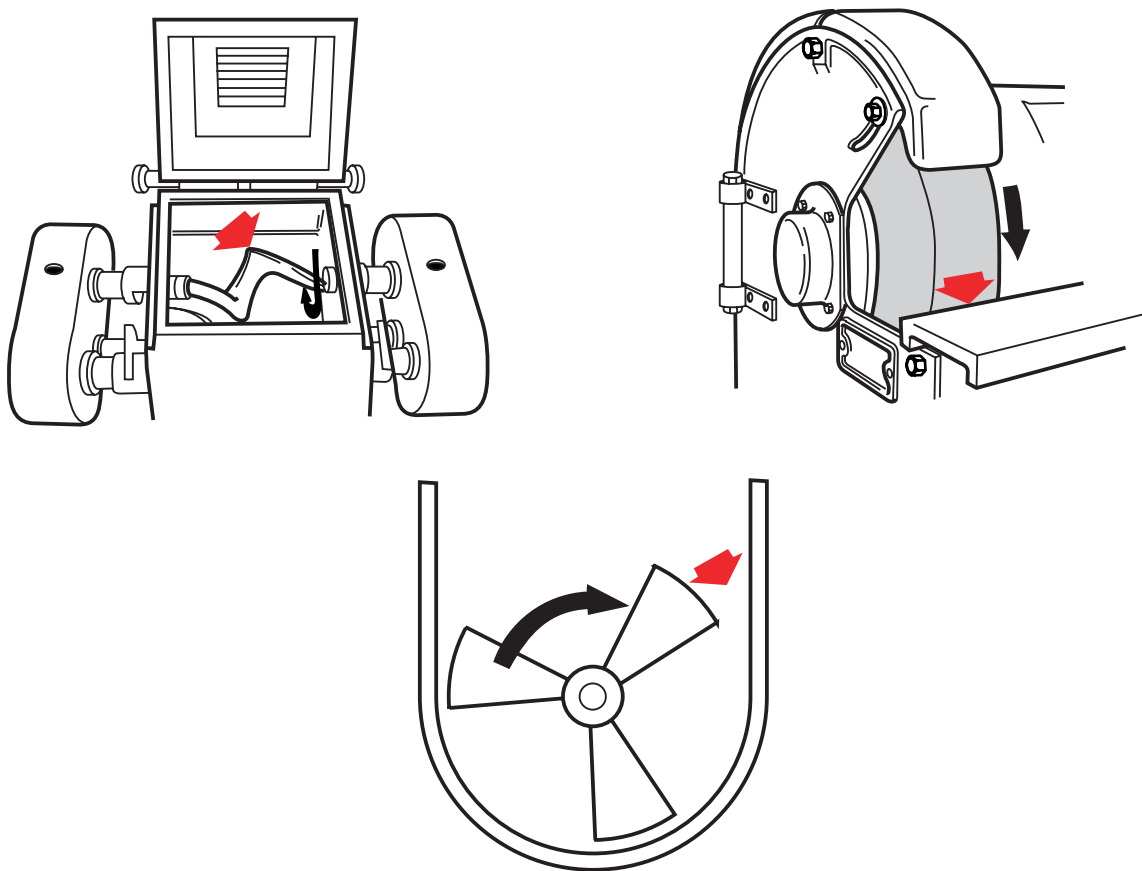


Figure 6 — Entanglement caused by catching between rotating and fixed parts

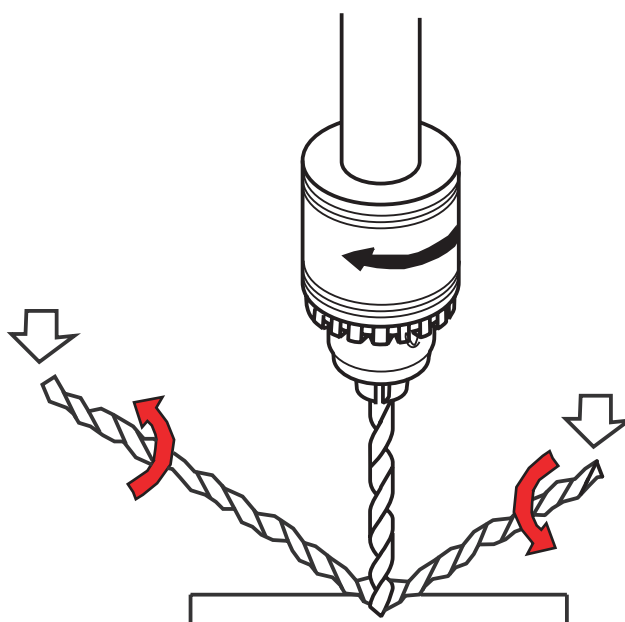
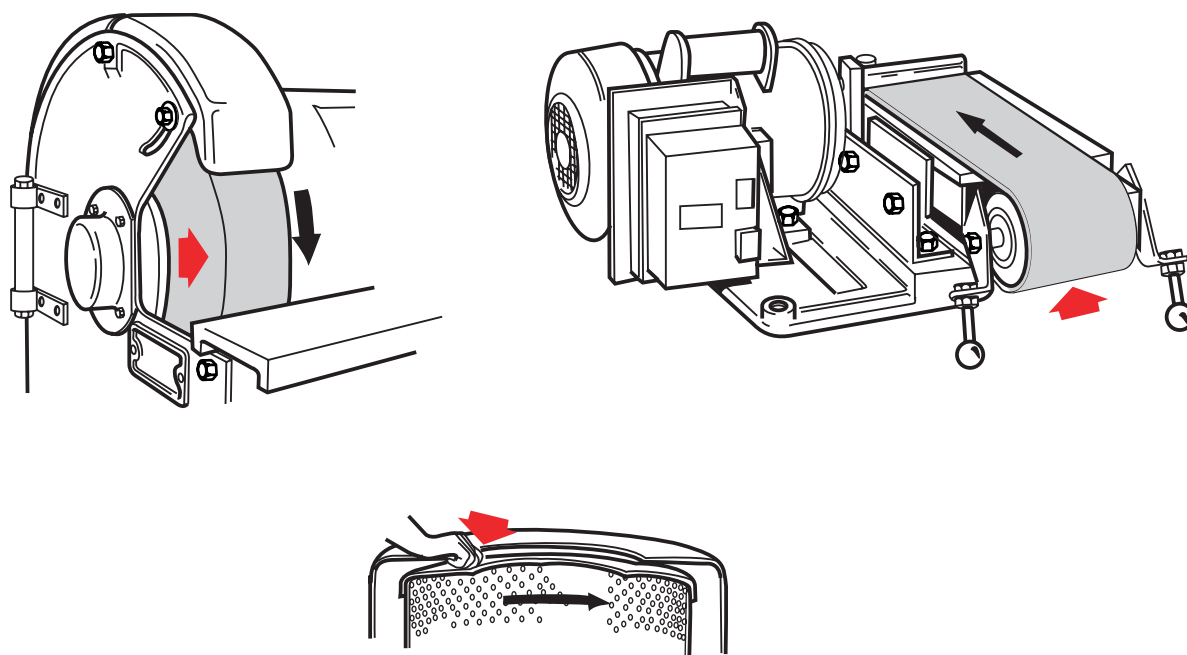


Figure 7 — Entanglement caused by catching in materials in motion (swarf)



NOTE Only these hazards are shown; there may be others.

Figure 8 — Friction and abrasion hazards

4.2.4 Cutting or severing

Examples of cutting or severing hazards (see Figure 9) 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 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.

