

Safe use of machinery

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Foreword

This Published Document “Safe use of machinery” replaces BS 5304:1988 “Code of Practice — Safety of Machinery” which is withdrawn.

BS 5304:1988 was made obsolescent following publication of a series of harmonized European machinery safety standards.

This Published Document is directed at the safe use of machinery, it provides advice on the basic principles of safeguarding, with reference to current European machinery safety standards where applicable, to the extent that a manufacturing engineer, plant engineer or works manager may be able to interpret the advice and apply it to any particular machinery.

Illustrations are used to demonstrate the general application of these principles although alternative safeguarding solutions may be equally effective.

If machinery has been designed and manufactured in accordance with harmonized European machinery safety standards it is essential that the user maintain the levels of protection contained in those relevant standards. Such standards should also be taken into account when refurbishing or upgrading machinery.

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

Ensuring risks associated with machinery are eliminated or reduced is a task which requires unremitting and careful attention at all times in the interests of industrial accident prevention. It is hoped that this Published Document will make a worthwhile contribution to the prevention of machinery accidents and that it will serve as a useful guide to all those with responsibility for safe use of machinery and duties under the Health and Safety at Work Act 1974 [1] and the Provision and Use of Work Equipment Regulations 1998 [2].

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

Summary of pages

This document consists of a front cover, an inside front cover, pages i to viii, pages 1 to 191 and a back cover.

Section 1. General

1.1 Scope

This Published Document identifies the hazards arising from the use of machinery and describes methods for the elimination or reduction of risk from these hazards, for the safeguarding of machinery and for the use of safe working practices.

Reference is made to non-mechanical hazards but these are primarily covered by reference to standards.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this Published Document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

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

BS 4575, *Fluid power transmission and control systems.*

BS 5378-1, *Safety signs and colours — Specification for colour and design.*

BS 5378-3, *Safety signs and colours — Specification for additional signs to those given in BS 5378-1.*

BS 5395-3, *Stairs, ladders and walkways — Code of practice for the design of industrial type stairs, permanent ladders and walkways.*

BS 5655-1, *Lifts and service lifts — Safety rules for the construction and installation of electric lifts.*

BS 5760, *Reliability of systems, equipment and components.*

BS 6753, *Specification for shotbolts (solenoid operated) for guarding machinery.*

BS 7671, *Requirements for electrical installations — IEE Wiring Regulations — Sixteenth edition.*

BS EN 292-1, *Safety of machinery — Basic concepts, general principles for design — Basic terminology, methodology — Description: Specifies general design methods to help designers and manufacturers achieve safety of machinery.*

BS EN 292-2, *Safety of machinery — Basic concepts, general principles for design — Technical principles and specifications.*

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

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

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

BS EN 457, *Safety of machinery — Auditory danger signals — General requirements, design and testing.*

BS EN 547-1, *Safety of machinery — Human body measurements — Principles for determining the dimensions required for openings for whole body access into machinery.*

BS EN 547-2, *Safety of machinery — Human body measurements — Principles for determining the dimensions required for access openings.*

BS EN 547-3, *Safety of machinery — Human body measurements — Anthropometric data.*

BS EN 574, *Safety of machinery — Two-hand control devices — Functional aspects — Principles for design.*

BS EN 811, *Safety of machinery — Safety distances to prevent danger zones being reached by the lower limbs.*

BS EN 894-1, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — General.*

BS EN 894-2, *Safety of machinery — Ergonomics requirements for the design of displays and control actuators — Displays.*

BS EN 953, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards.*

BS EN 954-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design.*

BS EN 954-2, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation (in preparation).*

PD CR 954-100, *Safety of machinery — Safety-related parts of control systems — Part 100: Guide on the use and application of EN 954-1:1996.*

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

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 1037, *Safety of machinery — Prevention of unexpected start-up.*

BS EN 1088, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection.*

BS EN 1152, *Tractors and machinery for agriculture and forestry — Guards for power take-off (PTO) drive shafts — Wear and strength tests.*

BS EN 1417, *Rubber and plastics machines — Two roll mills — Safety requirements.*

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

BS EN 1672-2, *Food processing machinery — Basic concepts — Hygiene requirements.*

prEN 12013, *Rubber and plastics machines — Internal mixers — Safety requirements (in preparation).*

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.*

prEN 1760-2, *Safety of machinery — Pressure sensitive protective devices — Requirements and test procedures for pressure sensitive edges and pressure sensitive bars (in preparation).*

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 DC and not exceeding 36 kV (in preparation).*

BS EN 60204-32:1998, *Safety of machinery — Electrical equipment of machines — Part 32: Requirements for hoisting machines.*

BS EN 60529, *Degrees of protection provided by enclosures (IP code).*

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

BS EN 60947-4-2, *Specification for low-voltage switchgear and controlgear — Part 4: Contactors and motor starters — Section 2: A.C. semiconductor motor controllers and starters.*

BS EN 60947-5-1, *Specification for low-voltage switchgear and controlgear — Control circuit devices and switching elements — Electromechanical control circuit devices.*

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 60947-5-5, *Specification for low-voltage switchgear and controlgear — Control circuit devices and switching elements — Electrical emergency stop device with mechanical latching function.*

BS EN 61310-1, *Safety of machinery — Indication, marking and actuation — Part 1: Requirements for visual, auditory and tactile signals.*

BS EN 61310-2, *Safety of machinery — Indication, marking and actuation — Part 2: Requirements for marking.*

BS EN 61310-3, *Safety of machinery — Indication, marking and actuation — Part 3: Requirements for the location and operation of actuators.*

BS EN 61496-1:1998, *Safety of machinery — Electro-sensitive protective equipment — Part 1: General requirements and tests.*

BS EN ISO 10472-1, *Safety requirements for industrial laundry machinery — Common requirements.*

BS EN ISO 10472-2, *Safety requirements for industrial laundry machinery — Washing machines and washer-extractors.*

BS EN ISO 10472-3, *Safety requirements for industrial laundry machinery — Washing tunnel lines including component machines.*

BS EN ISO 10472-4, *Safety requirements for industrial laundry machinery — Air dryers.*

BS EN ISO 10472-5, *Safety requirements for industrial laundry machinery — Flatwork ironers, feeders and folders.*

BS EN ISO 10472-6, *Safety requirements for industrial laundry machinery — Ironing and fusing presses.*

BS EN ISO 11546-2, *Acoustics — Determination of sound insulation performances of enclosures — Measurements in situ (for acceptance and verification purposes).*

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

BS EN 61496-3, *Safety of machinery — Electro-sensitive protective equipment — Part 3: Particular requirements for equipment using active opto-electronic protective devices responsive to diffuse reflection (AOPDDR) (in preparation).*

BS EN 61810-1, *Electromechanical non-specified time all or nothing relays — Part 1: General requirements.*

BS EN 50205, *Relays with forcibly guided (linked) contacts.*

PD R044-001, *Safety of machinery — Guidance and recommendations for the avoidance of hazards due to static electricity.*

IEC 61496-3, *Safety of machinery — Electro-sensitive protective equipment — Part 3 (in preparation)*

IEC 61508-1, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General requirements.*

IEC 61508-2, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 2: Requirements for electrical/electronic/programmable electronic systems.*

IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 3: Software requirements.*

IEC 61508-4, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 4: Definitions and abbreviations.*

IEC 61508-5, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 5: Examples of methods for the determination of safety integrity levels.*

IEC 61508-6, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3.*

IEC 61508-7, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 7: Overview of techniques and measures.*

IEC 61800-5, *Electrical power drive systems — Part 5: Electrical, thermal and functional safety — Electrical adjustable speed power drive systems (in preparation).*

IEC 62061, *Safety of machinery — Functional safety of electrical, electronic and programmable electronic control systems for machinery (in preparation).*

IEC 62046, *Safety of machinery — Application of electro-sensitive protective equipment (ESPE) and pressure sensitive mats and floors to machinery (in preparation).*

1.3 Definitions

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

1.3.1

machinery

an 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

1.3.2

hazard

a source of possible injury or damage to health

1.3.3

risk

a combination of the probability and the degree of the possible injury or damage to health in a hazardous situation

1.3.4

danger zone

any zone within and/or around machinery in which a person is exposed to risk of injury or damage to health

1.3.5

safeguarding

safety measures consisting of the use of specific technical means called safeguards (guards, safety devices), to protect persons from hazards which cannot be reasonably removed or sufficiently limited by design

1.3.6

guard

a part of machinery specifically used to provide protection by means of a physical barrier. Depending on its construction, a guard may be called casing, screen, door, enclosing guard, etc.

1.3.7

safety device

a device other than a guard that eliminates or reduces risk, alone or associated with a guard

1.3.8

safe working practice

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

1.3.9

interlock

a safety device that interconnects a guard with the control system or the power system of the machinery

1.3.10

failure to danger

any failure of the machinery, its associated safeguards, control circuits or its power supply that generates a hazardous situation

1.3.11

integrity

the 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

1.3.12

scotch

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

1.3.13

use

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

Section 2. General guidance

2.1 Application of the Published Document

2.1.1 Use of the Published Document

This Published Document is intended for those who use machinery, machinery guarding or safety devices.

It is also intended to be used by those concerned with information, instruction and training in safe working practices.

2.1.2 General principles

The aim of the Published Document is to promote a high standard of machinery safety during use. It describes and illustrates a variety of safety measures and explains methods by which it is possible to assess which measure or measures it is reasonable to adopt in particular circumstances. It will, however, be necessary 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.

Annex D provides a list of transposed harmonized standards that are applicable to machinery and many 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 may be published from time to time and other relevant new developments.

2.2 Strategy for selecting safety measures

2.2.1 General

The strategy for reducing risk of injury that may be applied to mechanical hazards are as follows:

- a) identify the hazards and assess the risks;
- b) eliminate the hazards by inherently safe design or limit the risk by:
 - 1) use of safeguards; or
 - 2) use of safe working practices.

Designers and suppliers should have taken account of mechanical hazards and taken steps to reduce the scale of injury that can be caused, e.g. by reducing speeds or forces.

Where machinery has been designed or modified without taking these hazards into consideration, their identification and elimination should be considered by the user. Modifications may be possible which, although not capable of eliminating injury, reduce its scale. (Section 3 refers to identification of hazards and Section 5 to elimination measures and measures to reduce injury.)

When a hazard cannot be eliminated or avoided, other measures for reducing the risk of injury should be sought. These measures may include reducing the scale of injury, providing safeguards and safe working practices. The avoidance of injury depends on the reliability of these measures.

Unless a danger point or area is safe by virtue of its position, the machinery should be provided with appropriate safeguarding which eliminates or, where this is not practicable, reduces the risk.

It may be difficult to guarantee that machinery is safe by virtue of its position, and where access and consequent injury is reasonably foreseeable, safeguards should be provided.

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 4.

Certain safety measures are more reliable than others. The order of priority is determined by reliability and therefore safeguards should be considered before safe working practices. Safeguards are considered in Section 6, Section 7, Section 8 and Section 9 and safe working practices in Section 13.

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 may require personal protection equipment and this is also considered in Section 13.

In addition to measures which are taken explicitly for safety reasons, a large number of other factors influence the safe use of machinery which may or may not have been taken at the design stage. For the benefit of the user these are considered in Section 5, Section 10, Section 11 and Section 12.

2.2.2 Selection of safety measures

When applying the strategy for selection, it may not be possible to use the more effective types of safety measures because they are either not technically feasible or are not suitable for their particular application.

In considering measures for all the hazards during each relevant phase of machine life, risk assessment techniques will assist in choosing the best possible combination of safety measures. (See Section 4.)

2.2.3 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 may 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, toolsetting and adjustment phases may require greater emphasis. The aim is to minimize the total risk.

2.2.4 Specific legislation, codes of practice and European standards

In some cases, particular safeguards or safe working practices are required by legislation such as the Provision and Use of Work Equipment Regulations [2], the Lifting Operations and Lifting Equipment Regulations:1998 [3], etc. Guidance on selecting safety measures for use on particular types of machinery may be found in transposed harmonized standards listed in Annex D.

Section 3. Identification of hazards

3.1 Dangers from machinery

A person may 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 may be regarded as mechanical hazards. Some machinery may also present non-mechanical hazards in which the dangers are less obvious or tangible.

This Published Document deals principally with safeguards applicable to the mechanical hazards identified in 3.2. To assist with non-mechanical hazards not covered in detail in this Published Document, brief comment is made in 3.3 and Section 10, and references are made to appropriate transposed harmonized standards listed in Annex D.

3.2 Mechanical hazards

3.2.1 General

Movement of machinery parts consists basically of rotary, sliding or reciprocating motion or a combination of these.

These movements may 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 examples in the groups detailed in 3.2.2 to 3.2.10 are typical and one or more will be found on most units of machinery, but the list is not exhaustive. It should be noted that individual machines and individual parts of machines may cause one or more of these types of injury. (See Figure 1.)

3.2.2 Entanglement

Bodily contact with the following features may 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, are 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) By catching between two parts (see also 3.2.9).

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 16), 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.

