PD 5304:2014

BSI Standards Publication

Guidance on safe use of machinery

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British Compressed Air Society

British Fluid Power Association

Department for Business, Innovation and Skills

Food and Drink Federation

GAMBICA Association Ltd

Health and Safety Executive

Institute of Measurement and Control

Manufacturing Technologies Association

Safety Assessment Federation Limited

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Introduction by Dave Bench

Health and Safety Executive Director of Science

The Health and Safety Executive (HSE) welcomes the publication by the British Standards Institution of PD 5304:2014, which was developed by Technical Committee MCE/3, *Safeguarding of machinery*, with contributions and support from HSE.

PD 5304:2014 covers the safe use of machinery and provides comprehensive guidance on practical measures and techniques that may be applied to machinery to safeguard operators, maintenance personnel and others. The guidance deals with issues ranging from risk assessment through safeguarding to maintenance and safe working practices, with practical examples throughout.

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 (PUWER 98). PUWER 98 applies to any machine during modification, refurbishment or change of use, and this Published Document will provide guidance to those competent in relevant aspects of machinery safety carrying out these activities.

Developments in the field of machinery safety have been taken into account during the development of PD 5304:2014, and the principles of safeguarding are described with reference to current harmonized European machinery safety standards.

HSE is pleased to have contributed to and supported the development of PD 5304:2014 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 sectors.

I am pleased to introduce PD 5304:2014 and commend its guidance to you as a valuable contribution to safe use of machinery in this country.

Dave Bench

Foreword

Publishing information

This Published Document is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2014. It was prepared by Technical Committee MCE/3, *Safeguarding of machinery*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This Published Document supersedes PD 5304:2005, which is withdrawn.

Information about this document

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

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

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

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

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

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

The documents available as downloads from the sites referenced throughout the document were last accessed on 5 December 2014.

Presentational conventions

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

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

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

Contractual and legal considerations

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

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

Section 1: General

1.1 Scope

This Published Document provides guidance on the safe use (see **1.3.22**) of machinery, including that supplied prior to the implementation of the Supply of Machinery (Safety) Regulations 1992 [1].

It provides guidance on:

a) the basic principles of safeguarding, with reference to current harmonized European machinery safety standards; and

b) the continuing safe use of machinery manufactured in accordance with harmonized European machinery safety standards, in conjunction with the machine supplier's instructions for use.

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

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

NOTE 1 See also Approved Code of Practice: Safe use of work equipment [3].

NOTE 2 Significant modification, refurbishment, upgrading or change of use to existing machinery that results in, for example, changes of the measures used to reduce risk(s) or the introduction of a new hazard(s), can make it necessary to satisfy relevant requirements from the Supply of Machinery (Safety) Regulations 1992 [1], in particular Schedule 3.

NOTE 3 PD 5304 is not intended to be used as an alternative to the current harmonized European machinery safety standards for machinery supplied in accordance with the Supply of Machinery (Safety) Regulations 1992 [1].

1.2 Normative references

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

BS EN 953, *Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards* [1)]

BS EN 1037, *Safety of machinery – Prevention of unexpected start-up*

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

BS EN 60204-1:2006+A1:2009, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

BS EN 60947-4-1:2010+A1:2012, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

BS EN 60947-5-1:2004+A1:2009, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

1) BS EN 953 will eventually be superseded by BS EN ISO 14120.

BS EN 61810, *Electromechanical elementary relays*

BS EN ISO 4413, *Hydraulic fluid power – General rules and safety requirements for systems and their components*

BS EN ISO 4414, *Pneumatic fluid power – General rules and safety requirements for systems and their components*

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

BS EN ISO 13850:2008, *Safety of machinery – Emergency stop – Principles for design (ISO 13850:2006)*

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

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

PD CLC/TR 50404, *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:

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

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

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

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

a) permanently present during the intended use of the machine (e.g. motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature); or

b) might appear unexpectedly (e.g. explosion, crushing hazard as a consequence of an unintended/unexpected start-up, ejection as a consequence of a breakage, fall as a consequence of acceleration/deceleration).

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

NOTE Also knows as "danger zone".

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

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 intensification
increase in pressure above the relief valve setting

1.3.9 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)

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

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

NOTE BS EN ISO 14119 gives detailed provisions.

[BS EN ISO 12100:2010]

1.3.11 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.

1.3.12 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.