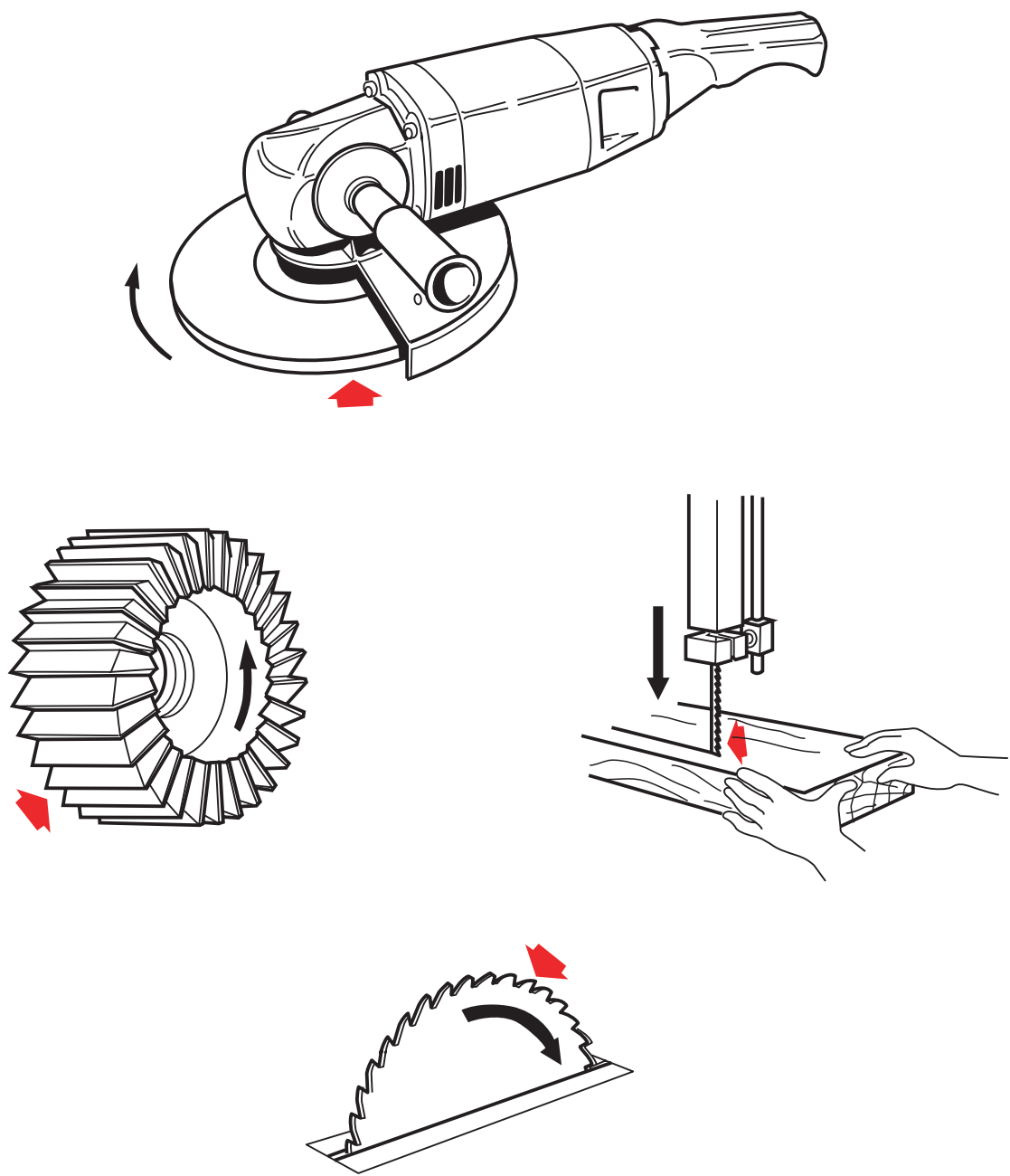


Figure 9 — Cutting hazards

4.2.5 Shear or shearing

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

- a) between two machine parts (see Figure 10), e.g. 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;
- b) between a machinery part and a workpiece (see Figure 11), e.g. transfer mechanisms, the tool of a broaching machine.

The principal measures which could be adopted to eliminate shear traps are:

- c) filling the gaps, such that the shear trap is minimized (see Figure 12 and Figure 13);
- d) 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;
- e) 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 is used, consideration should be given to the body parts which it is possible to insert in the trap. Where it relies on pushing body parts out of the way, it is only appropriate on low-speed machinery, and detailed consideration of other hazards often rules it out. However the technique is not effective against double shear traps. Guidance on safety distances is given in BS EN 349 and 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 or press tools.

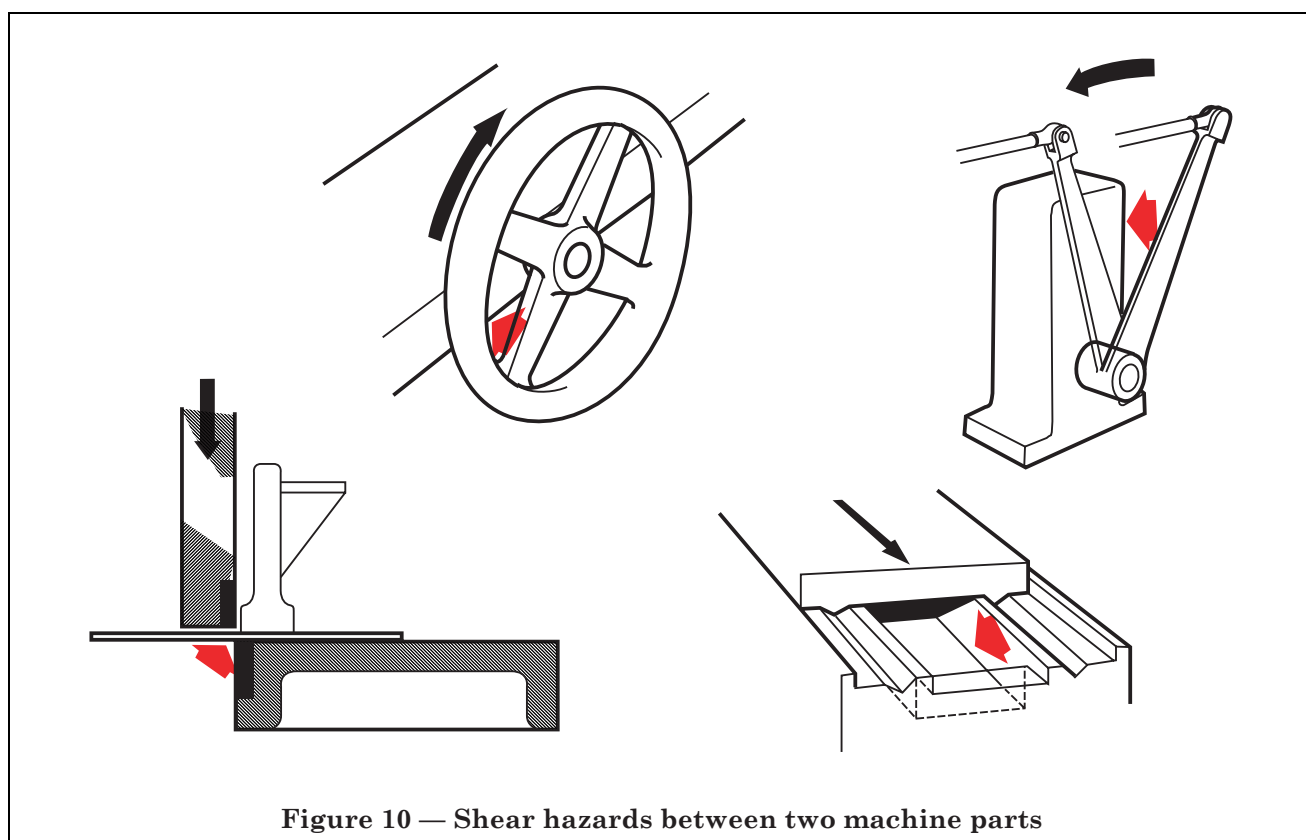
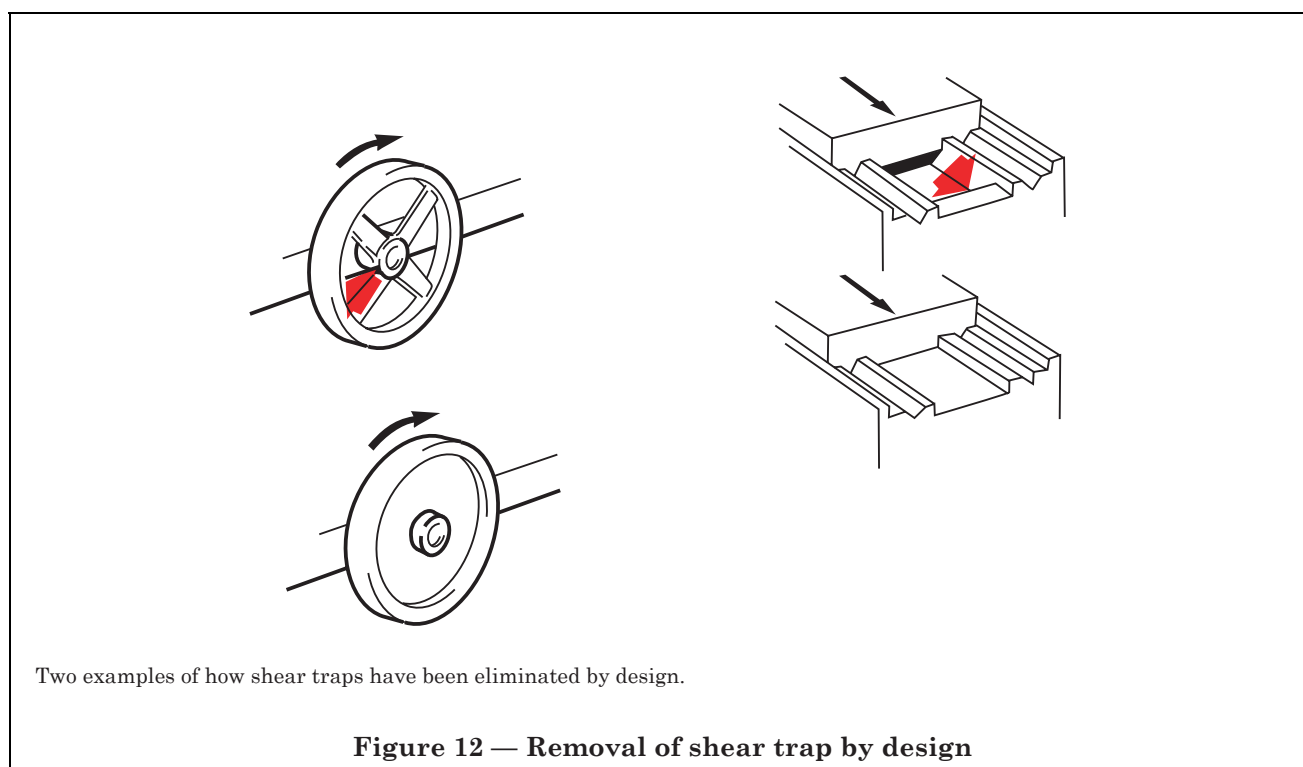
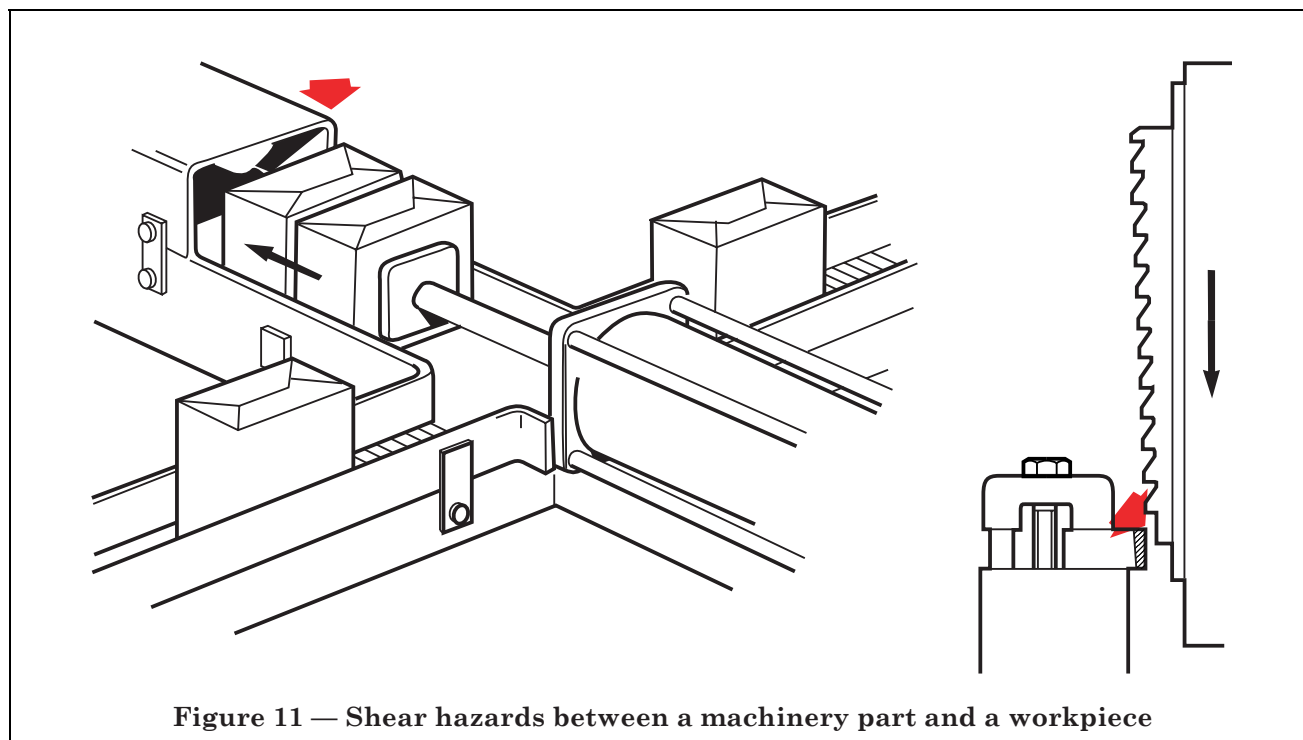
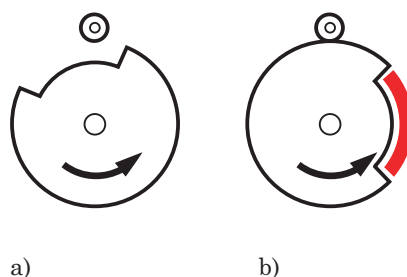