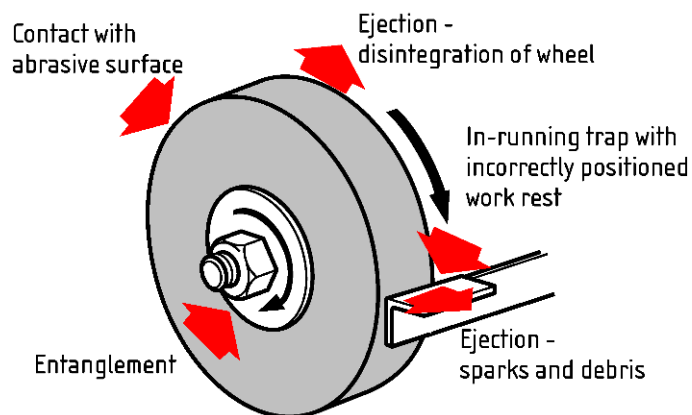


Figure 1 — Individual parts of machines causing one or more types of injury, e.g. hazards at an abrasive wheel

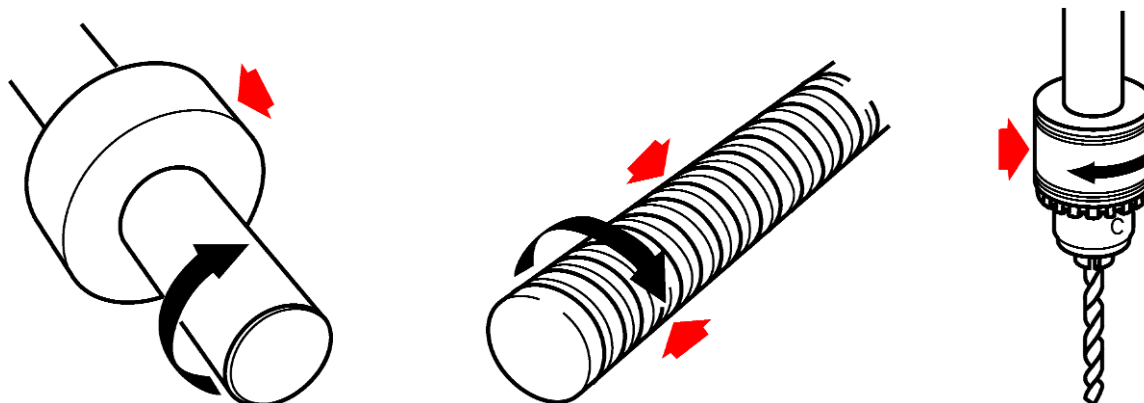


Figure 2 — Entanglement caused by contact with a single rotating surface

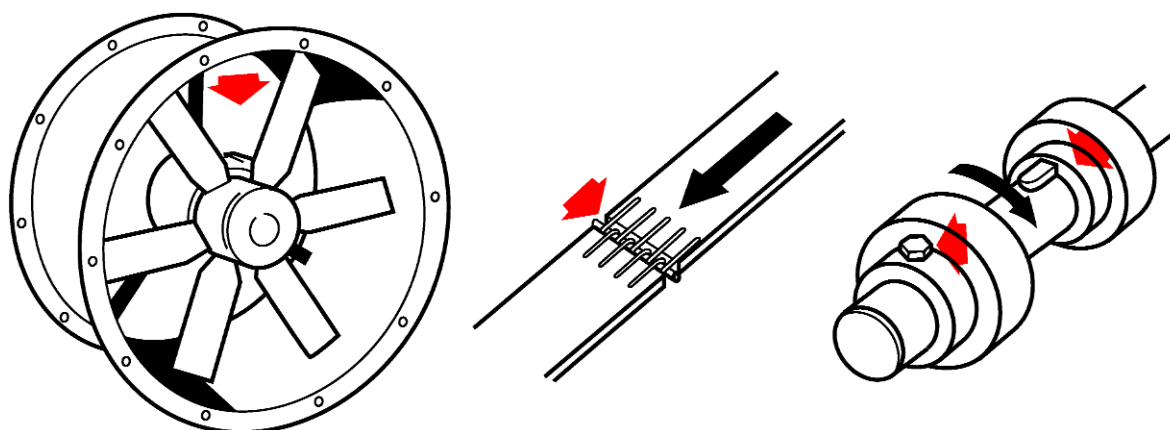
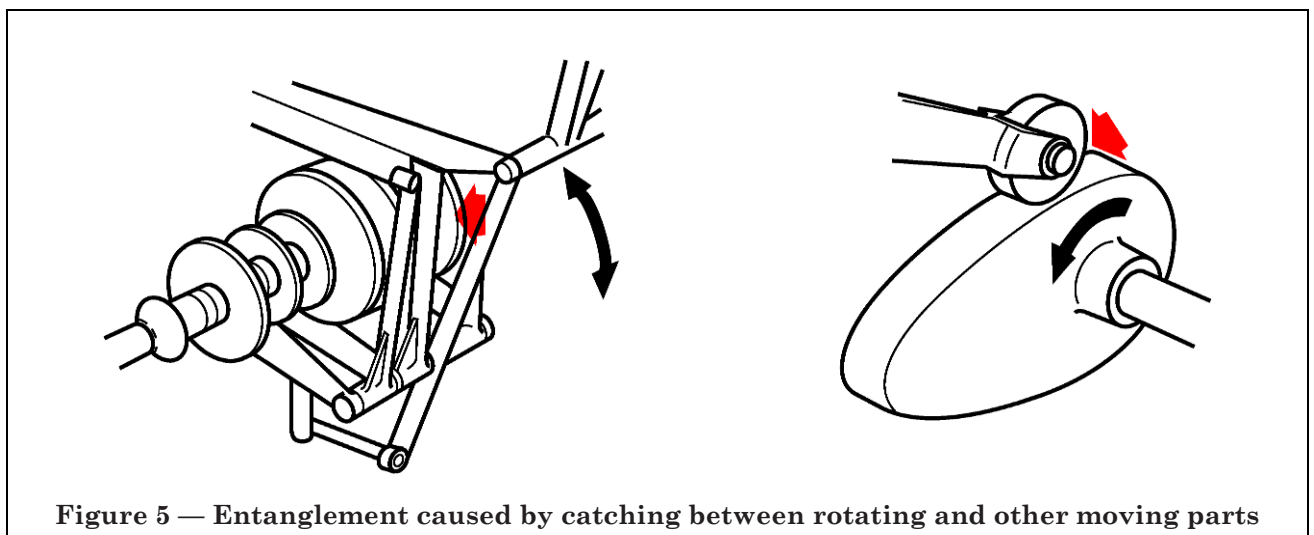
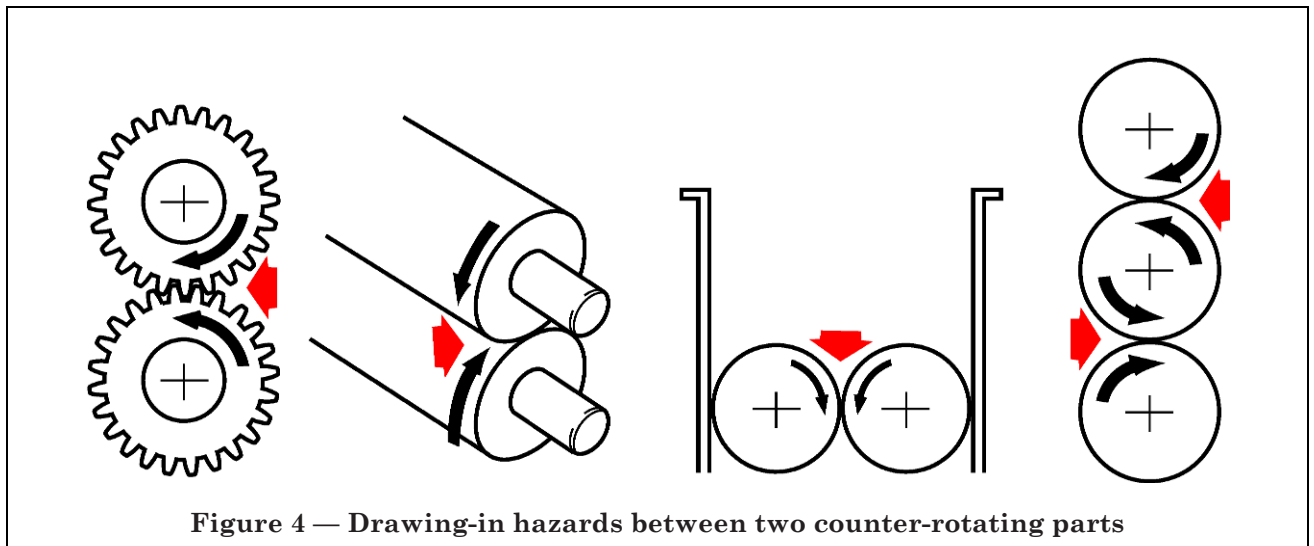


Figure 3 — Entanglement caused by catching on projections or in gaps



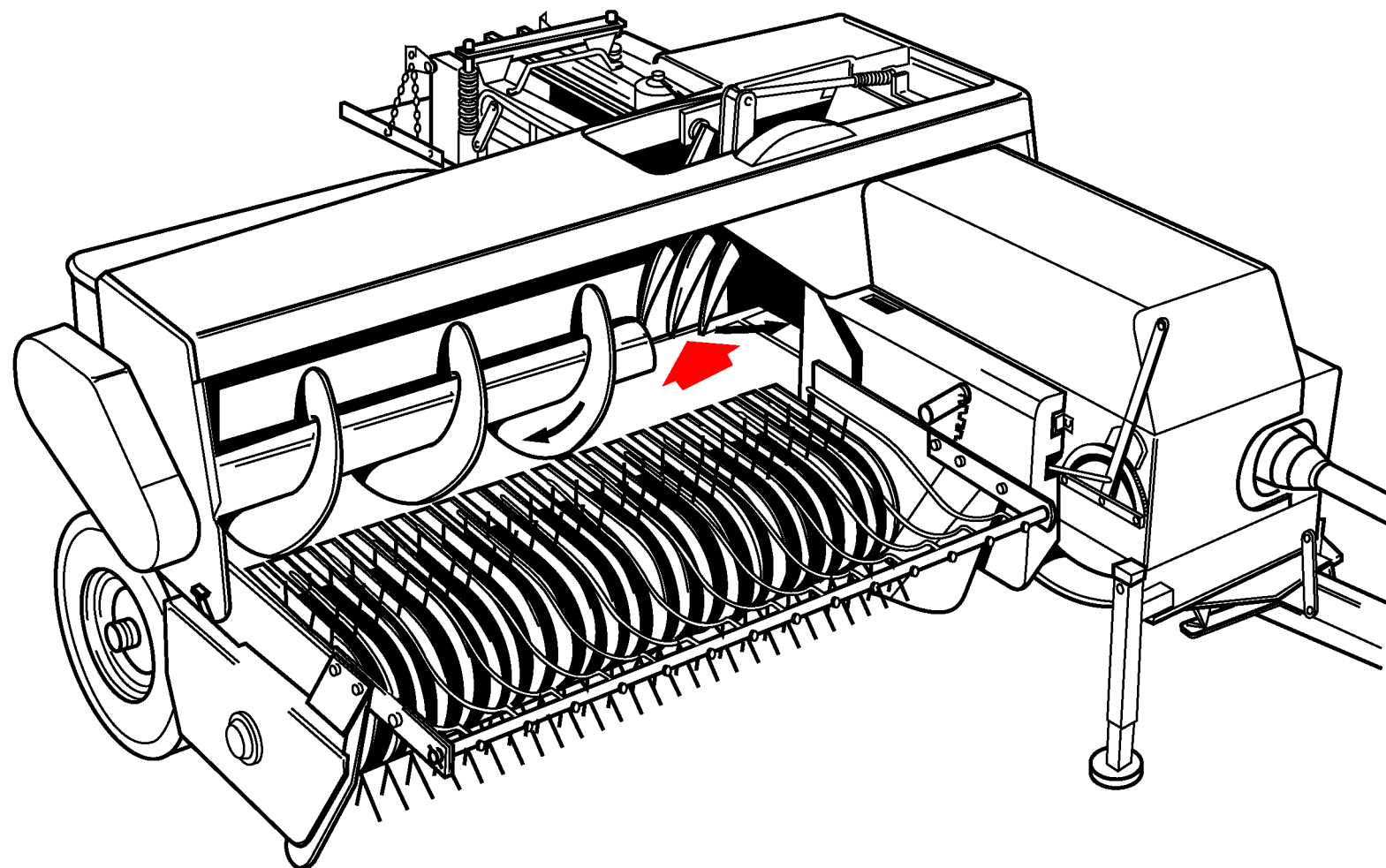


Figure 5 — Entanglement caused by catching between rotating and other moving parts (*concluded*)