1.3.13 protective measure
measure intended to achieve risk reduction, implemented by:

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

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

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

[BS EN ISO 12100:2010]

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

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

NOTE BS EN ISO 12100 gives more information on safeguarding.

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

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

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

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

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

a) a start command which is the result of a failure in, or an external influence on, the control system;

b) a start command generated by inopportune action on a start control or other parts of the machine, e.g. a sensor or a power control element;

c) restoration of the power supply after an interruption;

d) external/internal influences (e.g. gravity, wind, self-ignition in internal combustion engines) on parts of the machine.

NOTE 2 Machine start-up during normal sequence of an automatic cycle is 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 12100:2010, ***6.3****).*

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

Section 2: Strategy for selecting protective measures

2.1 General

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

a) identify the hazards and assess the risks of injury and damage to health;

b) eliminate the hazards by inherently safe design to the extent that it is practicable;

c) reduce the remaining risk by use of safeguards and/or complementary protective measures to the extent that it is practicable; and

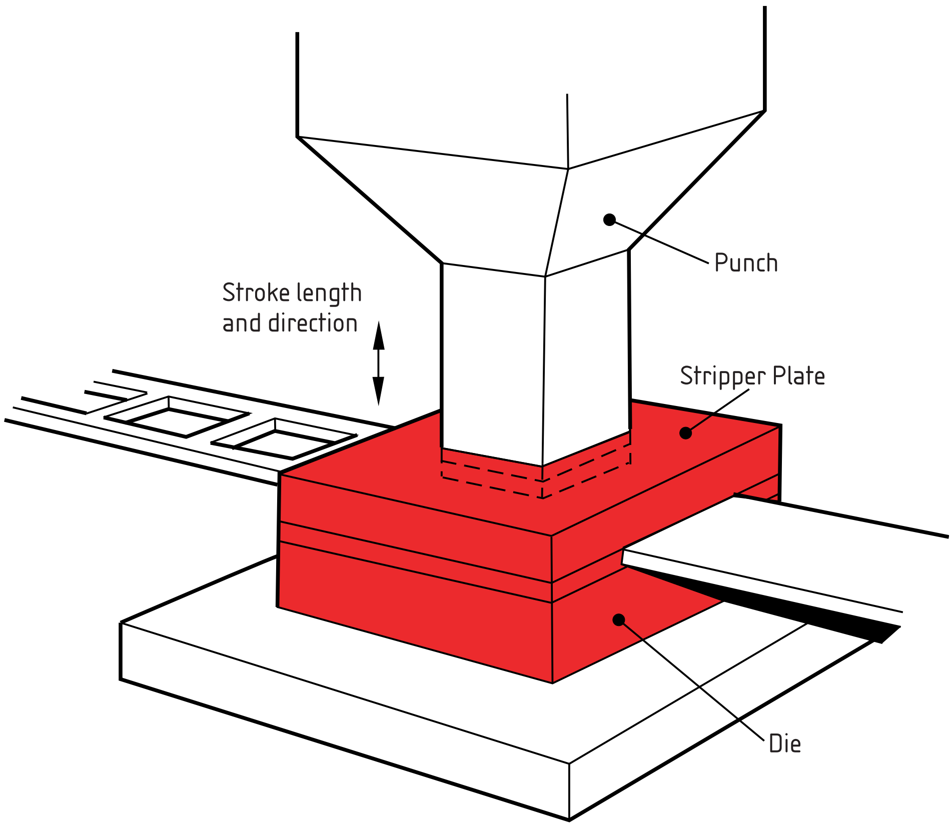
d) use of safe working practices, including provision of information, training and personal protective equipment.

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

NOTE 1 Examples of inherently safe design are given in Figure 1 and Figure 14.

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

Figure 1 **Enclosed tools at a power press**



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. Here, enclosure is 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**).

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, etc. Systematic methods of assessing these devices and systems are available. Systems of work are subject to the same principle, but cannot usually be assessed to the same extent.

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

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

Where the supplier has been unable to take every hazard into consideration, for example those arising from use, their identification and elimination should be considered by the user. Modifications might be possible which, although not capable of eliminating injury or damage to health, reduce its scale. Section 4 gives information on identification of hazards and Section 5 on methods to reduce risks.

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

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

Certain protective measures are more effective than others. Safeguarding and complementary protective measures should be considered before safe 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 not have been taken into account at the design stage. These are considered in Section 5, Section 11 and Section 12.