Figure 10 — Shear hazards between two machine parts





When a cylinder has a gap in it as shown in a), a gap cover which completes the periphery of the cylinder as shown in b) can be fitted. This eliminates the shear trap which arises when the cylinder rotates past the fixtures.

Figure 13 — Gap cover to prevent shear trap

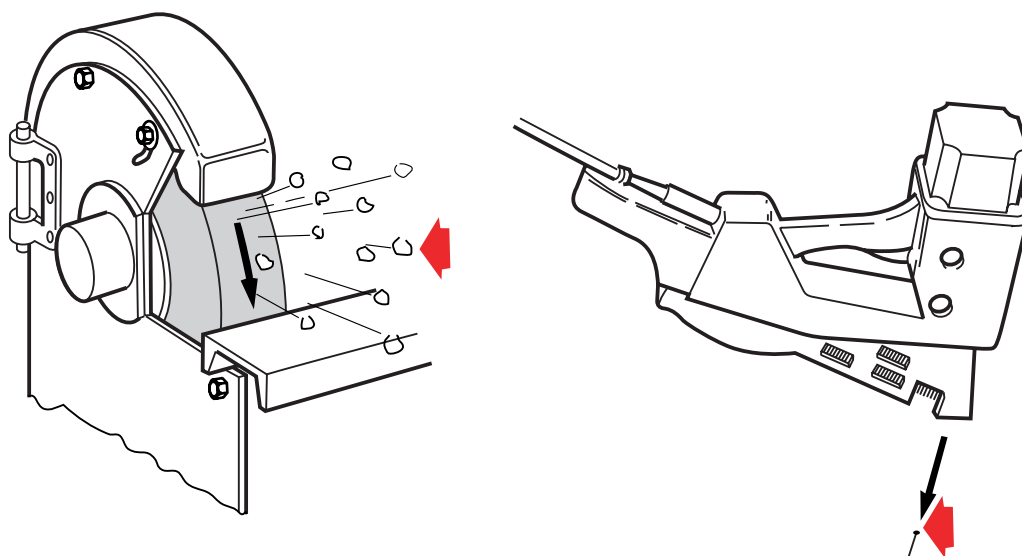
4.2.6 Stabbing or puncture

The body can be penetrated by:

- a) flying objects (see Figure 14);
 - 1) ejection of parts of machinery, e.g. 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, e.g. 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;
- b) rapidly moving parts of machinery or pieces of material (see Figure 15), e.g. sewing machines, drilling 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 which could penetrate the skin, the use of sheet material instead of mesh should be considered for guards.



NOTE Right hand example shows a nail ejected from a nail gun

Figure 14 — Stabbing and puncture by flying objects

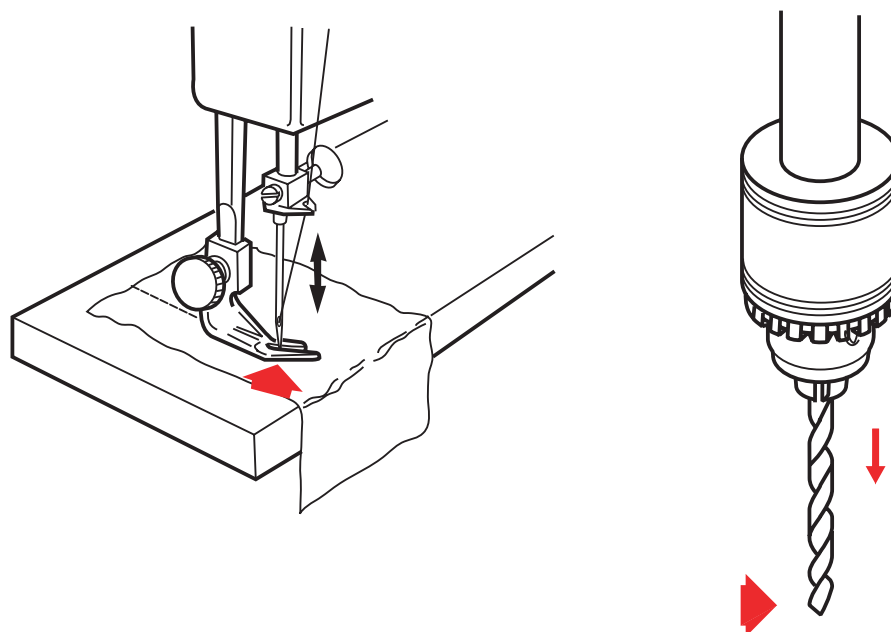


Figure 15 — Stabbing and puncture by rapidly moving parts of machinery or pieces of material

4.2.7 Impact

Impact hazards are caused by objects which act against the inertia of the body but do not penetrate it (see Figure 16), 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.

4.2.8 Crushing

Crushing occurs when one part of machinery moves against another with a part of the body in between (see Figure 17), 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.

Some information on the factors necessary to reduce crushing is given in BS 5655-1.