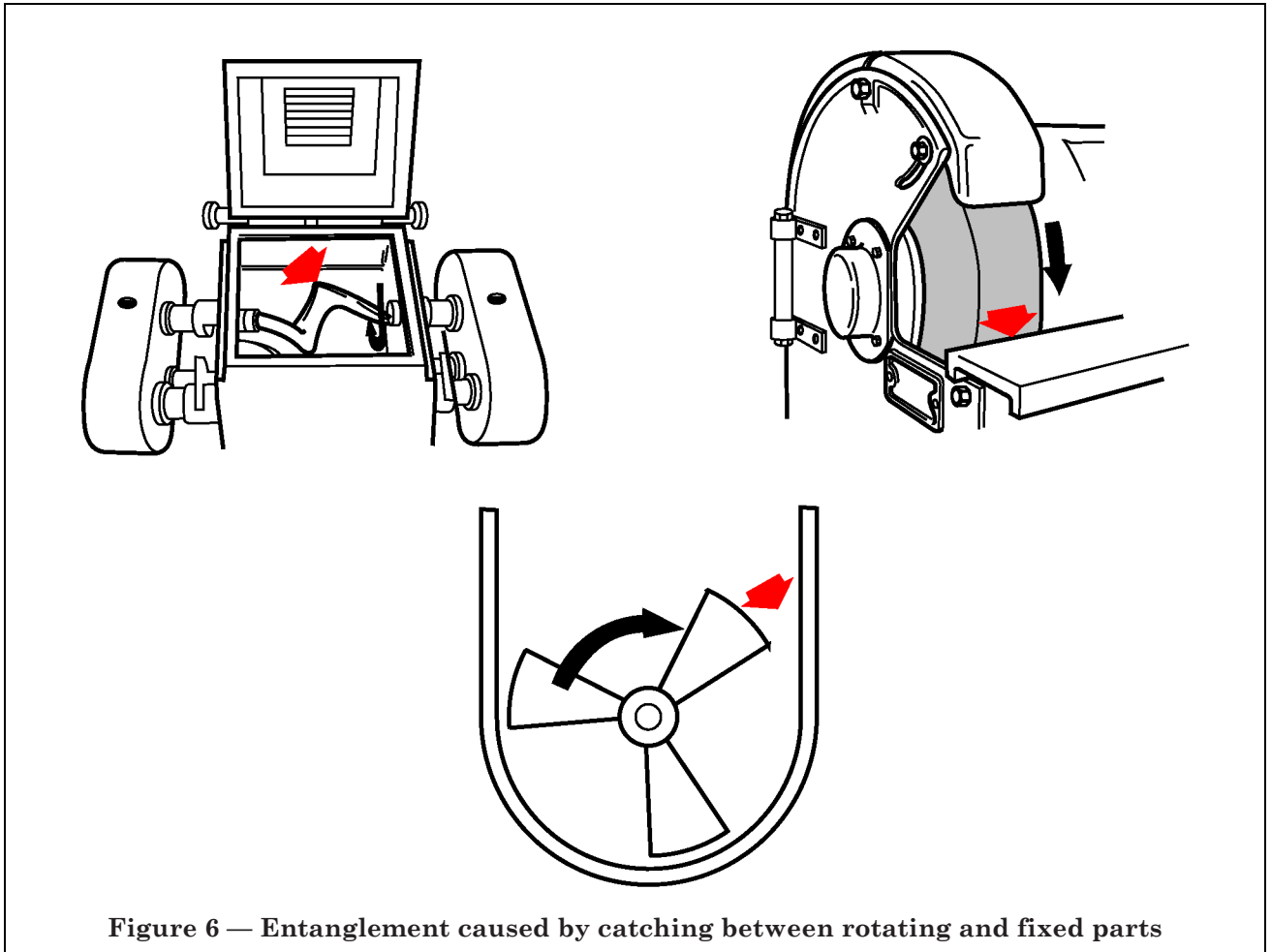


Figure 6 — Entanglement caused by catching between rotating and fixed parts

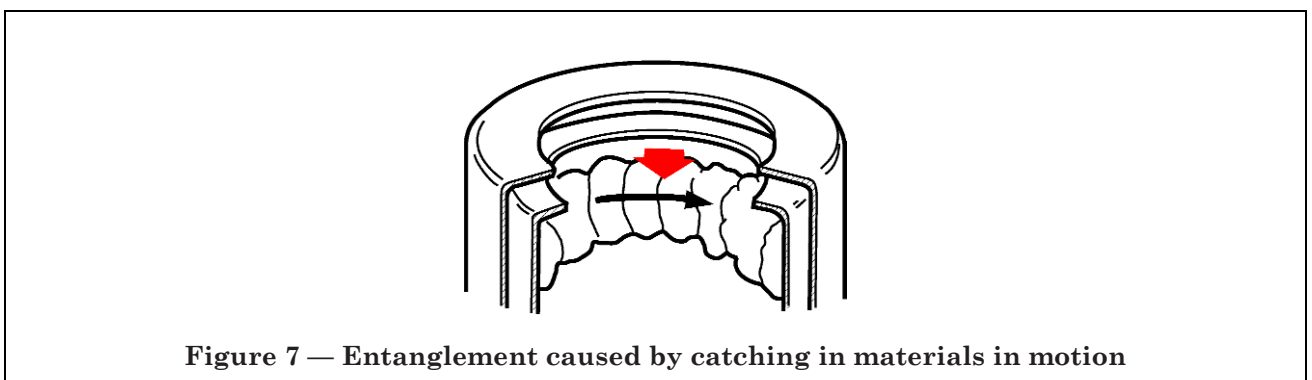


Figure 7 — Entanglement caused by catching in materials in motion

3.2.3 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, e.g. 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 3.2.9 and Figure 16), and fast moving ropes or belts.

3.2.4 Cutting

Examples of cutting hazards 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 (see Figure 9).

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 may 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.

3.2.5 Shear

Parts of the body may 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, 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.

3.2.6 Stabbing and puncture

The body may be penetrated by the following:

- a) flying objects (see Figure 12);
 - 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, or debris from rotary mowers and hedge-cutters;
- b) rapidly moving parts of machinery or pieces of material (see Figure 13), e.g. sewing machines, drilling machines.

3.2.7 Impact

Impact hazards are caused by objects which act against the inertia of the body but do not penetrate it (see Figure 14), e.g. the traversing motion of a machinery part, oscillating pendulum movements, striking by projections or moving counterweights.

3.2.8 Crushing

Crushing occurs when one part of machinery moves against another with a part of the body in between (see Figure 15), e.g. the ram of a forging hammer, the tools of power presses, the callipers of spot welding machines, garment press closure, the closing nip between two platen motions, hand-fed platen machines, foundry moulding machines, counterweights. The traversing motion of a machinery part, e.g. the table of a machine tool, and a fixed structure not being part of the machinery may also create this type of hazard.

3.2.9 Drawing-in

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:

- a) 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;
- b) in-running nips between a rotating surface and a tangentially moving surface (see Figure 16), e.g. power transmission belt and pulley, chain and chain wheel, rack and pinion;
- c) 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.

3.2.10 Injury by compressed air or high pressure fluid injection

Injection of fluids through the skin can cause tissue damage similar to crushing. Examples are compressed air jets, diesel injectors, paint sprayers, high pressure water jetting and high pressure hydraulic systems.

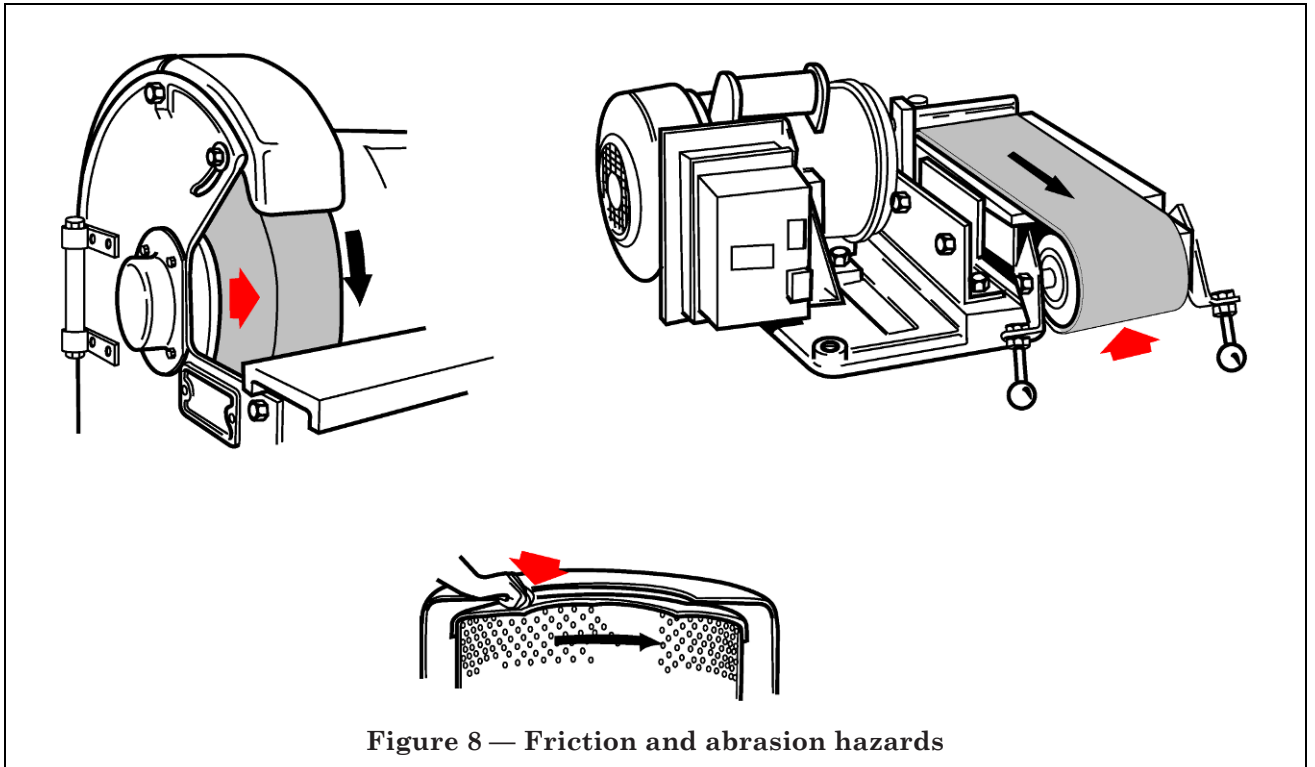


Figure 8 — Friction and abrasion hazards

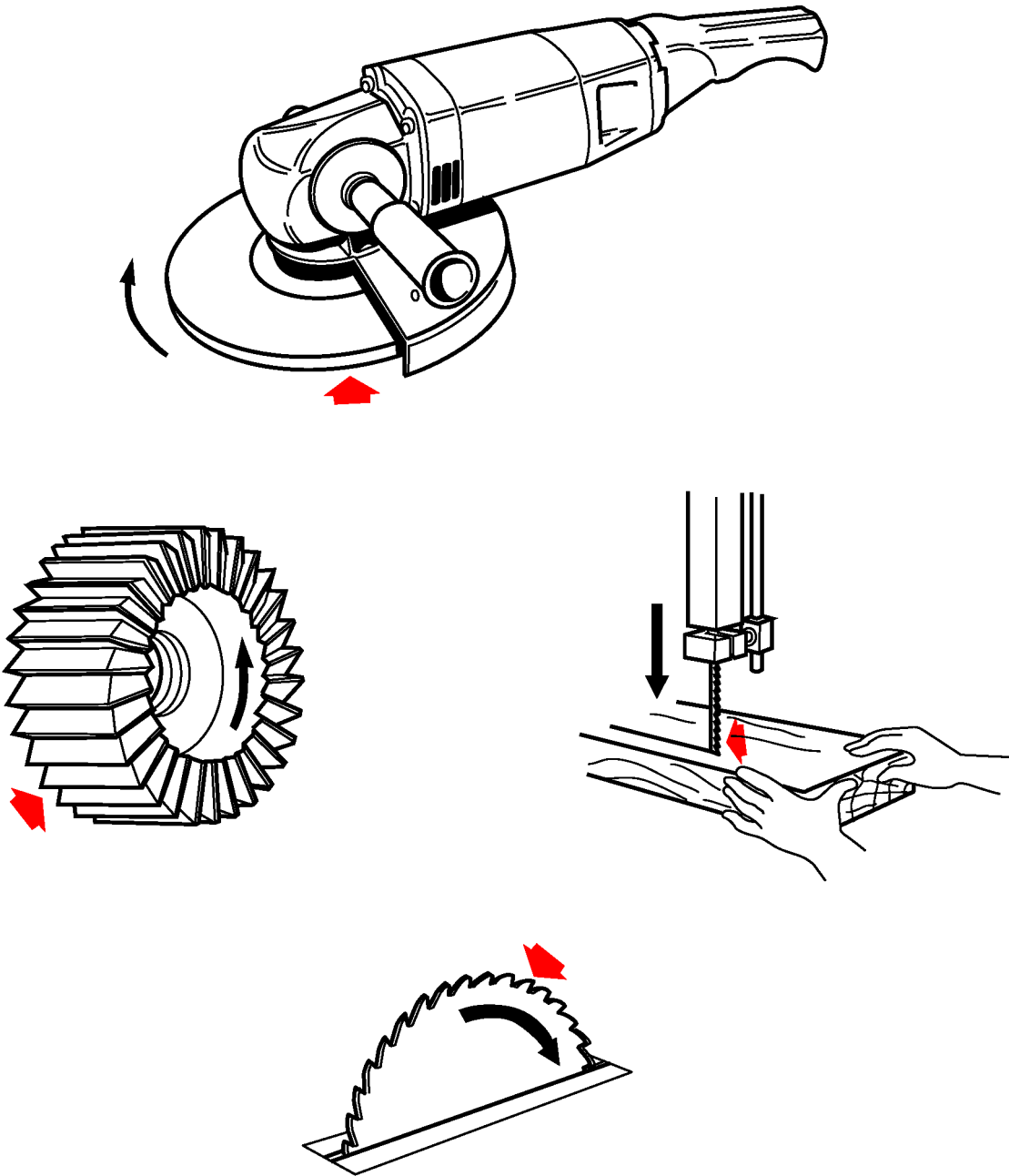
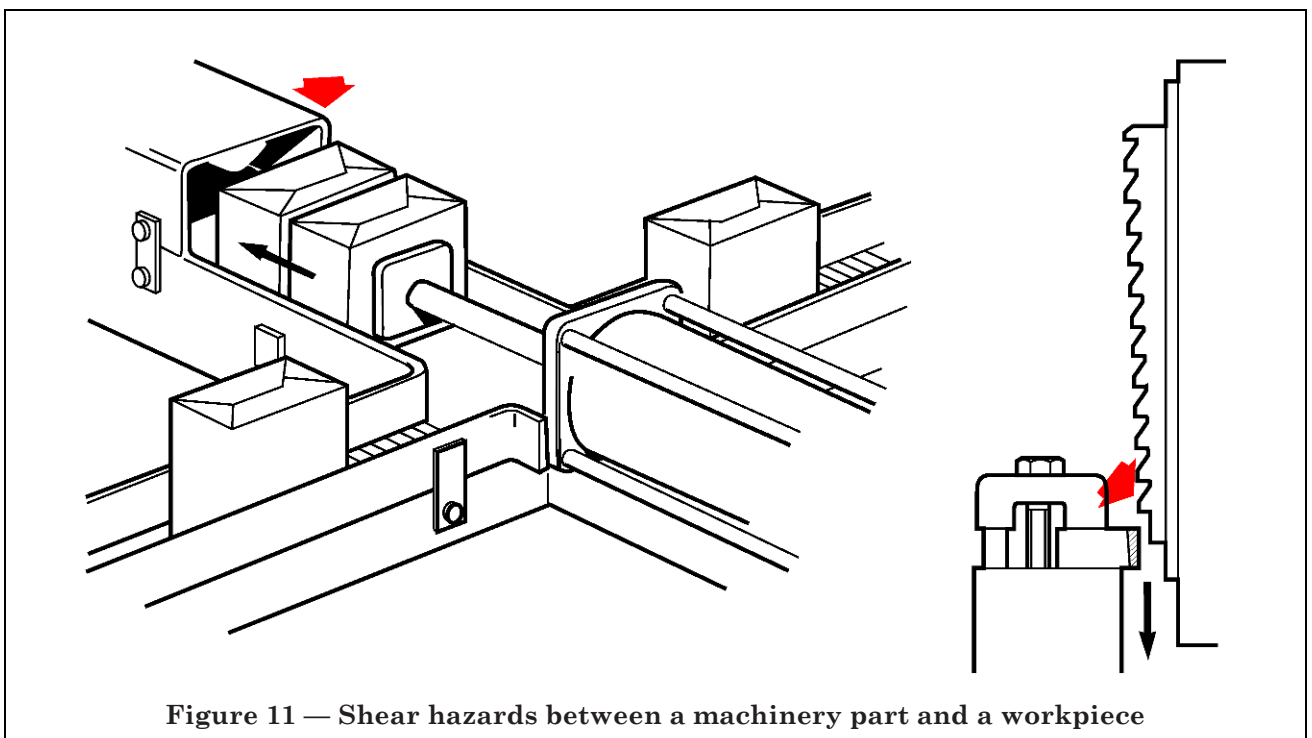
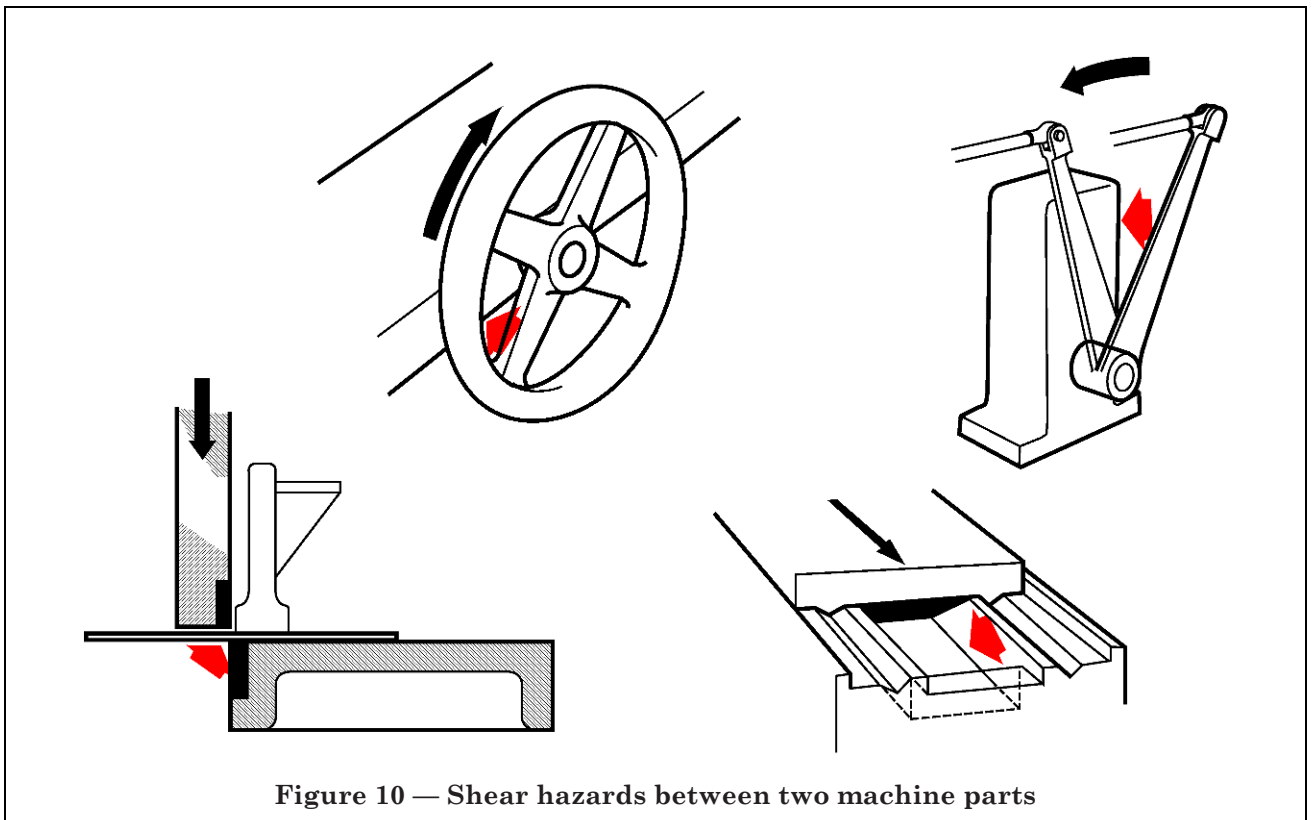