2.2 Selection of protective measures

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

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

2.3 Avoidance of reasonably foreseeable misuse of guards and protective devices

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

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

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

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

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 shutdown;

e) setting or process changeover;

f) cleaning;

g) adjustment;

h) maintenance; and

i) decommissioning and dismantling.

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

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Section 3: Risk assessment

3.1 General

3.1.1 Risk assessment is a requirement of the Management of Health and Safety Regulations 1999 [5]. The technique of risk assessment formalizes the process by which designers, suppliers and users of machinery use their experience to identify hazards, estimate the risks from each identified hazard and evaluate these to decide whether risk reduction is necessary, either by eliminating the hazard or reducing the risk(s) associated with the hazard(s) by selecting appropriate protective measures (see Section 4).

3.1.2 Risk assessments should be conducted when the machinery is first taken into service and when there are changes, such as the following:

a) modifications to a machine;

b) changes to a machine as a result of repair;

c) an incident or dangerous occurrence;

d) changes to work practices, operating procedures, materials processed or methods of use;

e) changes to the environment or location in which a machine is used;

f) new information becomes available about a hazard that indicates the risks associated with it are different to what was previously thought; and

g) any other indications that the existing risk assessment is no longer valid.

3.1.3 Risk assessments should be reviewed at planned, regular intervals as part of standard management practice. The frequency of reviews should take into account the nature of the risks and the degree of change likely in the work activity.

3.1.4 The extent and complexity of the assessment required can only be determined after an initial appraisal of the risks and existing safety measures. The absence of an accident history, a small number of accidents or low severity of accidents should not be taken as an automatic presumption of a low risk.

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

Subclauses **3.2**, **3.3**, **3.4** and **3.5** describe the underlying principles involved.

3.1.5 Risk assessment (see Figure 2) involves the following:

a) risk analysis, comprising:

   1) determination of the characteristics and limits of the machinery;

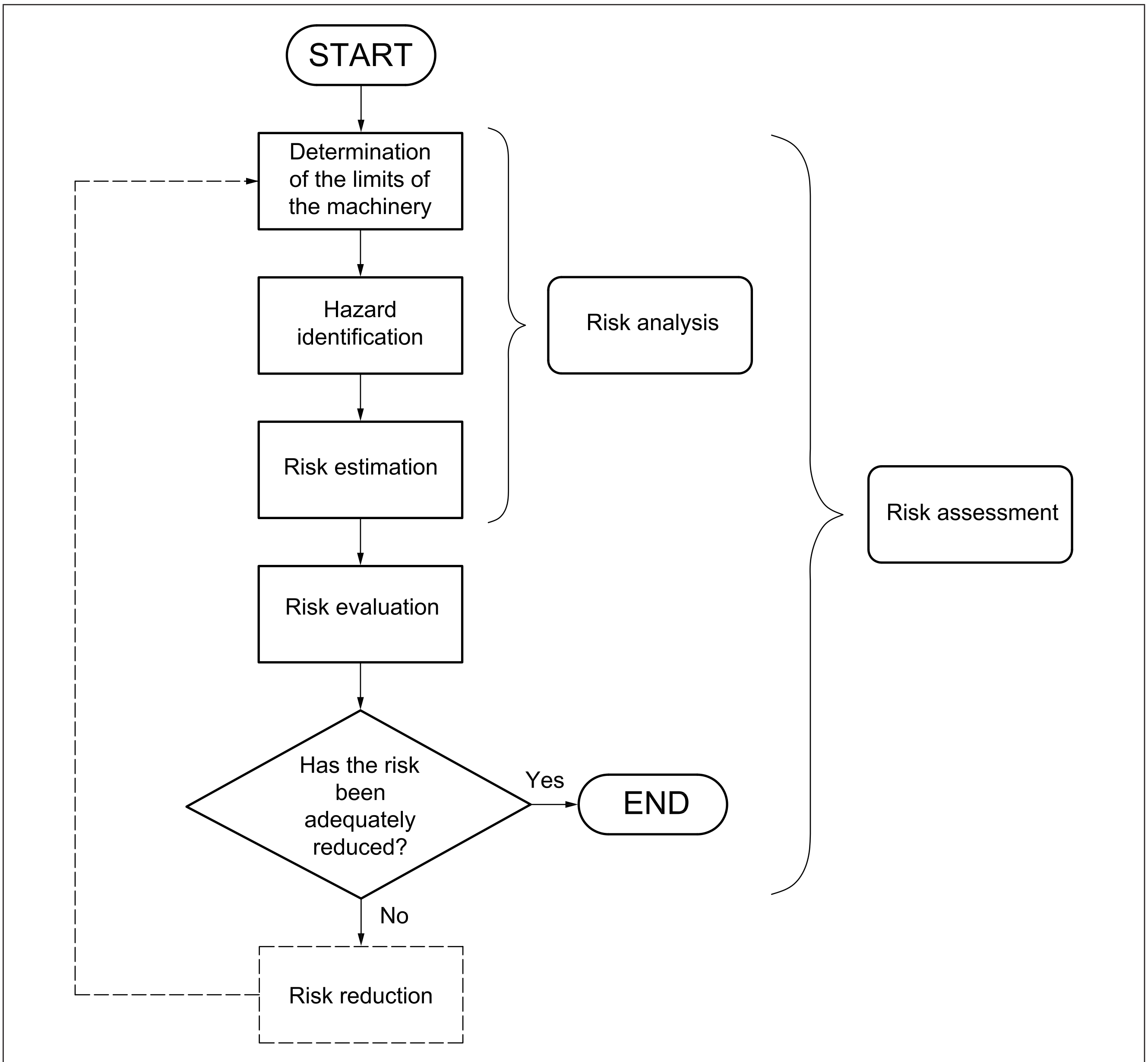
   2) hazard identification: what can cause harm, where, when and how (see Section 4); and