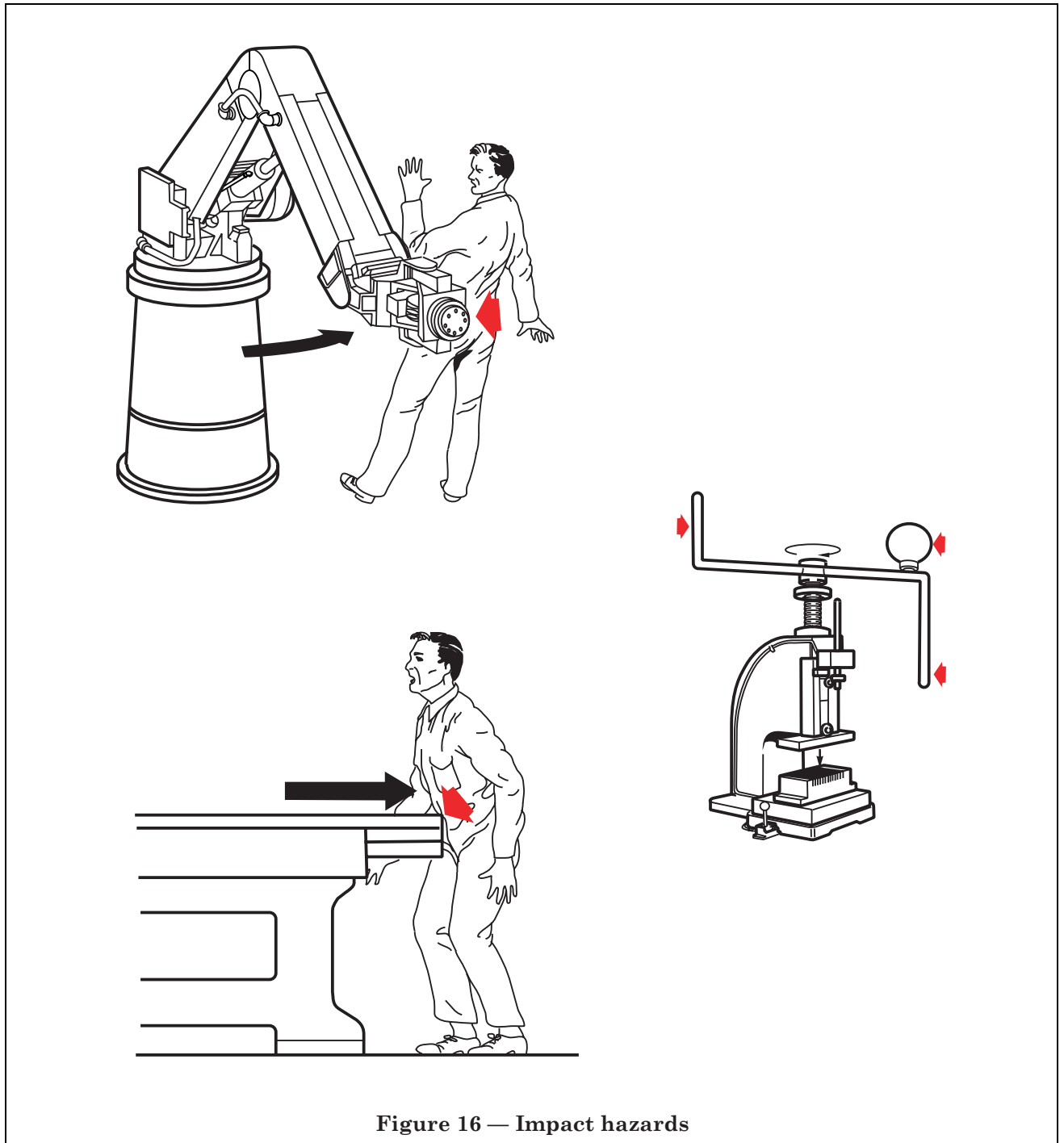


Figure 16 — Impact hazards

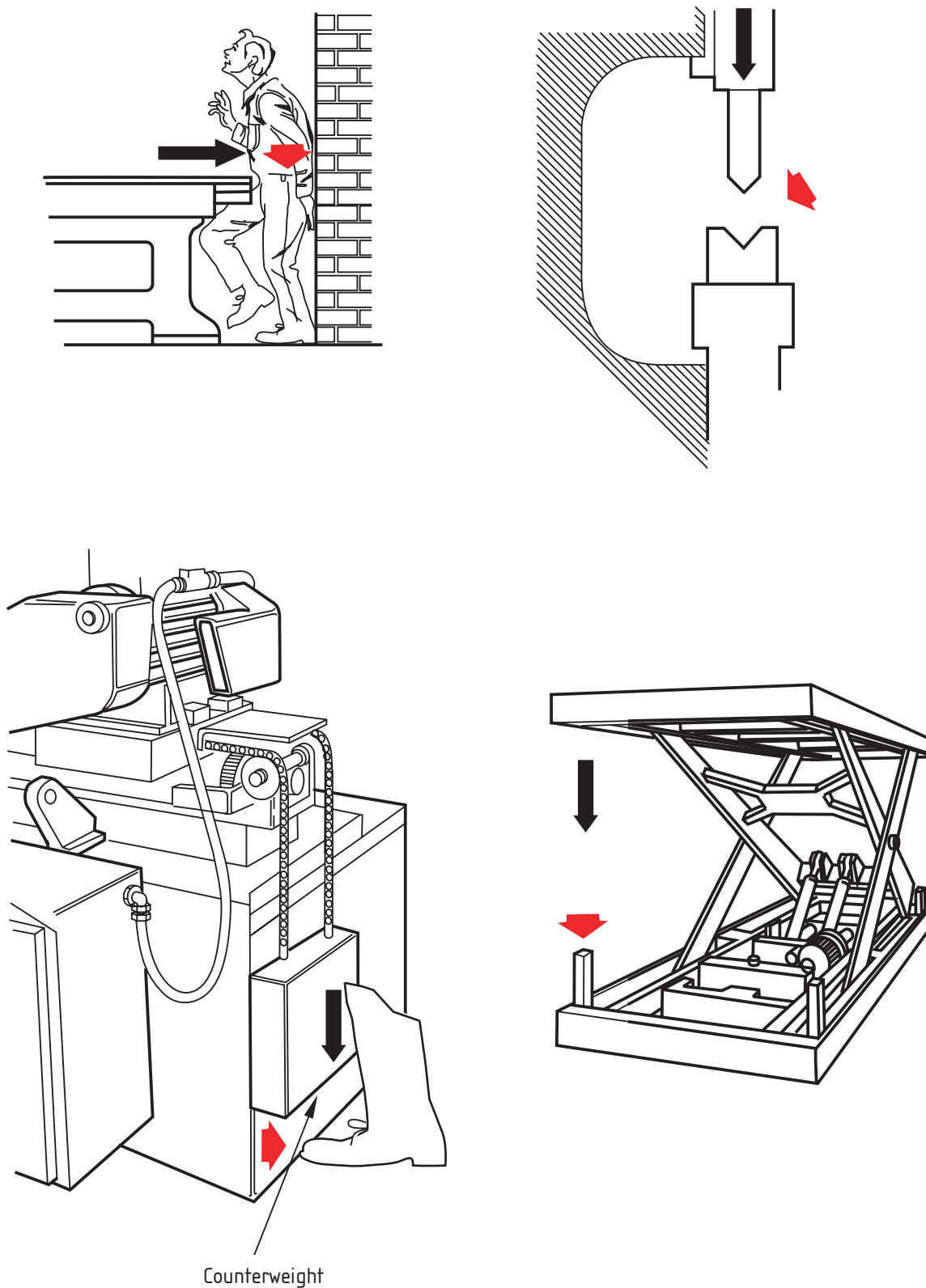


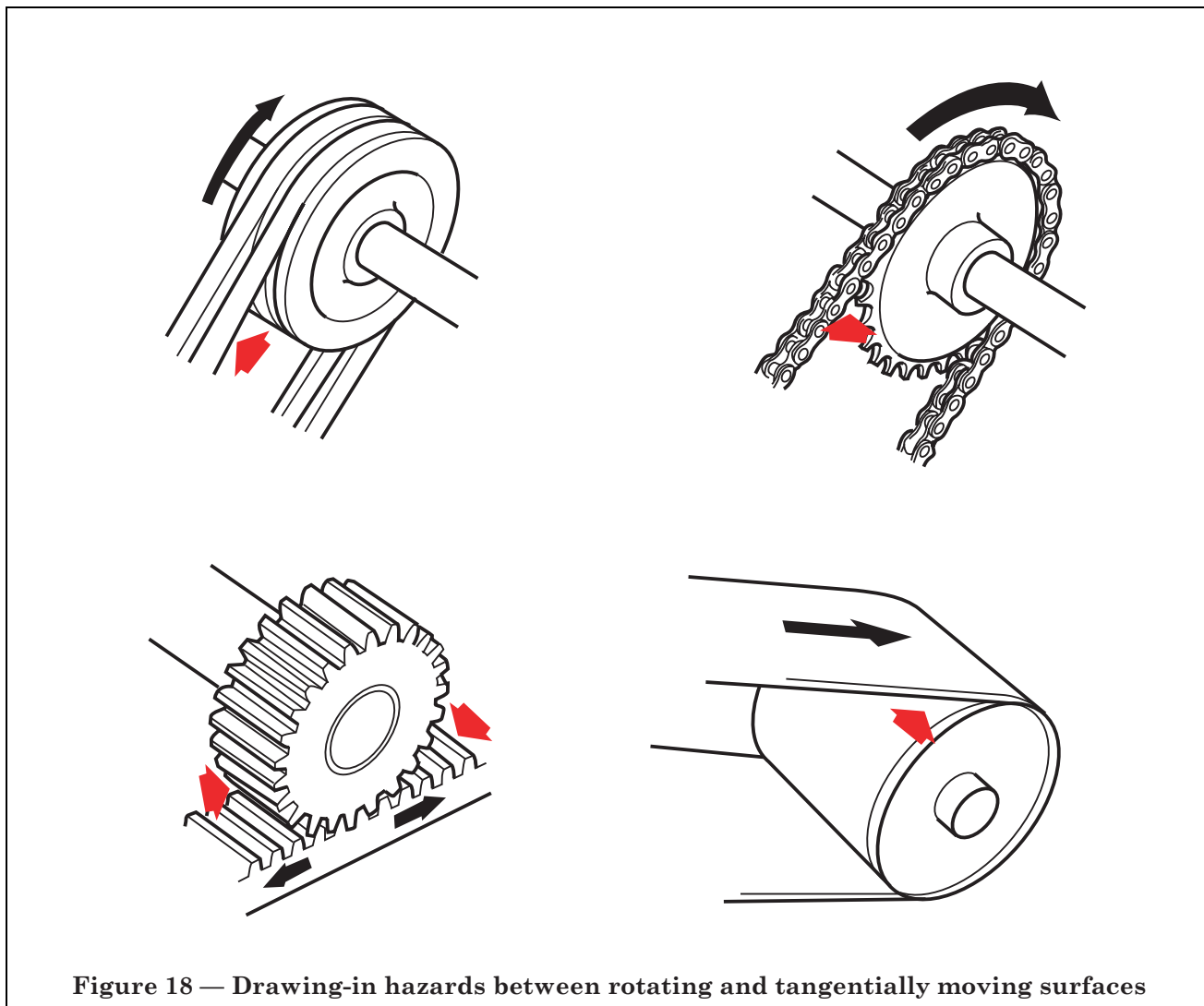
Figure 17 — Crushing hazards

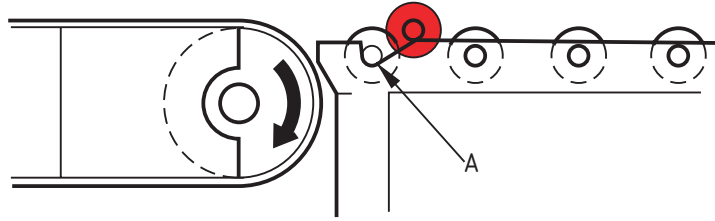
4.2.9 Drawing-in or trapping

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 4), e.g. 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 18), e.g. power transmission belt and pulley, chain and chain wheel, rack and pinion;
- running nips between a rotating surface and a tangentially moving surface where material, e.g. 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, e.g. in a belt or in material being reeled up. Surface roughness and any tendency to adhesion have a similar effect (see Figure 19). Adjacent parts of structures can increase injuries.





The possibility of trapping at the junction of a powered conveyor and an idle roller conveyor can be reduced by making the first idle roller free to move away along an incline A cut in the sides of the conveyor. The angle of the incline is so arranged as to prevent lateral movement of the roller during the passage of goods from the belt to the idle roller conveyor. Any rigid cross-members should be removed from this point. Care should be taken, however, to check that the weight and dimensions of the loads being conveyed do not prevent the roller from lifting. In some installations more than one free roller might be required.

Figure 19 — Roller conveyor: first idle roller free to prevent drawing-in

4.2.10 Injury by compressed air or high pressure fluid injection

Injection of fluids through the skin can cause tissue damage similar to crushing. 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 4.2.6).

4.3 Non-mechanical hazards

4.3.1 General

Machinery can also present other hazards and protective measures need to be taken to prevent harm. The nature of the measure depends on the type of hazard. Where measures taken for one hazard could conflict with those taken for another, the principle should be adopted of aiming for the minimum 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 4.3.2 to 4.3.10.

4.3.2 Electricity, including static electricity

Electrical hazards include:

- a) injury or death arising from shock and burn as a result of contact of persons (or approach to in case of high voltage equipment) with (normally) live parts or parts which have become live under faulty 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;
- 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.

In the absence of standards for specific machines (e.g. the BS EN 60335 series, BS EN ISO 10472-4), designers and suppliers ought to have used BS EN 60204-1 (and BS EN 60204-11 in the case of high voltage) when specifying the electrical equipment of the machine. Also hazards due to static electricity ought to have been avoided in accordance with PD CLC/TR 50404. Modifications arising, for example from change of use, should be carried out in accordance with BS EN 60204-1 and PD CLC/TR 50404.

Other injuries, e.g. those arising from a fall, can be a consequence of someone reacting to the effects of receiving an electric shock.

4.3.3 Thermal

Thermal hazards include:

- a) burns and scalds arising from contact with parts or materials operating at extremes of temperature (hot or cold);
- b) flames or explosions and radiation from heat sources;
- c) harm arising from a hot or cold working environment.

Designers and suppliers ought to have used those protective measures together with the information necessary to adequately reduce the risk arising from these hazards. Protective measures include, but are not limited to, 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.

4.3.4 Noise

Exposure to excessive noise can result in:

- a) permanent hearing loss;
- b) tinnitus;
- c) tiredness, stress;
- d) other effects such as loss of balance, loss of awareness;
- e) impairment of speech communication and awareness of auditory signals.

Consideration ought to have been given to noise reduction when designing protective measures for mechanical hazards. It is often possible for guard enclosures (see BS EN ISO 15667) 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 because of poor design or fixing. Additional protective measures include, for example, screens fitted to the machine and silencers (see BS EN ISO 14163). Consideration also needs to 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 [5] with regards to the limits of levels of exposure to noise. Details of this new legislation and how it differs from the old legislation is given at www.hse.gov.uk/noise/issues.htm.