Figure 9 — Cutting hazards



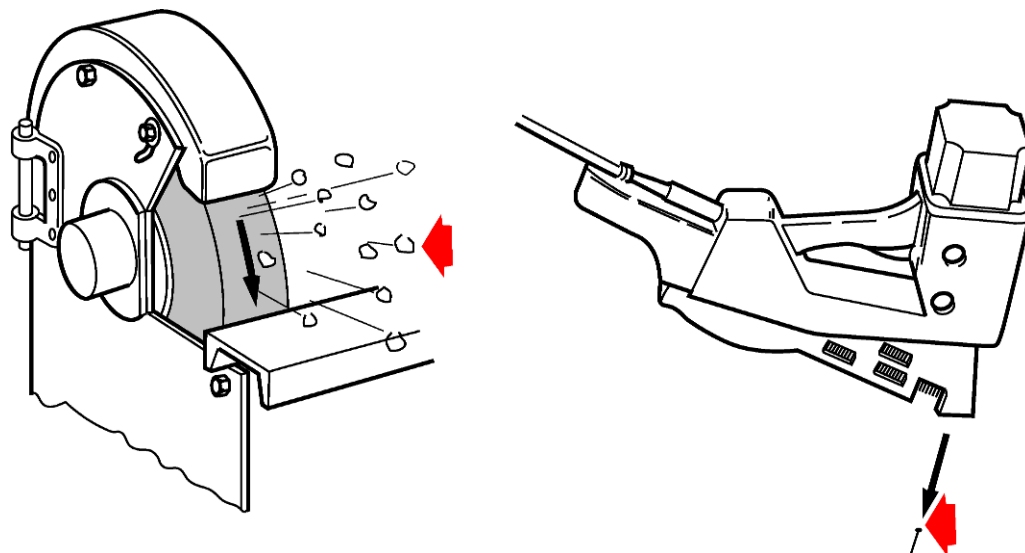


Figure 12 — Stabbing and puncture by flying objects

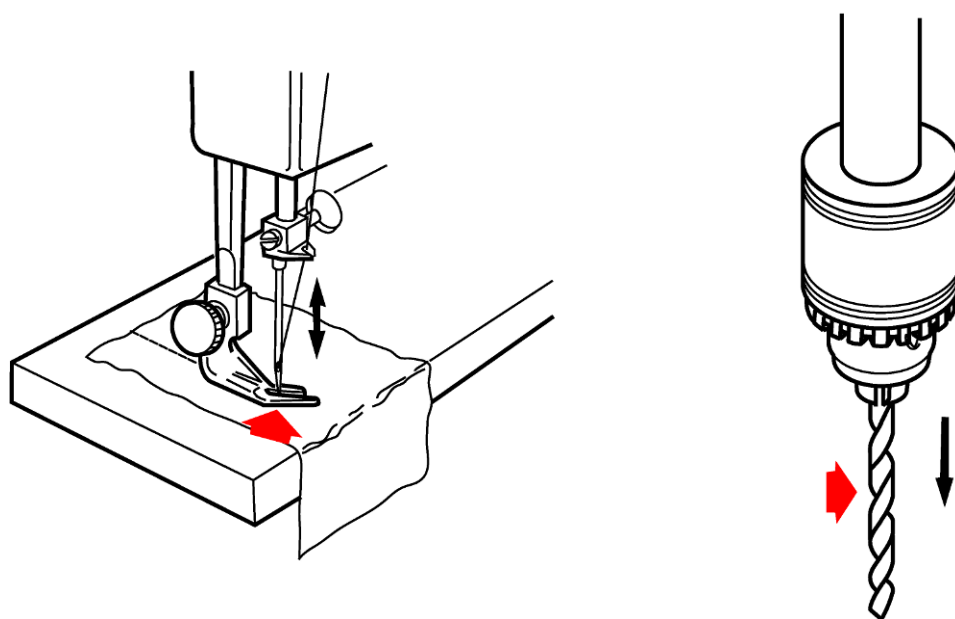


Figure 13 — Stabbing and puncture by rapidly moving parts of machinery or pieces of material

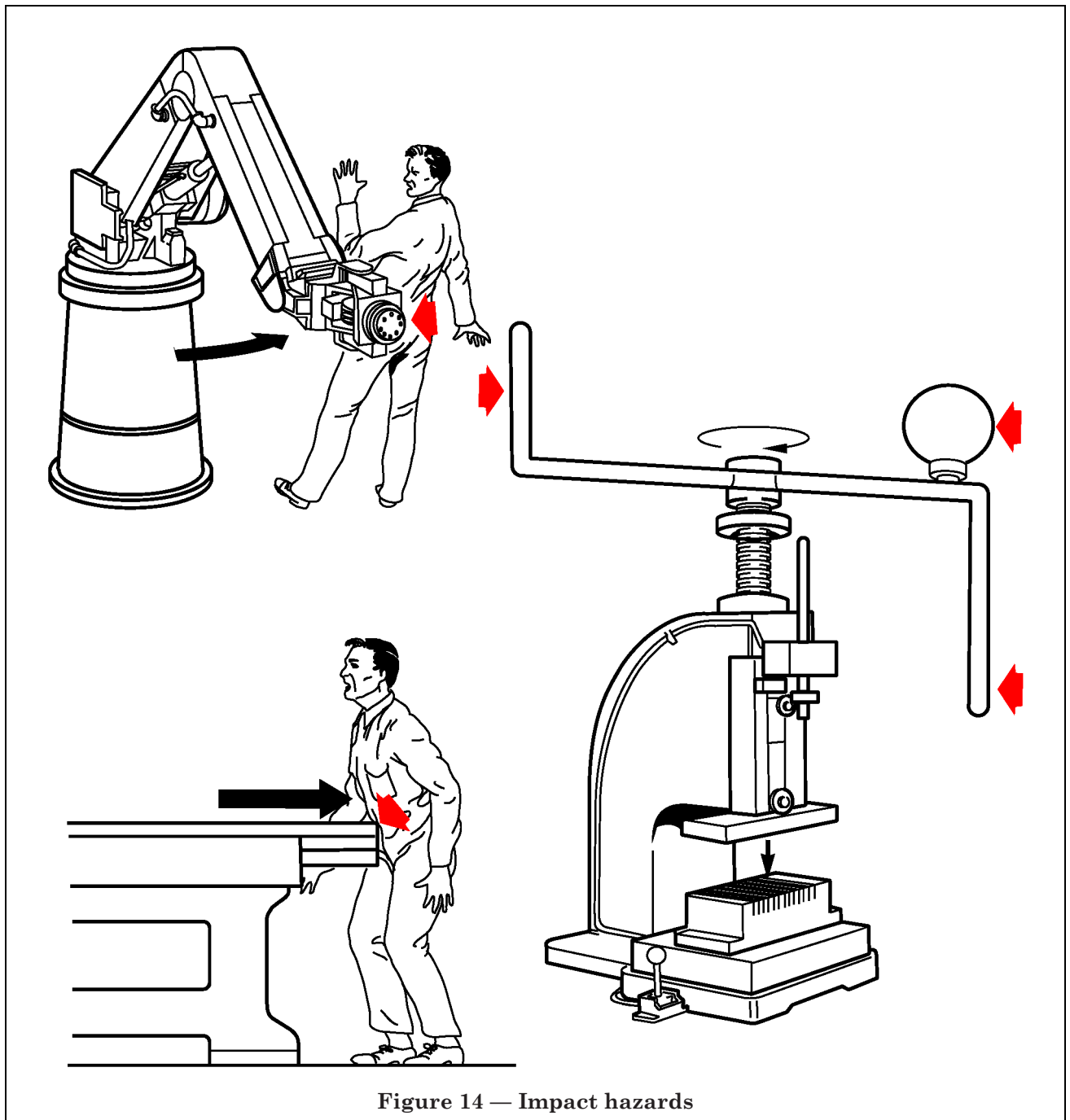
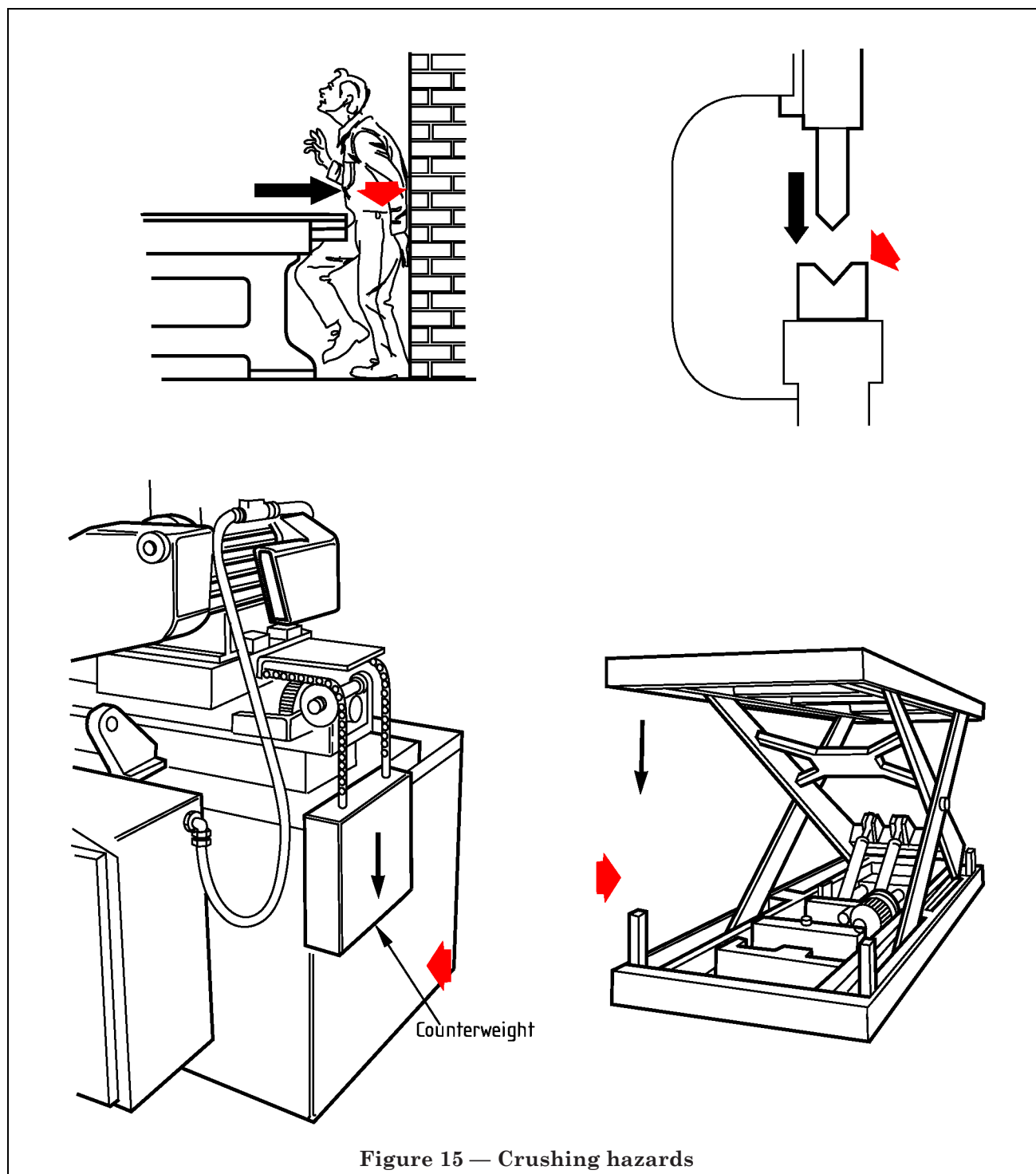
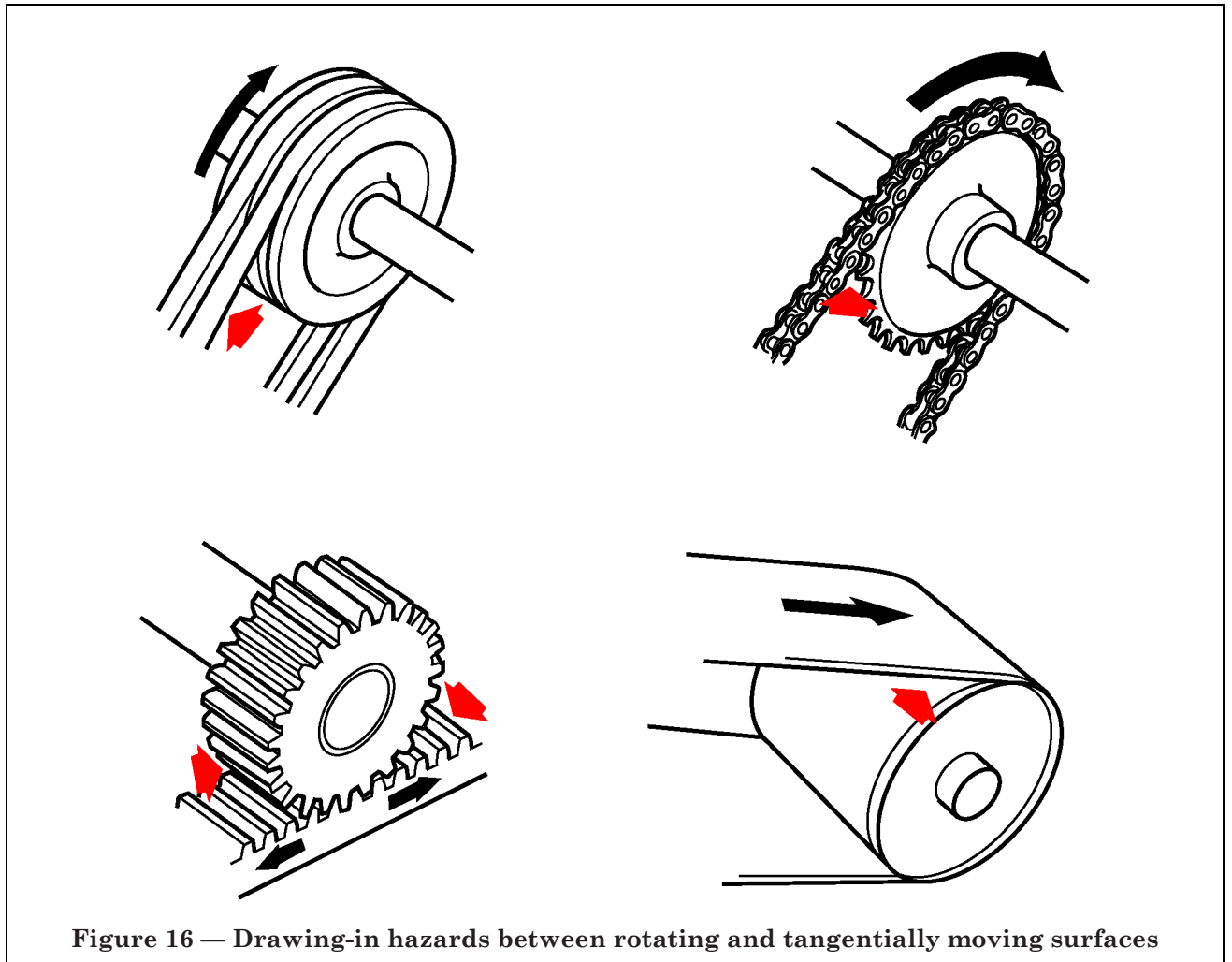