   3) risk estimation: How severe and how likely is harm?

b) risk evaluation: Can the risk be tolerated?

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

Figure 2 **Iterative process to reduce risk**



3.1.6 The risk from each identified hazard consists of:

a) the severity of potential harm from each identified hazard (see **3.2**);

b) the probability of occurrence of that harm (see **3.3**), which is a function of:

1) the exposure of person(s) to the hazard;

2) the occurrence of a hazardous event; and

3) the technical and human possibilities to avoid or limit the harm.

Many formal and systematic methods of risk assessment for machinery exist and others are currently under development. In addition, there are methods that apply the principles of risk assessment to the assignment of performance criteria to safety-related electrical control systems for machinery. Examples of such methods are given in BS EN ISO 13849-1:2008, Annex A, and BS EN 62061:2005+A1:2013, Annex A.

3.2 Severity of harm

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

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

Deliberate or accidental access to the hazardous area should be considered for all phases of machine life (see **2.4**). For each phase the following questions should be asked, to determine the possible severity of harm.

a) What type of mechanical or other hazard is involved? (See **4.2** and **4.3**.)

b) What type(s) of harm is foreseen? (See **4.2**.)

c) What is the probability of each possible severity of harm, given the conditions under which access occurs?

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

3.3 Probability of occurrence of harm

When examining a machine, either from first principles or by making comparisons with similar machines, account should be taken of the frequency and/or duration of access to, or through, a hazardous area during each phase of machine life, e.g. machine operation and breakdown, commissioning, maintenance, setting and process changeover (see **2.4**). When carrying out this examination, the user might need to consider situations that were not foreseen by the machine manufacturer (see **2.1**).

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

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

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 EN 60812). It is also necessary to consider the reliability of operating procedures, where safety depends upon them, and this encompasses both inadvertent failure to follow procedures and deliberate failure to do so.

3.5 Documentation

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

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

b) the information/data upon which the risk assessment has been based, including any relevant assumptions that have been made (e.g. loads, strengths, safety factors); and

c) the hazards and hazardous situations identified and the hazardous events considered in the assessment.

Section 4: Identification of hazards

4.1 Hazards at machinery

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

a) contact or entanglement with the machinery;

b) trapping between the machinery and any material or fixed structures;

c) contact or entanglement with any material in motion;

d) being struck by ejected parts of the machinery; and

e) being struck by material ejected from the machinery.

Advice and safeguards applicable to identified mechanical hazards are given in **4.2**.

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

1) electric shock or burn from the electrical equipment or from the processing of material (e.g. in electric welding);

2) thermal hazards;

3) exposure to excessive noise and/or vibration;

4) exposure to excessive ionizing or non-ionizing radiation;

5) burns and other injuries arising from fire and explosion of materials or substances processed, used, produced, exhausted, etc., by the machinery;

6) harm arising from ingestion of materials or substances processed, used, produced, exhausted, etc., by the machinery;

7) effects of failure to observe good ergonomics principles in machine design and use;

8) injuries arising from slips, trips and falls occurring from failure to create and maintain safe access to and onto machinery during use; and

9) effects of the environment in which the machine has to be used.