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 **12.5.5**. Standards giving advice on noise emission and measurement are listed in the Bibliography with “Acoustics” as the introductory element of the title.

4.3.5 Radiation

Exposure to excessive non-ionizing or ionizing radiation can result in either 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 (e.g. in the frequency ranges from low frequency through radio frequencies up into microwave);
- b) light including infra-red, visible, ultra violet and laser light radiation.

Sources of non-ionizing radiation include electrical equipment itself and that specifically designed to generate radiation (e.g. radio frequency transmitter, cavity magnetron, laser, light source) and other non-electrical equipment (e.g. 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.

Additional protective measures include the use of, for example:

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

4.3.6 Use of harmful materials and substances

Certain materials and substances processed, used, produced or exhausted by machinery, and materials used to construct the machine 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);
- c) biological (mould) and micro-biological (viral or bacterial).

Additional protective measures include, for example:

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

4.3.7 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), serious discomfort resulting from whole body vibration and vascular disorders (e.g. white finger disease, neurological, osteo-articular disorders) from hand-arm vibration occur as a result of the most severe vibration or lower levels over a long period of time. Protective measures include, for example, 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.

4.3.8 Ergonomic principles

Failure to use good ergonomic principles in machine design can give rise to a mismatch of machinery with human characteristics and can show itself by:

- 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;
- c) human errors.

Advice on the observation of ergonomic principles is given in BS EN ISO 12100-2:2003, 4.8 and is supposed to have been followed by the machine designer. Any aspect of machine use or change of use that could affect the ergonomic principles used should result in additional appropriate measures being applied.

4.3.9 Access

Inadequate or unsuitable access, and failure to maintain otherwise suitable access to an adequate degree can give rise to injuries from slips, trips and falls. The user should ensure that means of access is not affected when installing, using or reinstalling upon change of use or production reorganization (see also 5.22 and 11.3.3).

4.3.10 Environment

Certain machines are designed and used in an environment that is itself hazardous or could give rise to harm, for example temperature, wind, snow, lightning. The necessary protective measures in accordance with the instructions provided with the machine should be put in place. Also, when the use of the machine is in an environment outside its original range of intended use, any additional hazards should be taken into account and the necessary protective measures implemented.

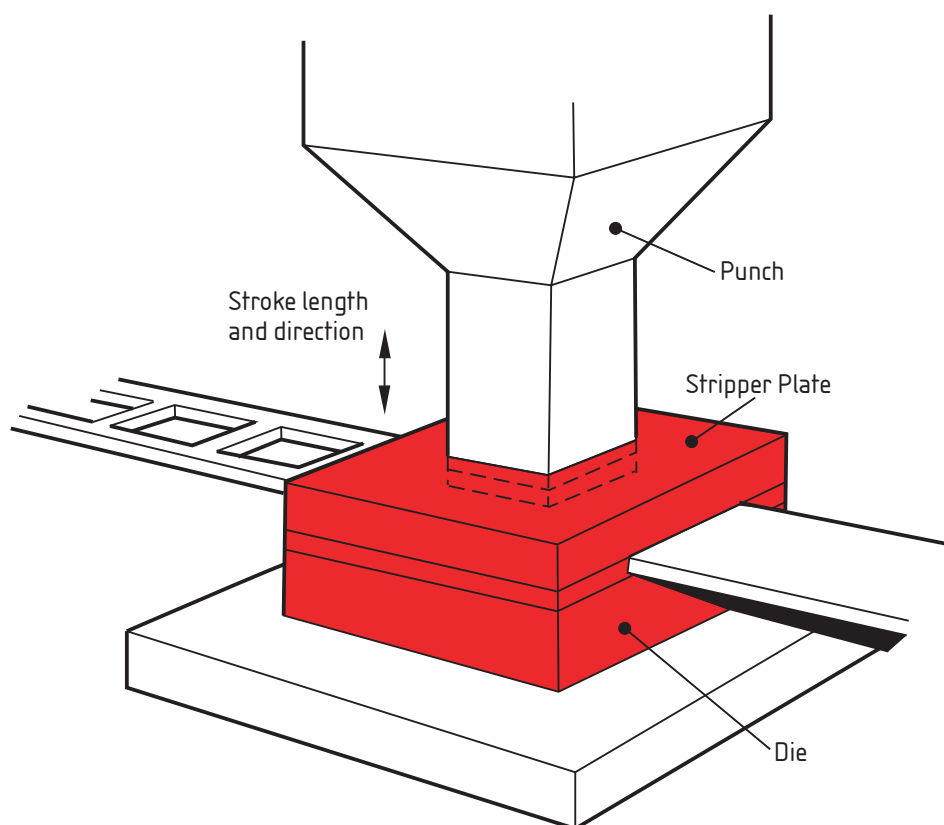
Section 5. Aspects of machine design to eliminate or reduce risks

5.1 Checks by user

When considering safety, designers of new machinery ought to have followed the general principles given in BS EN ISO 12100-1 and BS EN ISO 12100-2, and taken account of the relevant type B and type C standards (see BS EN ISO 12100-1:2003, Introduction) applicable to the particular machine. The user could find reference to these standards useful when assessing the safety of a machine. As a basic guide wherever practicable, hazards ought to have been eliminated or hazard zones effectively enclosed (see Figure 20). If they could not be eliminated, then suitable safeguarding ought to have been incorporated as part of the design, or if this was not possible, it is hoped provision would have been made for safeguarding to be easily incorporated at a later stage.