Figure 14 — Impact hazards





3.3 Non-mechanical hazards

3.3.1 General

Machinery may also present other hazards and suitable measures need to be taken to prevent injury. The nature of the measure will depend on the type of hazard. Where measures taken for one hazard may conflict with those taken for another, the principle should be adopted of aiming for the minimum possible risk. This will normally mean that precedence is given to dealing with the hazard creating the greatest risk, whether or not this is a mechanical hazard. Designers and suppliers should have considered all hazards in accordance with BS EN 292.

3.3.2 Source of danger (hazard)

As stated in 1.1 and 3.1, this Published Document does not deal specifically with these non-mechanical sources of danger. However, brief comment on some of the more important environmental aspects is given in Section 10.

The various sources of danger other than mechanical hazards include the following:

- a) access;
 - 1) slips, trips, falls;
 - 2) falling and moving objects;
 - 3) obstructions and projections;
- b) handling and lifting;
- c) electricity (including static electricity):
 - 1) shock;
 - 2) burns;

NOTE Designers and suppliers should have used BS EN 60204-1 (and BS EN 60204-11 in the case of high voltage) for the electrical equipment of the machine. See also PD R044-001 for avoidance of hazards due to static electricity.

d) chemicals that are:

- 1) toxic;
 - 2) irritant;
 - 3) flammable;
 - 4) corrosive;
 - 5) explosive;
- e) fire and explosion;
 - f) noise and vibration;
 - g) pressure and vacuum;
 - h) temperature (high, low);
 - i) inhalation of mist, fume and dust;
 - j) suffocation;
 - k) ionizing and non-ionizing radiation;
 - l) biological, e.g. viral and bacterial.

3.3.3 Linking mechanical and non-mechanical hazards

Many of the safeguards which are adopted in order to eliminate or mitigate personal harm from non-mechanical hazards will need to be considered in conjunction with the safeguards against the mechanical hazards identified in 3.2 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.

Section 4. Risk assessment and integrity

4.1 Risk assessment

4.1.1 General

The technique of risk assessment formalizes the intuitive process by which designers and safety engineers use their experience to identify hazards, assess risks and select the appropriate safety measures.

The assessment of risk determines, to a large extent, the safety measures which it is necessary to take. Two factors should be taken into account:

- a) the severity of foreseeable injuries;
- b) the probabilities of their occurrence.

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 4.1.2, 4.1.3 and 4.1.4 describe the underlying principles involved. It should be noted that many of the more formal methods as yet have limited application because of the lack of reliable data. BS EN 1050 outlines some principles for carrying out risk assessments.

4.1.2 Probability of injury

When examining a machine either from first principles or by making comparisons, account should be taken of the frequency of access to or beyond a danger point during each phase of machine life, e.g. machine operation and breakdown, commissioning, maintenance, setting and process changeover (see 2.2.3).

By considering foreseeable human behaviour at each phase, the designer, etc. can assess the probable total frequency of access to the danger points. Next, an estimate should be made of the proportion of each type of access likely to be injurious, which may require a reliability assessment of safety or other features, and of the severity of injury in each case. It should be noted that the severity of injury may vary because of variations in the position of access for different reasons.

It is emphasized that the absence of injury from machinery used without 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 will be able to gather sufficient accident data from within their own plant to give a statistically significant indication of the probability of injury from a given type of machine.

Limited accident statistics are available from various sources, e.g. 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 injury should still be based on individual and collective experience of other machinery with similar modes of operation, maintenance, etc.

4.1.3 Severity of injury

The severity of possible injury has an important influence on the level of safety measures. Where two machines present the same probability of injury, but in one case the 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 injury, particularly those involving injury to health, are not immediately apparent and may be manifested some time after exposure to a hazard has ceased. Other injuries build up over a long period of exposure to a hazard.

Access to the hazard area may occur during all phases of machine life (see 2.2.3) and for a variety of reasons, either deliberate or accidental. The following questions should be asked, to determine the possible severity of injury.

- a) What type of mechanical or other hazard is involved? (See 3.2 and 3.3.)
- b) What type(s) of injury can be foreseen? (See 3.2.)
- c) What is the probability of each possible severity of injury, given the conditions under which access occurs?
- d) What loss to the individual, his/her family, the employer and the community does each possible degree of injury represent?

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

4.1.4 Overall risk assessment

Risk is a combination of the probability of injury and the severity of the injury. For each hazard, the total risk is the sum of the risks under all the different circumstances given in 4.1.1, 4.1.2 and 4.1.3. The overall risk from the use of a given machine is the sum of the risks from the various hazards.

Where high risks are involved a more formal and systematic method of assessment should be used as described for the selection of interlocking methods in Annex B.

4.2 Integrity

4.2.1 Reliability

The greater the risk, the greater is the need to protect against it. The greater the probability or severity of injury resulting from failure of the safety measure, the greater should be the reliability of the measure.

This applies to safeguards 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 which might lead to these hazards causing injury.

In any system where a failure may 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 higher risks are involved, a more formal method of assessment should be used, e.g. failure modes, effects and critical analysis (see BS 5760). It is also necessary to consider the reliability of operating procedures, where safety depends upon them, and this will encompass both inadvertent failure to follow procedures and deliberate failure to do so.

4.2.2 Defeatability of guards and safety devices

Guards and safeguarding systems for machinery should achieve their safety function with minimal downtime and the least reduction in productivity. It should be recognized that production pressures, incentive schemes or well intentioned zeal can lead to safeguards being defeated.

Designers and suppliers should have designed and constructed safeguards to make 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 will encourage attempts to defeat them.

See Section 7 regarding the design and construction of guards intended to discourage guard defeatability. See also **5.7** of BS EN 1088 for designs to minimize defeat possibilities of interlocking devices associated with guards.

Section 5. Machinery design

5.1 Checks by user

Designers of new machinery, when considering safety, should have followed the general principles laid down in BS EN 292-1 and -2, and taken account of the relevant type B and type C standards (see clause 0 of BS EN 292-1) applicable to the particular machine. The user may find reference to these standards useful when assessing the safety of a machine and they are listed in Annex D. As a basic guide wherever practicable, hazardous parts should have been eliminated or effectively enclosed (see Figure 17). If they could not be eliminated, then suitable safeguarding should have been incorporated as part of the design, or if this was not possible, provision should have been made for safeguarding to be easily incorporated at a later stage.

Provision should 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 it will vary.

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

Designers of machinery should have taken into account the ergonomics of machinery use, i.e. they should 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 can be found in BS EN 894 see Annex D. Among the aspects to consider should 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 (see Section 10), they are important and should not be overlooked. Although it should 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, for example, dust and noise. If not, there may be an opportunity to do so 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 547-1 to -3, BS EN 811 and Annex A).

These aspects should have been considered during the machinery design and installation planning stages. If not, the user will need to take remedial action to provide the necessary safeguards and should, in the first instance, consult the manufacturer or supplier. It should be borne in mind that the addition of safeguards as an afterthought may result in awkward design problems involving unnecessary expense, reduced production and possibly inefficient safeguard performance. The following paragraphs give examples of possible hazards and solutions.

5.2 Hazard analysis

5.2.1 General

A machine designer should be aware of the hazards identified in Section 3 and as many of these hazards as possible should have been avoided by suitable choice of design features. Where it was not possible to avoid these hazards, the designer should have examined the factors which influence the magnitude of the risk such as speed of movement, force, etc. which may influence the severity of injury and selected them accordingly. Factors which may influence the frequency of exposure and hence the probability of injury should also have been considered. This could have resulted in the use of remote and automatic feeding and waste disposal and "sealing for life" (or remote lubrication) to reduce maintenance access.

The user should be aware that on machinery where the preceding appears not to have been considered, modifications can sometimes be made on the basis described as follows.

5.2.2 Entanglement

Entanglement hazards may be reduced 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. Guards for rotating shafts should preferably be 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.

5.2.3 Friction and abrasion

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, e.g. a badly adjusted work rest on an abrasive wheel.

5.2.4 Cutting

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.

5.2.5 Shear traps

The principal measures which may be adopted to eliminate shear traps are as follows:

- a) filling the gaps, such that the shear trap is minimized see Figure 18 and Figure 19;
- b) 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;
- c) increasing the minimum clearance between the shearing parts, such that parts of the body can enter the gap safely.

When the technique of separating the shearing parts is used, consideration should be given to the body parts which it is possible to insert in the trap. Since it relies on pushing body parts out of the way, it is not appropriate except on low-speed machinery, and detailed consideration of other hazards will often rule it out. It should be noted that the technique is not effective against double shear traps. Guidance on safety distances is given in BS EN 349 (see Annex A).

When it is not possible to avoid the creation of a shear trap, it may still be possible to restrict reach past the trap, so that injury is reduced. It may 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.

5.2.6 Stabbing and puncture

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 moving away may aggravate the effect.

Where there is a risk of small or sharp ejected objects which may penetrate the skin, sheet material should be considered in lieu of mesh for guards.