Advice and safeguards applicable to non-mechanical hazards are given in **4.3**.

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

All potential hazards ought to have been identified (see Section 3) and a risk reduction process performed, using the hierarchy in **2.1**, but for existing machinery there can be less scope for elimination of hazards by inherently safe design, so it is usually necessary to apply safeguards and/or complementary protective measures.

Many of the protective measures for eliminating or mitigating personal harm from non-mechanical hazards identified in **4.3** should be considered in conjunction with the safeguards against the mechanical hazards identified in **4.2**, e.g. acoustic guards to prevent access and contain/absorb noise, and welding curtains to protect against radiation, spatter and burns.

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

4.2 Mechanical hazards

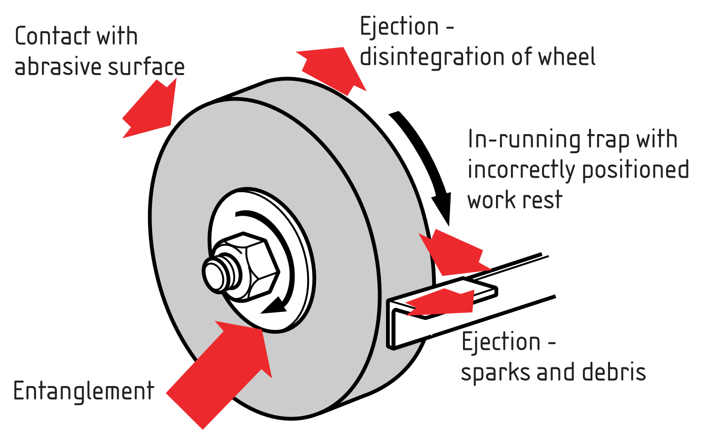
4.2.1 General

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

These movements can cause injury by entanglement, friction or abrasion, cutting, shear, stabbing or puncture, impact, crushing, or by drawing a person into a position where one or more of these types of injury can occur. The non-exhaustive list of examples in **4.2.2** to **4.2.10** is typical, and one or more of these are found on most units of machinery. Individual machines and individual parts of machines can cause one or more of these types of injury (see Figure 3). Furthermore, the shape of parts of a machine (including tools and fixtures), workpieces or loads can generate mechanical hazards even if they are motionless.

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

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



4.2.2 Entanglement

Bodily contact with the following features can lead to entanglement.

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

b) Catching on projections or in gaps (see Figure 5), for example, fan blades, spoked pulleys, chain wheels, gear wheels and flywheels, mixer and beater arms, spiked cylinders, belt fasteners, projecting keys, set screws, cotter pins on shafts or slat conveyors.

c) Catching between two parts (see also **4.2.9**).

  1) Between counter-rotating parts (see Figure 6), e.g. gear wheels, rolling mills, mixing rolls and calenders, or material being drawn between two rolls.

  2) Between rotating and tangentially moving parts (see Figure 7 and Figure 20), e.g. a power transmission belt and its pulley, a chain and chain wheel, a rack and pinion, metal, paper, rope, etc., and a reeling drum or shaft, batch-up, reel-up, etc., or a conveyor belt and its driving pulley or any bend pulley.

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

3) Between rotating and fixed parts (see Figure 8), e.g. spoked hand-wheels or flywheels and the machinery bed, screw or worm conveyors and their casing, revolving mixer and mincing mechanisms in casings having unprotected openings, Z-blade and ribbon-blade mixers, extruder scroll and barrel, or the periphery of an abrasive wheel and an incorrectly adjusted work rest.

d) Being caught by materials in motion (see Figure 9), e.g. in centrifuges, tumble driers, dough mixers, or swarf from machining operations.

The risk of entanglement is increased by loose clothing, gloves, neckties, jewellery, hair, cleaning brushes or rags, medical dressings or materials being handled. Entanglement hazards can be lessened by reducing speed or distance of movement, by avoiding projections and recesses, by restricting force, torque and inertia, and by aiming for smooth polished surfaces. These measures apply both to machinery and process material. It 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 ideally be fixed and of solid construction. However, guards of the loose tube type or of bellows construction may also be used in some applications.