Provision ought to have been made to facilitate the fitting of alternative types of safeguarding on machinery where it was known that this would be necessary because the work to be done on machinery varies.

At the design stage arrangements ought to have been made, where practicable, to eliminate the need to expose persons to any hazards during operation, examination, lubrication, adjustment and maintenance.



Enclosed tools are designed and constructed to be safe in themselves, there being insufficient space between possible trapping parts in the tool set to permit entry of any part of a hand. They should be used whenever the operation allows as they provide a high standard of protection and eliminate the need for further guarding. The use of enclosed tools is usually practicable when blanking operations from strip are carried out and when more than one operation is combined in a single set of tools. Enclosure can be achieved by arranging for the stripper plate, which is attached to the die, to be sufficiently thick to prevent the punch from being withdrawn from it, and by making the feed opening below the stripper plate so small that fingers cannot reach through it to the punch. (See also 5.1.)

Figure 20 — Enclosed tools at a power press

Designers of machinery are supposed to have taken into account the ergonomics of machinery use, i.e. they ought to have considered all aspects of the work situation for which the machine was intended. The user's objective should be to provide the optimum conditions to achieve the most efficient safe performance of the machinery and the operator. Further advice is given in BS EN 894. Among the aspects to consider ought to be the creation of a favourable environment for the operator and others in the vicinity by providing heating, cooling, lighting and, where necessary, mechanical aids to reduce physical effort, and by controlling to an acceptable level the emission of heat, light, noise, dust, fumes, vapours and liquids. Although these topics are not covered in detail in this Published Document, they are important and should not be overlooked. Although it is supposed to have been catered for by the designer, the user should check whether enclosure guards fitted to machinery to prevent access to mechanical and electrical hazards also control to an acceptable level the emission of heat, light, dust, noise, etc. If not, there is an opportunity to do so, for example by substituting sheet material for mesh. The user should also check whether any physical barriers, provided to prevent access to danger zones, are of a size and in a position that take into account the bodily proportions of the working population (see BS EN 294, BS EN 547, BS EN 811 and Annex A).

These aspects ought to have been considered during the machinery design and installation planning stages. If not, the user should take remedial action to provide the necessary safeguards and consult the manufacturer or supplier. The addition of safeguards as an afterthought can result in awkward design problems involving unnecessary expense, reduced production and possibly inefficient safeguard performance (see also 9.5). Examples of possible hazards and solutions are given in 5.3 to 5.23.

5.2 Further considerations for safeguards

5.2.1 General

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

5.2.2 Corrosion

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

5.2.3 Coolant and swarf

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

5.2.4 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.

5.2.5 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 4.3.6).

NOTE Attention is drawn to the Control of Substances Hazardous to Health Regulations [6] 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 EH40/2000 [7].

5.3 Controls

5.3.1 Position

Designers and suppliers ought to have positioned and spaced controls to provide safe and easy operation, so there should be ample clearance between each control and other parts of the machinery and their operation should not cause additional risk (see BS EN ISO 12100-2:2003, 4.8.7). Controls should be so placed 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.

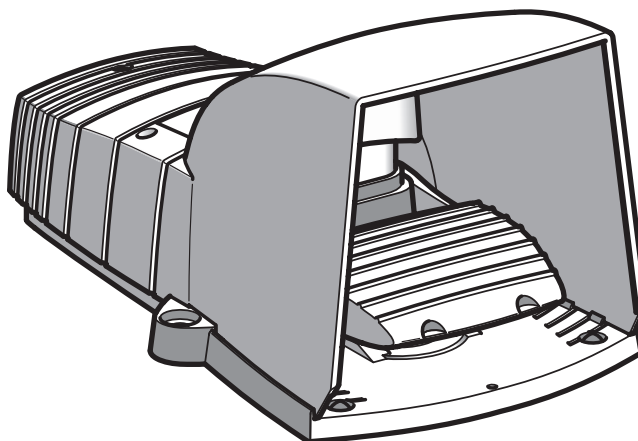
Start controls should be shrouded, gated or so positioned that they cannot be operated inadvertently.

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

Where more than one control station is provided, these should be arranged to take account of any increased risk to people who might be affected by the operation of one of the controls. This can be achieved by providing unambiguous control circuit selection at the 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 5.14.)

Handles, hand-wheels and levers should be so positioned that when the operator is operating them other controls cannot inadvertently be operated. Two-hand controls should be so placed, separated and protected as to prevent them from being operated by any means other than two hands [see 8.6 and BS EN 574 (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 21).



Where possible, the entire length of the foot pedal and its lever should be covered to prevent any part from being struck by material. Side panels prevent operation, deliberate or accidental, except from the front.

Figure 21 — Foot pedal protected from accidental operation by means of a cover

5.3.2 Identification

Designers and suppliers are supposed to have ensured that controls are clearly identifiable and readily distinguishable from each other by varying their separation, size, shape, colour or feel, and by labelling the controls with either words or symbols to identify the function or consequence of use of the control (see BS EN ISO 12100-2:2003, 4.8.7, BS EN 60204-1, BS EN 61310-1 and BS EN 61310-2). Where practicable, controls for different motions should be operated from different points. For example, the operating handle for a cross-slide automatic feed should be separated from the handle of a traversing feed.

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 60204-1:1998, **10.7** and BS EN 418:1992, **4.4.1** (see also **8.9.1**).

5.3.3 Operation

Designers and suppliers ought to have ensured where appropriate that the direction of movement of a control corresponds 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 his/her 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 mode and direction of movement of controls should be so varied as to prevent inadvertent operation of the wrong control. Clutch control levers should be provided with adequate means of retaining them in a safe position.

5.3.4 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 may vary in accordance with the type of machine and industry.

Where a guard has to be displaced or removed for setting or adjustment of machinery or the feeding of material and it is necessary for the purpose of these operations for the machinery to be in motion, the setter should be protected, where practicable, by one of the following protective devices, in order of merit (see also BS EN ISO 12100-2:2003, **4.11.9**):

- a) a hold-to-run control (see **8.4**) with the machinery running at crawl speed, or a limited movement device (see **8.7**);
- b) a hold-to-run control with the machinery running at the slowest practicable operating speed;
- c) a hold-to-run control with the machinery running at normal speed.

The hold-to-run control and another means of control (enabling device, see **8.5**) are also described in BS EN ISO 12100 and BS EN 60204-1:1998, Clause **9**.

5.3.5 Handles and hand-wheels

Where a handle or hand-wheel is provided to operate manually a mechanism that can also be driven by mechanical power, the handle or hand-wheel ought to have been designed not to rotate when the power drive is operating. Otherwise hand-wheels should either be of the solid type without spokes or projections and/or provided with handholds of restricted size.

5.3.6 Warning signals

On installations where the main operating station or start control is in a position from which the hazardous parts of the machinery or people in the vicinity cannot be seen clearly, audible and visual warnings ought to have been supplied operated through a suitable interlock for a predetermined time before the machinery starts to operate. The audible signals ought to be easily distinguishable from those at other machines.

On installations where malfunction of the machinery creates a hazardous situation, suitable warning signals are supposed to have been provided. It is preferred that these signals are given automatically and are both audible and visual.

Audible and visual warnings might have been provided in addition to, but not in substitution for, physical safeguards.

Further information on warning signals is given in BS EN ISO 12100-2:2003, **6.3**, BS EN 457 and BS EN 61310-1.

5.3.7 Program or sequence control

Where machinery is program or sequence controlled, parts which might not normally be considered as hazardous, could become so in the event of program or sequence error, failure or malfunction causing, for example, over-speeding of normally slow-moving parts, or unintended movement during setting-up. Therefore, in order to establish the full safety implications, a hazard analysis and risk assessment ought to have been carried out by designers and suppliers as described in Section 3 and Section 4. These ought to have included hazards arising from control or other malfunctions in all phases of machine life, for example, a bursting abrasive wheel caused by a misfeed.

Assurance of the integrity of control systems, including programmable electronic systems, is described in 10.3. Programmable systems are described in 5.23.

5.4 Indicators

Where necessary, a qualitative, quantitative or check reading indicator is supposed to have been provided to warn of a hazardous situation (see BS EN ISO 12100-2:2003, 4.8.8). Such indicators are supposed to be designed to minimize the risk of failing to danger. Explanations of these indicators are as follows.

- 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.
- c) Check reading: gives information automatically or when demanded as to 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 use of colours of indicator lamps.