5.2.7 Impact

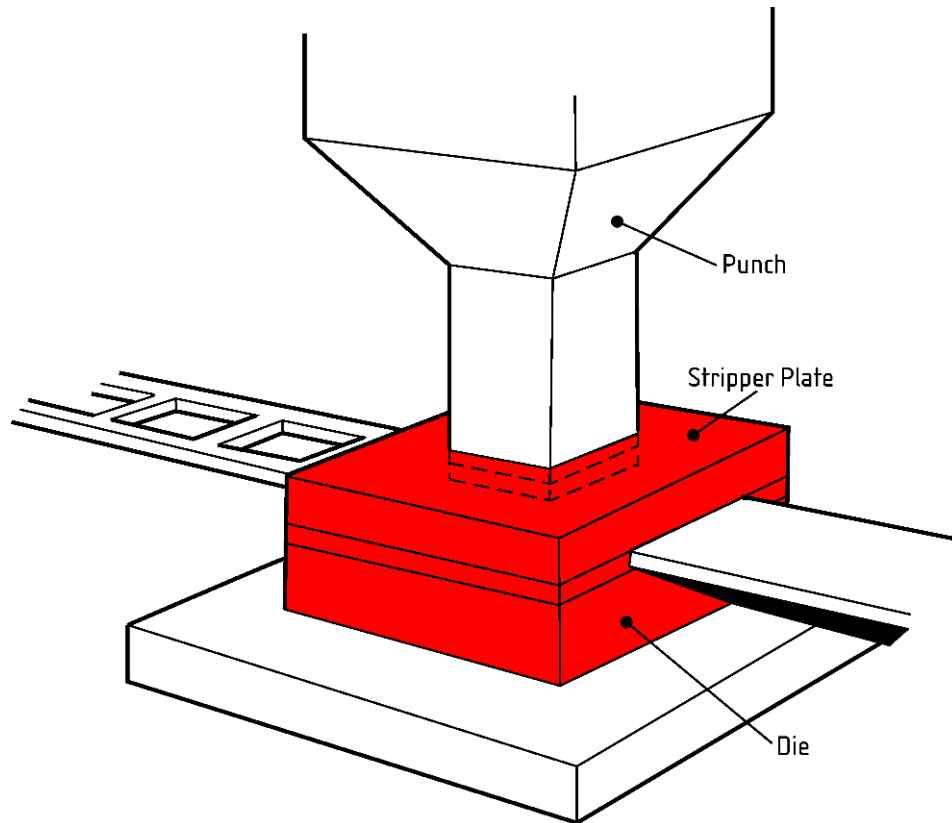
The considerations for impact injuries are much the same as for stabbing or penetration injuries.

5.2.8 Crushing

Crushing injuries, like shear injuries, are due to the relative motion of two objects with a body part in between, and are affected by similar considerations. Some information on the factors necessary to reduce crushing is given in BS 5655-1.

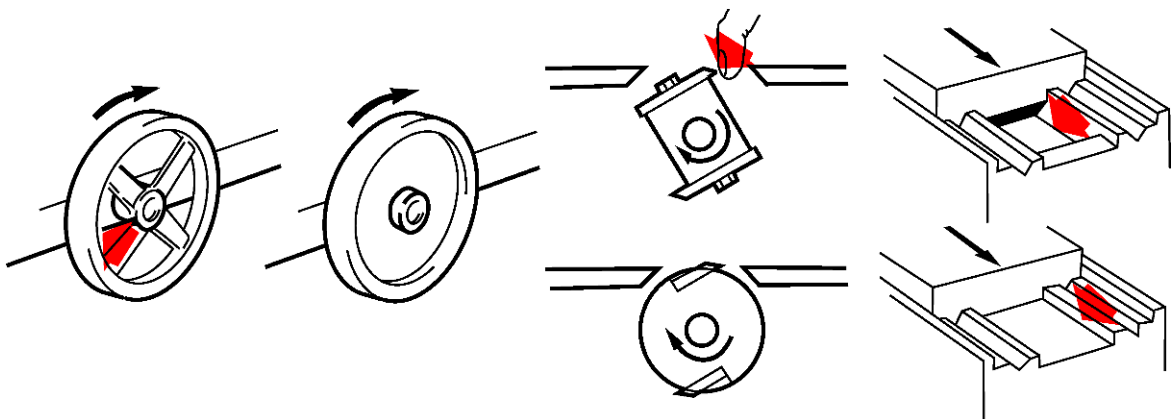
5.2.9 Drawing-in

Drawing-in, 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 will have a similar effect (see Figure 20). Adjacent parts of structures may increase injuries.



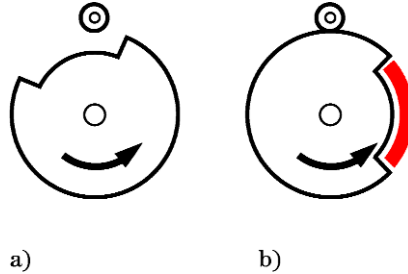
Enclosed tools are designed and constructed to be safe in themselves, there being insufficient space between possible trapping parts in the tool set to permit entry of any part of a hand. They should be used whenever the operation allows as they provide a high standard of protection and eliminate the 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 17 — Enclosed tools at a power press



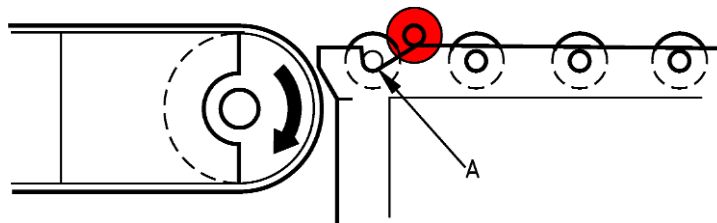
Three examples of how shear traps have been eliminated by design.

Figure 18 — Removal of shear trap by design



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 19 — Gap cover to prevent shear trap



The possibility of trapping at the junction of a powered conveyor and an idle roller conveyor can be avoided 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 may be required.

Figure 20 — Conveyor: first idle roller free to prevent drawing-in

5.3 Controls

5.3.1 Position

Designers and suppliers should have positioned and spaced controls so as to provide safe and easy operation and there should be ample clearance between each control and other parts of the machinery. 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 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 may be affected by the operation of one of the controls. This may be achieved by providing positive 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 5.12.)

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 BS EN 574 and 8.2).

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).

5.3.2 Identification

Designers and suppliers should 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 60204-1 and BS EN 61310-1 and -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 controls should be coloured red, with a yellow background where one exists, in accordance with BS EN 60204-1 and BS EN 418 (see also 5.3.6).

5.3.3 Operation

Designers and suppliers should have ensured that where appropriate, 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

5.3.4.1 General

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

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 methods, which are listed in order of merit:

- a) a hold-to-run control (see 5.3.4.2) with the machinery running at crawl speed, or a limited movement device (see 5.3.4.3);
- 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;
- d) the hold-to-run control and another means of control (enabling device, see 5.3.4.6) are also described in BS EN 292 and clause 9 of BS EN 60204-1.

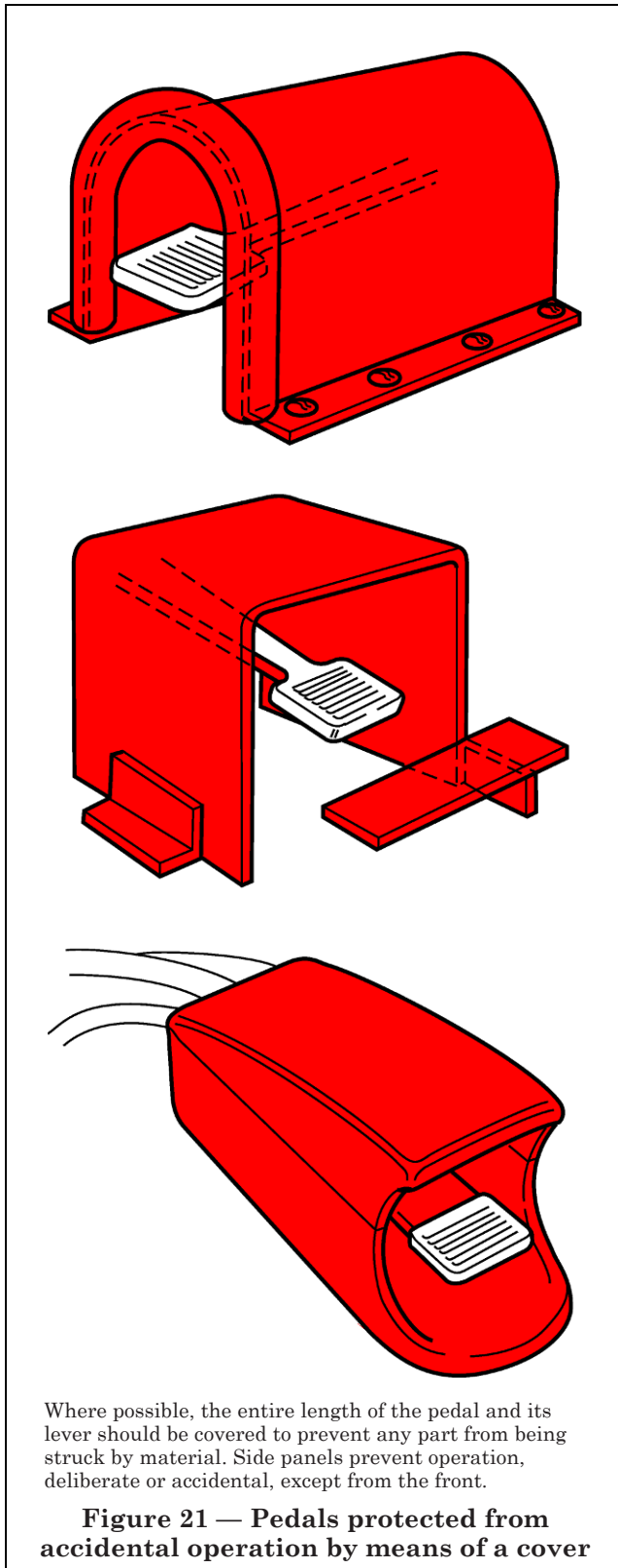
5.3.4.2 Hold-to-run control

A hold-to-run control permits movement of the machinery only as long as the control is held in a set position. The control should return automatically to the stop position when released. Where the machinery runs at crawl speed, this speed should be kept as low as practicable.

A two-hand control (see 8.2) may be used as a hold-to-run control but it should be emphasized that neither protects anyone other than the person operating the control.

The use of a hold-to-run control for remote operation of machinery is, however, acceptable only where it is not practicable to provide effective guarding and where there is no risk of injury from overrun of the hazardous parts when the control has been released.

In addition to its value as a safety device during setting, a hold-to-run control, if placed at sufficient distance from the danger zone, also provides a means of ensuring that a machinery operator is in a position of safety when the machinery is operating normally [see 6.3g].



5.3.4.3 Limited movement devices

A limited movement device is a control system, the operation of which permits only a limited amount of travel of a part of machinery on each occasion that the machinery control is operated, further movement of the machinery is precluded until there is a subsequent and separate operation of the control.

Care should have been taken to ensure that the fitting of a limited movement device does indeed increase the overall safety of the machinery and that this will not be outweighed by an increased risk of failure of other components or associated control circuits.

The fitting of a limited movement device will inevitably result in a greater number of start/stop operations therefore care should be taken to ensure that:

- a) the machinery is mechanically robust enough to withstand the possible extra duty;
- b) the drive motors will not overheat; it will be necessary for the starting duty to be reasonably accurately established;
- c) the rating of the contactors, relays, etc. is adequate; it is possible that the increased number of operations at low power factor and near stall current will have an adverse effect on existing equipment;
- d) a brake can be fitted; if the load on the machinery varies during the process cycle, a brake will almost certainly be necessary if effective limited movement control is to be attained;
- e) where reversal of motion is possible, the control operations needed are readily distinguishable.

Further advice for b), c), d) and e) is contained in BS EN 60204-1.

A limited movement device can be either a timed impulse device, in which a predetermined timed impulse is given with the object of achieving a limited movement, or a controlled movement device, in which the actual amount of movement is predetermined.

Whichever type of device is used, the installation should be such that the operator cannot tamper with the controls. Systematic maintenance arrangements should be instituted to ensure regular checking and any necessary resetting.

5.3.4.4 *Timed impulse device*

A timed impulse device is simple to apply but it has a limitation because the resultant movement of the machinery may vary for a given setting of the control, depending on:

- a) variations of load on the machinery during its work or process cycle;
- b) the position of the crank where rotary motion is being converted to linear motion;
- c) frictional variations depending on temperature, etc.

The method adopted is to close a contactor or relay supplying the drive motor or clutch for a predetermined time. Control of the time of closure can be effected by mechanical means, e.g. oil dashpots or pneumatic devices. Electrical timing methods include resistance/capacitance timing circuits and induction type relays, e.g. induction disc or slugged (delayed) operation type relays.

5.3.4.5 *Controlled movement device*

Controlled movement devices are designed to give a reasonably accurate predetermined movement in which stopping is effected as soon as the required movement has taken place. Once properly set, they are only affected to a very limited and probably negligible extent by ambient temperature, varying load on the machine, etc. These devices are applicable only in conjunction with an efficient means of stopping the hazardous parts. The actual movement of the machinery should be transmitted by gearing, chain drive, or other form of positive coupling to the device itself.

5.3.4.6 *Enabling device*

An enabling device is an additional manually operated control device used in conjunction with a start control and which, when continuously actuated in one position only, allows a machine to function. In any other position, motion is stopped, or a start is prevented.

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 should preferably have been designed so as 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 *Emergency stopping device*

5.3.6.1 *General*

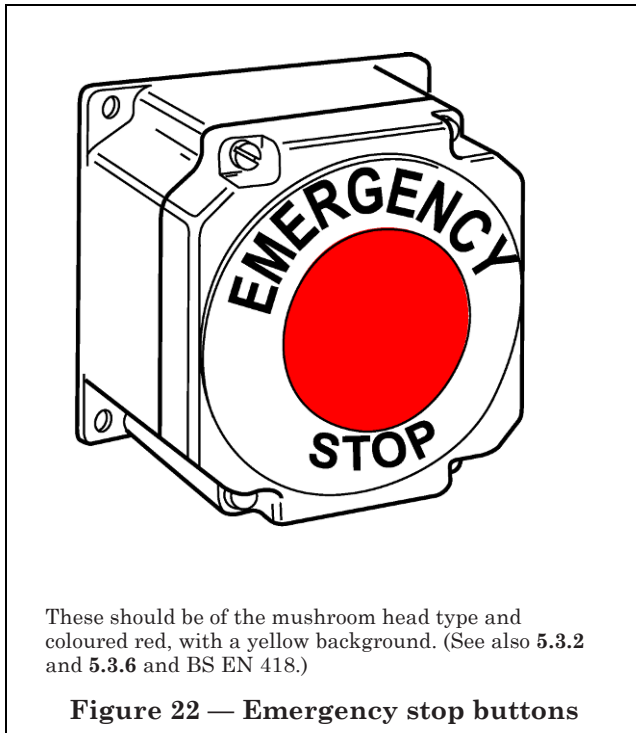
An emergency stopping device is a manually operated control device that requires deliberate action to bring a machine to rest when a hazardous situation is recognized. The emergency stop should not be used for normal stopping, be available at all times and it should not be relied on as a means of isolation.