5.5 Unexpected/unintended start-up

Keeping a machine in a non-operating condition whilst persons are present in hazard zones is one of the most important conditions for the safe use of machinery and one of the major aims of the machine designer and user (see 8.2.1 and 9.1). The machine designer ought to have ensured that adequate built-in means together with instructions for use were provided (for example, see 5.3.1). See BS EN 1037 (ISO 14118) and BS EN 60204-1:1998, 5.4 for requirements. Providing means for isolation and energy dissipation is a way of preventing unexpected/unintended start-up and is often used when significant dismantling of the machine or work on power (for example electrical) circuits is carried out (see 12.3.3, BS EN 60204-1:1998, 5.5 and BS EN 60204-1:1998, 5.6). The user should ensure that the means provided are properly used.

5.6 Measures for the escape and rescue of trapped persons

Measures for the escape and rescue of trapped persons should be provided where necessary and might include:

- escape routes and shelters in installations generating operator trapping hazards;
- arrangements for operating some machine elements by hand;
- arrangements for reversing the direction of operation of some machine elements;
- anchorage points for descender devices;
- means of communication to enable trapped persons to call for help.

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

5.7 Clutches

Clutches are mechanical engagement and disengagement devices and, in mechanical interlocking systems, are the devices which interrupt transmission of the motive force. Where actuated by mechanical or other means, disengagement of the clutch should not depend on the maintenance of the power supply. This is commonly achieved by using compression type springs. The springs should be safely 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.

5.8 Braking systems

5.8.1 General

Reference is made in 5.3.4 and Section 8 to various protective devices that rely for their efficient operation on a brake in order to stop the machinery quickly.

Braking systems ought to be designed to bring hazardous moving parts to rest with a consistent performance as quickly as possible without generating other hazards. 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 and, in particular, the possibility of inserting a clutch mechanism should be considered as a means of limiting the momentum to be dealt with by the brake. Rotating parts and equipment fastened to rotating parts should be so secured as to prevent dislodgement in consequence of the brake action. Adequate precautions should be taken to prevent disengagement of screwed components due to reversed torque following brake application.

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

5.8.2 Mechanical (friction) braking systems

Mechanical (friction) brakes, e.g. drum, disc or external calliper, rely for their effect on the action of friction material on a moving surface, usually of smooth metal. The means of application should be independent of the power supply.

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 so as to prevent excessive temperature rise of the working parts.

The arrangements for guiding should be such as to minimize the risk of binding.

Where the effectiveness of braking could be adversely affected by contamination, 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;
- 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 concerning the setting of the brake should be available and include:

- 1) the length to which the spring(s) should be compressed;
- 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, e.g. the hoist motion of a crane. The electrical circuit ought therefore be designed so that failure of the supply in 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. See BS EN 60204-32:1998, 9.3.4 and BS EN 60204-32:1998, 9.4.4.

When hydraulic or pneumatic means are used to apply mechanical brakes, an accumulator/reservoir, connected as close as possible to the brake, should be provided 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 given in BS EN 982 and BS EN 983 respectively.

5.8.3 Electrodynamic braking systems

5.8.3.1 General

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

5.8.3.2 Reverse plugging

Reverse plugging is a method of braking whereby the electrical connections to a motor are changed so that a reverse torque is applied and the machine is brought rapidly to rest. The change-over contactor ought to have been so controlled that it opens when the machinery stops, otherwise the machinery restarts in the reverse direction.

5.8.3.3 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 5.8.3.2) 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.

5.8.3.4 Regenerative braking for a.c. motors (capacitor braking)

Regenerative 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 capacitors help to maintain the self excitation of the motor and there is an induced braking effect.
- b) Improving the braking effect during the final stages of decelerating by short-circuiting the motor terminals.

5.8.3.5 Regenerative braking for d.c. motors

Regenerative braking for d.c. motors consists of reconnecting the motor so that it acts as a generator to supply a load. The load can be a resistor or the main power supply.

5.8.3.6 Motor controllers (power drive systems)

Motor controllers incorporating electronic and computer control technology are sometimes used to control motor speed. Their capacity to perform electrodynamic braking is used for speed control. The electrical, thermal and energy safety requirements of these controllers are given in BS EN 61800-5-1, whilst a standard to address their functional safety performance is under development as IEC 61800-5-2.

5.9 Safety catches, overrun, runback and fall-back protection devices

Where risk of injury could arise, a safety device should be incorporated in the design to restrain any moving machinery part which can overrun beyond its normal stopping position due to gravity, the fall-back of a crankshaft, the failure of a counterweight system or any other similar failure (see 8.8).

5.10 Counterweights and similar devices

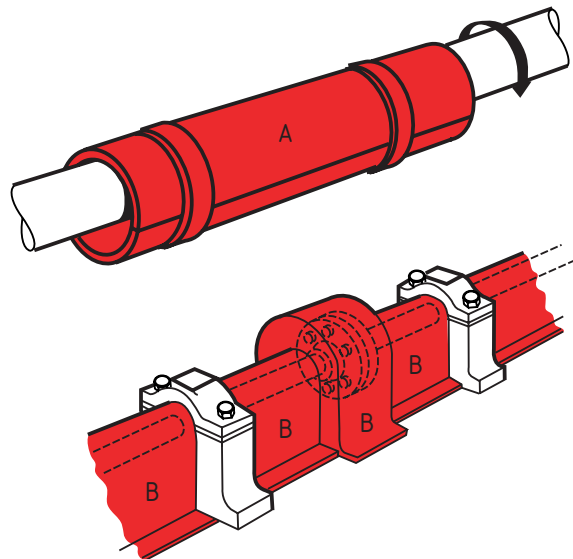
Counterweights which could fall upon or trap persons should be suitably safeguarded (see Figure 17). The movement of the counterweights should be safeguarded as far as necessary to provide complete protection against injury, in particular in the event of a power system failure.

Duplication of the flexible connections (chain or cable) between the mass and its balance weight(s) is good practice provided each connection is sufficiently strong to take the full load.

Similar precautions are necessary on other weights, e.g. those provided for tensioning ropes and belt conveyors, where such weights can move when the machinery is operated. In these cases, provision should be made to maintain safety in the event of rope or belt failure.

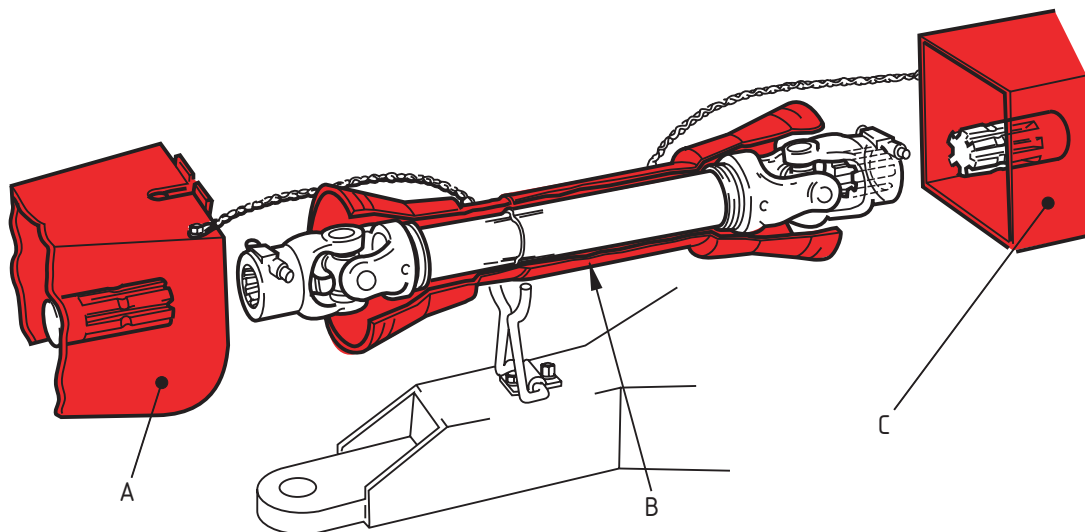
5.11 Rotating shafts, spindles and couplings

Every projection such as a setscrew, bolt or key on any exposed revolving part of machinery should be sunk, shrouded or otherwise effectively guarded. It is preferred that guards for rotating shafts are fixed guards of solid construction. However, guards of the loose tube type or of bellows or telescopic construction can also be used satisfactorily in some applications (see Figure 22, Figure 23 and Figure 24).



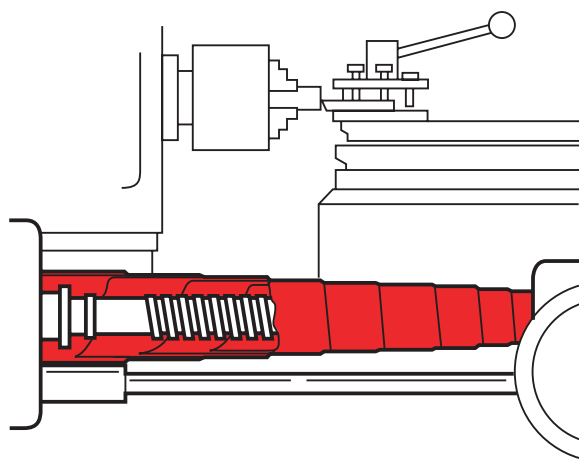
The loose sleeve A, which may be made of fibreboard or other light material, rides loosely on the shaft. It is split longitudinally so that it can be fitted over the shaft without the need for dismantling, and the ends are then secured either by steel clips or adhesive tape. The fixed guard B for a transmission shaft and coupling is made of sheet metal and is of U-section with flanges for fixing to the structure on which the bearings are mounted.

Figure 22 — Guarding of shafts and couplings



The power take-off drive from a tractor is responsible for many accidents due to persons becoming entangled with the rotating universal joints and telescopic shafts. The guarding illustrated is in three parts; power take-off master shield A, telescopic shaft guard B and power input coupling guard C. Non-rotating guards with flexible cones prove to be the most durable in practice. There has to be adequate overlap by the power take-off and power input coupling guards over the power take-off shaft guard during all angles of articulation. The telescopic shaft guard B has to be designed so that it can telescope sufficiently to avoid jamming. A support for the shaft and guard when not in use should be provided. Wear and strength tests for power take-off guards are given in BS EN ISO 5674.

Figure 23 — Tractor power take-off drives



This provides protection against the danger of contact with a rotating shaft, whether plain, splined or screwed, and is particularly useful when, as illustrated, it is fitted to a traversing part of a machine. It also protects the shaft against the ingress of dust and swarf. Where bellows or telescopic guards are used on long shafts, they should be supported at intervals by internal bushes.

Figure 24 — Telescopic type guard

5.12 Feeding and take-off devices

The use of automatic equipment to move components, materials and substances into and out of machine tools and process machinery should be favourably considered as this not only reduces the hazards to persons at the various operating points but also diminishes the risk of injury when materials would otherwise need to be moved manually. Examples are robots, tongs, chutes, slides, indexing tables, transfer mechanisms, automatic feeds, magazines, suction or magnetic devices, push rods, or air blast.

While automatic feeding and removal devices have much to offer in preventing accidents to machine operators, they can create danger when any faults are being rectified. Care should be taken to ensure that the use of these devices does not introduce further trapping hazards between the devices and parts of the machine or materials being processed. Suitable safeguards should be provided if any risk of injury could arise from moving parts.

5.13 Hydraulic and pneumatic systems

Hydraulic and pneumatic equipment should be in accordance with the safety recommendations given in BS EN 982 and BS EN 983 or the appropriate machine standard where one exists.

5.14 Electrical systems

The electrical equipment should either conform to BS EN 60204-1 or the appropriate machine standard where one exists (see 4.3.2).

5.15 Workholding devices

5.15.1 Power loss during operation

Where power operated workholding devices are supplied, they should be designed so that a hazardous situation is prevented in the event of a failure of the power supply to the system, i.e. the workpiece remains clamped. Further advice on the design and construction of work holding chucks is given in BS EN 1550.

5.15.2 Clamping for automatic machinery

The control system should be interlocked to prevent the machinery from being operated until power is supplied to the workholding device and the workpiece is clamped. Where power operated workholding devices are supplied, it is desirable that a means be provided to check or indicate that power has been supplied and the clamp is on, e.g. by an indicator visible from the operator's normal working position.

In order to be safe, the clamping movement, if accessible, should either not expose a gap of more than 6 mm or be guarded such that it is not possible to trap a hand or a finger. Guidance is given in Annex A and BS EN 349.

5.15.3 Prevention of inadvertent unclamping of the workpiece

The control system ought to be designed so that the power operating system for the workholding device cannot be operated to unclamp the workpiece whilst it is hazardous to do so. In certain situations there also ought to be an indication that the workpiece is actually clamped. For example, a hazard could arise where the clamp is located incorrectly and yet is shown as on. Also, if there is no workpiece, the power could be on and overtravel of the clamp could create a hazard.

5.16 Lifting, handling and transport

Machinery which cannot be moved or transported by hand, should either be equipped or be capable of being equipped with suitable attachment devices for transport by means of lifting gear. Transport personnel should be able to reach the attachment devices safely or provision for automatic attachment should be fitted. Taking into account the centre of gravity, the attachments should be arranged so that the machinery cannot be tipped during correct lifting. Weight details should be given on the machine, on its packaging or on transport documentation.

All machinery elements, including added fixtures, should be provided with means for their safe removal and replacement, unless their shape, size and weight permit these operations to be carried out safely by hand. Parts of machinery which can be removed in operation, e.g. tools and devices which on account of their weight cannot be lifted manually, should be marked with weight details. These have to be affixed so that they are clearly legible and visible, whether the details refer to the removable part or the complete machine.

NOTE Attention is drawn to LOLER [8] particularly regarding thorough examination and inspection when a machine is provided with lifting gear and appliances, e.g. for workpiece loading, unloading, tool mounting or delivery.

Eyebolts and eyebolt holes should be identified to prevent mismatching.

5.17 Lubrication

It is important that excess lubricants should be prevented from reaching the surrounding area and thereby creating a hazard.

On machines in which the failure of an automatic lubrication system could cause a hazard for the operator, such a lubrication system should incorporate a suitable indication of its correct functioning and/or warning of a malfunction.

If the automatic lubrication system fails, means might be required to stop the machine as soon as practicable (see 5.22.3).

5.18 Stability

Machines are supposed to have been designed to be stable (see BS EN ISO 12100-2:2003, 4.6 and BS EN ISO 12100-2:2003, 5.2.6), i.e. they do not fall over and are not capable of being unintentionally moved by vibration, wind pressure, impact, being overloaded or other foreseeable external forces. If this could not be fulfilled adequately by design then stability ought to have been obtained by special protective measures. For example, movements of parts of the machine can be restricted, indicators, alarms or interlocks to prevent tipping could be provided, or the machine can be securely anchored to a foundation. Both static and dynamic stability are supposed to have been considered. If special protective measures and/or precautions are required, a warning ought to have been provided on the machine and/or in the instructions for use.

5.19 Lighting

Local lighting on the machine for the illumination of the work area ought to have been provided when the construction of the machine and/or its guards render the normal lighting inadequate for the hazard-free and efficient operation of the machine. Local lighting also ought to have been provided in areas of regular maintenance which are likely to be poorly lit, e.g. the inside of certain electrical compartments where electrical isolation is necessary for access. Such lighting should conform to BS EN 60204-1 and BS EN 1837.

Fluorescent lighting may be used provided that any stroboscopic effects do not conceal a hazard.

If the position of the lighting has to be adjusted, its location should be such that it does not result in a hazard to the machine operator while the adjustment is being made.

See 11.3.1 for guidance on general lighting of the workplace.

5.20 Hygiene and guard design

Machinery used in certain industries, notably for the processing of food and pharmaceuticals, ought to be designed so that it is not only hazard-free during operation but 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. See BS EN 1672-2.

Where practicable, guards which are required to open for cleaning should be completely detachable in order to eliminate the need for inaccessible hinge pins which are difficult to clean. Where it is necessary to provide a safeguard which is not detachable, e.g. a non-detachable guard, hinges should be kept to a minimum in number and be located as far as possible from the material being processed.

A fixed guard should be so arranged as to have the minimum surface contact with the machine, by mounting it on spacers. This allows residues to be washed away through the gaps between the guard and the machine. The gaps should not, however, permit access of fingers to the hazardous parts whilst they are in motion. See BS EN 294 and Annex A.

Materials used for safeguards should be non-toxic, non-absorbent, shatterproof and readily cleanable, and be unaffected by the material being processed or by any cleaning or sterilizing agent. Welds used in the fabrication of guards should not form surfaces which cannot easily be cleaned. All tubes used in the construction should have their ends sealed.

5.21 Safety markings, signs (pictograms), written warnings

Safety markings, signs and written warnings should be applied as necessary to ensure safe use. They would indicate, for example, maximum speed of rotating parts, maximum working load, presence of a laser product or presence of electrical equipment under a cover, necessity of wearing personal protective equipment. BS EN 981 and the BS EN 61310 series give details for systems of auditory and visual danger and information signals (e.g. rotating shafts, gears or belts) and markings. See also BS EN ISO 12100-2:2003, 6.4.

5.22 Access (see also 11.3.3)

5.22.1 Operating stations

The controls ought to have been positioned relative to the machinery so that the operator has adequate vision for control of the process being undertaken. The operator ought to have been provided with adequate room in his/her working position and have all controls placed within comfortable range. Where it is necessary for an operator to stand or sit on machinery when it is being operated, a platform or seat is supposed to have been provided and designed and situated to protect the operator from any fixed or moving part which can cause injury.

Seats ought to be designed to provide adequate support and fitted with back rests or shaped to protect an operator against slipping from the seat. Suitable footrests should be provided, where necessary.

Access to hazardous parts of transfer mechanisms, conveyors, etc. also require consideration, usually on a larger scale than in the case of single operation processes. In large automated processes, particular attention ought to have been given to safe means of access such as walkways, conveyor bridges or crossover points.

5.22.2 Platforms and steps

Where work platforms are used, they are supposed to have been designed to prevent hazards and provide a level standing space of adequate size with a firm foothold. The stepping areas should be made from materials which remain as slip resistant as practicable under working conditions and suitable guard-rails, posts and toeboards should be provided.

An access ladder with handholds and, where necessary, with hoops, or a stairway with handrails or some other suitable means ought to have been provided to give safe and convenient access. Ladders should conform to BS 4211.

Recommendations for the design and general construction of factory stairways, ladders and handrails are given in BS 5395-3.

5.22.3 Access for adjustment, lubrication and maintenance

Machinery is supposed to have been designed to enable all routine adjustments, lubrication and maintenance to be carried out without removing safeguards and without extensive dismantling of machinery components. Ideally, lubrication and routine maintenance facilities ought to have been incorporated outside the hazardous area, wherever practicable.

All action points, i.e. those points where generally an external action is required to ensure the correct operation of a lubrication system, e.g. filling with lubricant or actuation of a lever, should be easily accessible and situated so as not to cause a hazard. Where access for lubrication is difficult, facilities for lubrication from a remote point or self-lubricated bearings ought to have been provided.