An emergency stopping device when operated should stop the machine as quickly as possible without generating additional hazards and apply a brake where provided. An emergency stop is not an alternative to guarding. Care should be taken that the operation of the emergency stop does not, in itself, increase the risk of injury from another source. Handles, bars, push buttons, etc. used for actuating the emergency stop should be coloured red, with a yellow background and suitably marked, prominently located and readily accessible. Push buttons should be of the mushroom head type (see Figure 22).

Where there is more than one control or work station, an emergency stopping device should be positioned as required by the risk assessment i.e. not necessary at each work station. Emergency stop control between and around the work station may also be provided by use of pull-cord operated switches. In these circumstances it may be desirable to incorporate a visual indicator. The emergency stop should be located within easy reach.

It is essential that release or resetting of the emergency stopping device does not cause the machine to operate. Restarting should only be by operation of the normal start control.

The requirements in BS EN 418 should be used. It should be noted the Introduction to BS EN 418 states some machines are exempted from the requirement. For such machines the machine supply disconnecting device when locally operated can serve this purpose, see 10.7.5 of BS EN 60204-1.



5.3.6.2 Lock-in emergency stopping devices

Where the stop/start controls are remotely located, push buttons and switches actuating emergency stopping devices should be of the lock-in type¹⁾ so that the machinery cannot be started again until they have been reset manually. On these machines the emergency stop should not be used for normal stopping.

NOTE Designers and suppliers should have provided all emergency stopping devices of the lock-in type in accordance with BS EN 418. Electrical emergency stop devices with mechanical latching function are specified in BS EN 60947-5-5.

5.3.6.3 Disconnection of main power supply

In some workshops an emergency stopping device may be installed to stop all the machinery by disconnecting the main power supply. Release of the emergency stopping device should not re-energize the machinery. If a mechanical hazard can exist as a result of restarting then warning notices are not sufficient (see BS 7671 [4] and 10.8 of BS EN 60204-1).

5.3.6.4 Emergency stop pull-cords and pressure sensitive cable devices (see Figure 23 and Figure 24)

Where emergency stop pull-cords or pressure sensitive cables are used they are not a substitute for effective guarding and should not be confused with the trip devices described in 8.1. Such devices should have been located in such a manner as to be clearly visible, readily accessible and so positioned that they can be used not only at the operator's normal control station but at other appropriate points.

The pull-cord system should have been designed and arranged so that it operates the associated switching device and generates the emergency stop signal when either:

- the pull-cord is pulled in any direction; and
- a perpendicular pulling force of less than 200 N is applied to the pull-cord; and
- a perpendicular deflection of the pull-cord of less than 400 mm occurs; or
- the pull-cord breaks; or
- the failure of a single spring occurs (see Figure 23b).

In addition, the pull-cord should be able to withstand without breaking a tension force 10 times higher than that necessary for generating the emergency stop signal. (See also 6.4.2 of BS EN 60947-5-5.)

As the movement of the pull-cord and the force to operate the system could be affected by the design of the pull-cord supports and the distance between them, care should be taken to ensure that the pull-cord is free to move through the supports at all times, particularly at changes of direction, without becoming disengaged from them. Where, in the case of long pull-cords, more than one switching device is necessary, a visual indicator should be incorporated to show which device has operated. The indicator can be at a central position or at an individual device. Further information is contained in BS EN 418.

Pressure sensitive cables (see the following note) may also have been used in place of the electromechanical pull-cord system already described. They are sometimes more convenient to install at conveyors or moving plant because they need not be restricted to straight runs but can follow a complex route around machinery. Such systems may be better suited than electromechanical systems in onerous environments where there is dust contamination, vibration or structural movement.

¹⁾ This is not applicable to emergency stops on underground mobile mining machines which are supplied by a flexible trailing cable and are designed to move while working.

NOTE Pressure sensitive cables are not currently specified for use for emergency stop in BS EN 418.

Pressure sensitive cables should have been used only in conjunction with control systems designed to switch off the machinery when malfunctions are detected which lead to open or short circuits.

5.3.7 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 should have been supplied operated through a suitable interlock for a predetermined time before the machinery starts to operate. Adjacent machines should have been provided with distinguishable audible signals.

On installations where malfunction of the machinery creates a hazardous situation, suitable warning signals should have been provided. These signals should preferably be given automatically and should be both audible and visual.

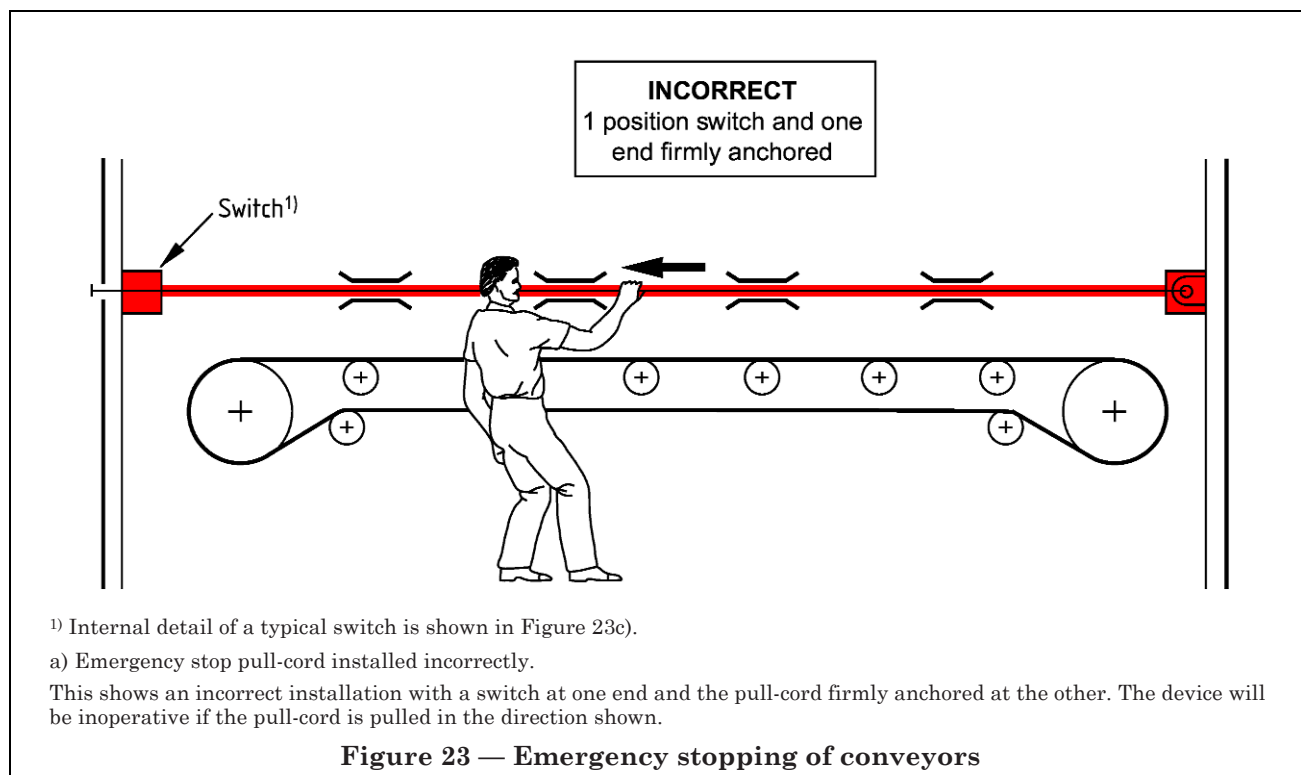
Audible and visual warnings may have been provided in addition to, but not in substitution for, physical safeguards.

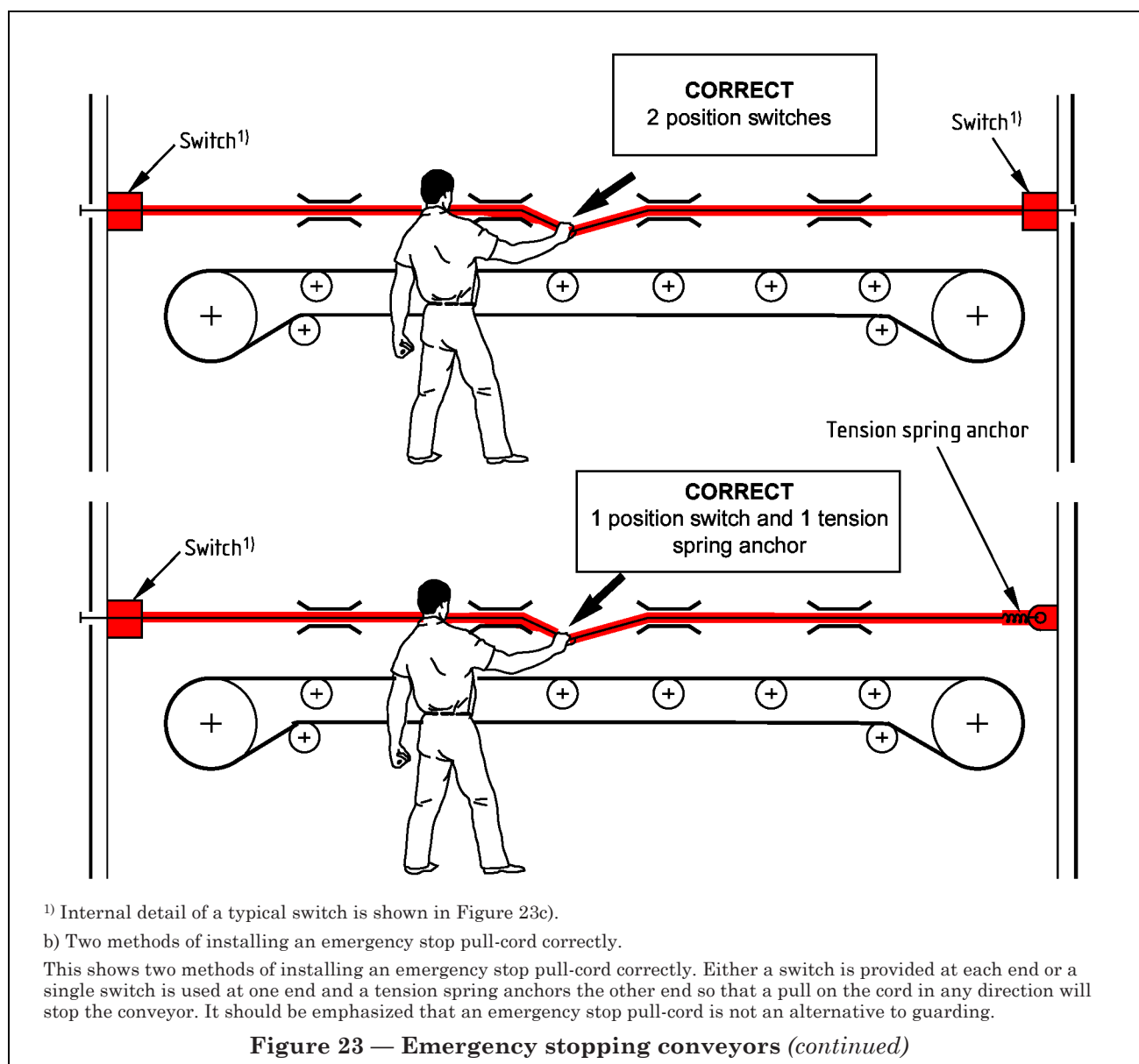
Further information is given in BS EN 457 and BS EN 61310-1.

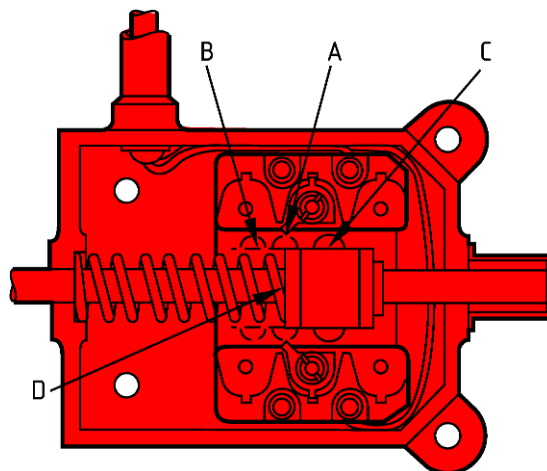
5.3.8 Program or sequence control

Where machinery is program or sequence controlled, it should be noted that parts which may not normally be considered as hazardous, may 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 should have been carried out by designers and suppliers as described in Section 3 and Section 4. These should 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 5.21.





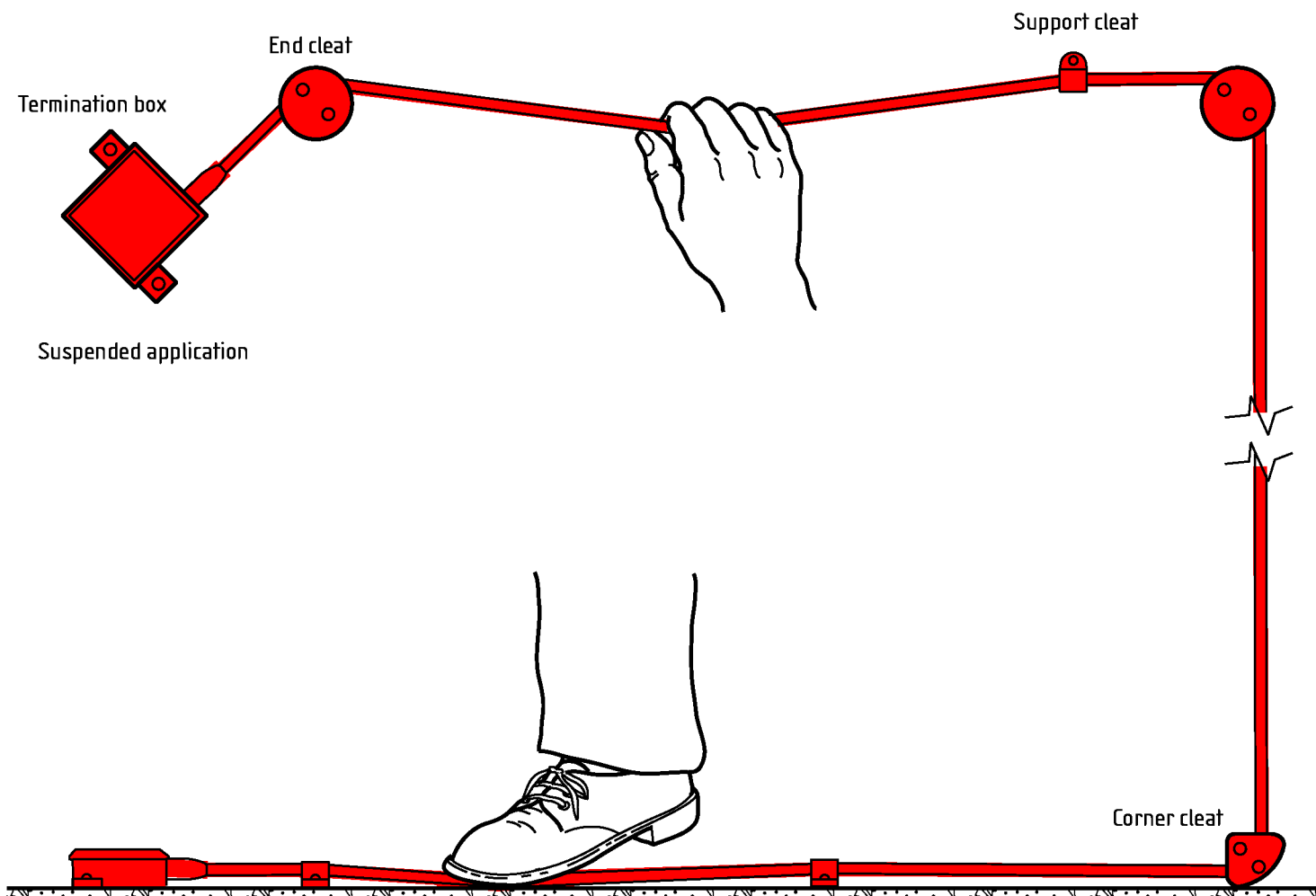


c) Electrical switch for emergency stopping of conveyors.

A switch operated by an emergency stop pull-cord should cut off the power supply not only when the cord is pulled but also if the pull-cord breaks or becomes slack. [See also Figure 23b).] The switch illustrated has a central spindle to which a pull-cord is connected at D. Tension in the pull-cord is so adjusted that the switch contacts are closed (position A) to allow the conveyor to run. A pull on the cord will open the contacts (position B) while breakage or slackness of the pull-cord will cause them to open in the opposite direction (position C) under the action of the compression spring.

At a long conveyor, instead of a number of separate emergency stopping devices, it is sometimes more effective to install an emergency stop pull-cord (wire or rope) along the whole length of the conveyor. A pull on the cord in any direction, or breakage of the pull-cord, will bring the conveyor to rest. The arrangement should be such that after manual operation resetting is necessary.

Figure 23 — Emergency stopping conveyors (concluded)



The illustration shows a pressure sensitive cable installed in a suspended and surface mounted manner.

Figure 24 — A typical pressure sensitive cable installation used as a trip device

5.4 Indicators

Where necessary, a qualitative, quantitative or check reading indicator should have been provided to warn of a hazardous situation. Such indicators should 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 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.

5.6 Braking systems

5.6.1 General

Reference is made in 5.3.4.3 and 9.4.2 to various devices which rely for their efficient operation on a brake in order to stop the machinery quickly.

Braking systems should be so designed as to bring hazardous moving parts to rest with a consistent performance as quickly as possible. 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 should be designed to minimize the risk of failure to danger.

This important part of a safeguard may take several forms. Examples are detailed in 5.6.2 and 5.6.3.

5.6.2 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 may 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, safely 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 these should 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 should therefore be so designed 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 also 9.3.4 and 9.4.4 of BS EN 60204-32.

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 reservoir/accumulator falls below a safe limit and the feed should be fitted with a non-return valve. Further safety requirements for hydraulic and pneumatic systems may be found in BS EN 982 and BS EN 983 respectively.

5.6.3 Electrodynamic braking systems

5.6.3.1 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 it should be borne in mind that they generally fail to danger in the event of supply failure. They should have been connected in such a way that their power supply is maintained when emergency stop controls are used.

5.6.3.2 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 should have been so controlled that it will open when the machinery stops, otherwise the machinery will restart in the reverse direction.

5.6.3.3 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 is better than reverse plugging (see 5.6.3.2) because there is no tendency to restart in the reverse direction.

5.6.3.4 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.

5.6.3.5 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 may be a resistor or the main power supply.

5.6.3.6 Designers and suppliers may have provided motor controllers which could also be computer controlled. These provide dynamic braking and a standard for electrical, thermal and functional safety performance is under development as of IEC 61800-5.

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

Where risk of injury may arise, a safety device should be incorporated in the design to restrain any moving machinery part which may overrun beyond its normal stopping position due to gravity, to the fall-back of a crankshaft, to the failure of a counterweight system or any other similar failure (see 8.3).

5.8 Counterweights and similar devices

Counterweights which may fall upon or trap persons should be suitably safeguarded. 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 balanceweight(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 move when the machinery is operated. In these cases, provision should be made to maintain safety in the event of rope or belt failure.

5.9 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. Guards for rotating shafts should preferably be fixed guards of solid construction. However, guards of the loose tube type or of bellows or telescopic construction may also be used satisfactorily in some applications (see Figure 25, Figure 26 and Figure 27).

5.10 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.

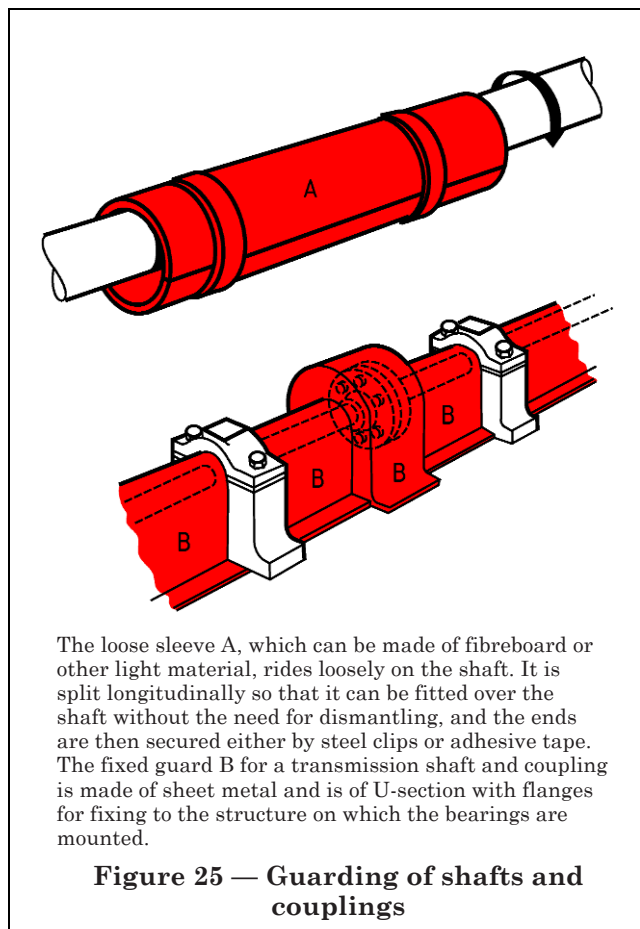
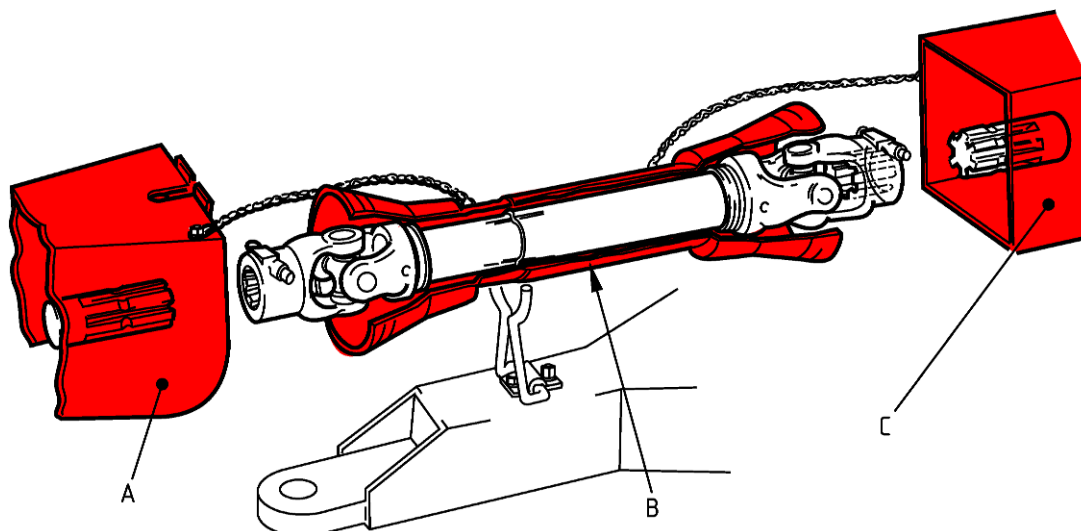
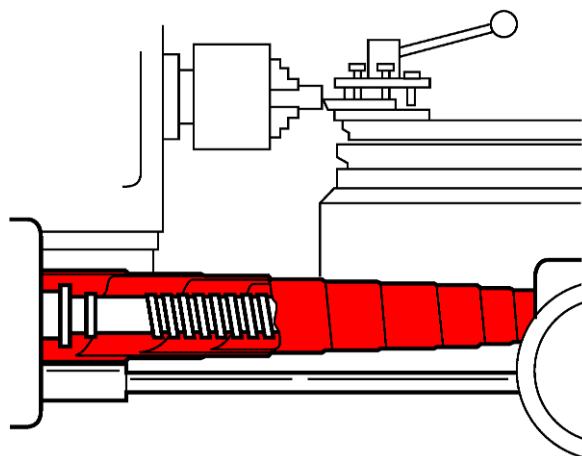


Figure 25 — Guarding of shafts and couplings



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 can be found in BS EN 1152 (see Annex D).

Figure 26 — 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 type guards are used on long shafts, they should be supported at intervals by internal bushes.

Figure 27 — Telescopic type guard

5.11 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.

When designing hydraulic and pneumatic circuits, all aspects of possible methods of failure, including control supply failure, should be considered. In each case, components should be selected, applied, fitted and adjusted so that in the event of a failure, maximum safety of personnel should be the prime consideration, and damage to equipment minimized (see also 3.2.10).

All components within the system should operate within their manufacturer's specification. All parts of the system should be protected against overpressure. The system should be designed and constructed so that components are located where they are accessible and can be safely adjusted and serviced. Circuits should be designed, constructed and adjusted to minimize surge pressures. Surge pressure or loss of pressure should not cause hazards.

The supplier and purchaser should discuss any special site conditions and the design of the system should take account of these conditions. Examples of information required are the possible existence of a fire hazard (use of fire-resistant fluid) and protection for electrical devices.

For methods of interlocking of hydraulic and pneumatic systems see Section 9.

5.12 Electrical systems

The electrical equipment should conform to the requirements of BS EN 60204-1. Advice on programmable control systems and methods of interlocking is given in 5.21 and 9.7.7.5.

5.13 Workholding devices

5.13.1 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 can be found in BS EN 1550 (see Annex D).

5.13.2 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 not expose a gap of more than 6 mm or should be guarded such that it is not possible to trap a hand or a finger. Guidance on minimum gaps to avoid crushing is given in BS EN 349, see Annex D.

5.13.3 Prevention of inadvertent unclamping of the workpiece

The design of the control system should be such 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 should also 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.

5.14 Lifting, handling and transport

Machinery which cannot be moved or transported by hand, should 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.

When a machine is provided with lifting gear and appliances, e.g. for workpiece loading, unloading, tool mounting or delivery, the user should be aware of his/her responsibilities regarding thorough examination and inspection as required by the Lifting Operations and Lifting Equipment Regulations 1998 [3].

Eyebolts and eyebolt holes should be identified to prevent mismatching in accordance with the HSE Guidance Note PM 16 [6].

5.15 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 may be required to stop the machine as soon as practicable. (See also 5.20.3.)

5.16 Stability

Machines should have been designed to be stable, i.e. they do not fall over and are not capable of being unintentionally moved by vibration, wind pressure, impact or other foreseeable external forces. If this could not be fulfilled adequately by design or stable weight distribution, then stability should have been obtained by special safety measures. For example, movements of parts of the machine may be restricted, indicators, alarms or interlocks to prevent tipping may be provided, or the machine may be securely anchored to a foundation. Both static and dynamic stability should have been considered. If special safety measures are required, a warning should be provided on the machine and/or in the operator's manual.

5.17 Lighting

Local lighting on the machine for the illumination of the work area should 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 should also 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 clause 16 of BS EN 60204-1:1998 (or clause 17 of BS EN 60204-1:1993).

Fluorescent type lighting conforming to BS EN 60204-1 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 general lighting of the workplace.

5.18 Hygiene

Machinery used in certain industries, notably for the processing of food and pharmaceuticals, should be so designed that it is not only hazard free during operation but can be readily cleaned without risk of injury. (See also 10.3.)

5.19 Safety colours and symbols

Where practicable, colours can be used to draw attention to a hazard. For example, certain parts of machines could have been painted a distinguishing colour which will only be visible when a hazardous situation is present. Such finishes have to be non-toxic when used in the food processing and pharmaceutical industries.

It is recommended that such painting be confined to the inside surfaces of hinged covers which, when open, expose machine parts which are hazardous when in motion, BS EN 981 and BS EN 61310-1 give details for systems of auditory and visual danger and information signals, e.g. rotating shafts, gears or belts. The outside of such covers should not be painted the same distinguishing colour.

If covers protecting hazardous parts of machinery or danger zones are completely removable, it is not satisfactory to paint the inside surface of the cover in a distinguishing colour. The colour should be applied to the part of the machine that remains with the hazard, e.g. the inside edge of a cavity housing the hazardous parts or the surface surrounding them which is at normal times hidden by the cover.

If it is not practicable to apply the distinguishing colour to an element of the machine structure, then the hazardous items themselves may be painted, for example, where the machine structure adjacent to the hazardous element is completely hidden by it. The whole of the hazardous part need not be painted; it is sufficient to paint the ends of shafts, rims of pulleys, edges of blades, etc.

Where safety colours and symbols are used, they should adopt a bold, recognizable, consistent pattern or symbol using standardized colours and should conform to BS 5378-1 and -3.