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

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

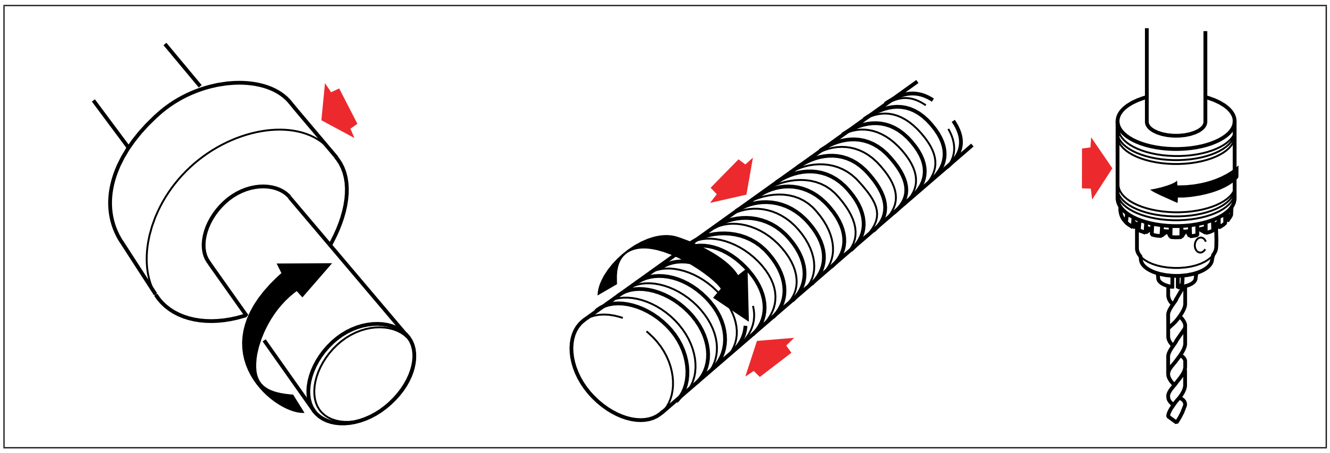


Figure 5 **Entanglement caused by catching on projections or in gaps**

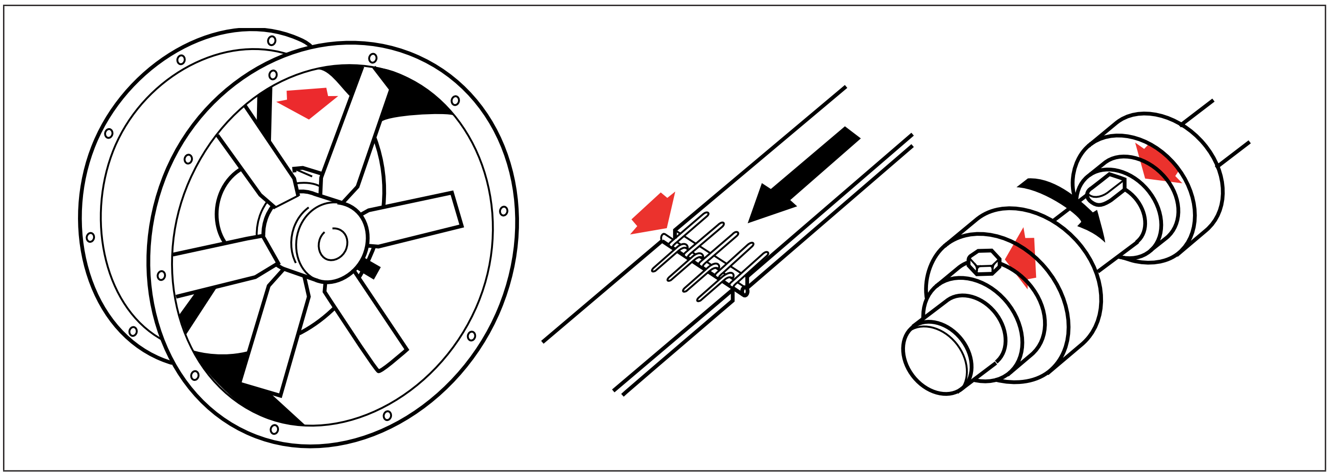


Figure 6 **Drawing-in hazards between two counter-rotating parts**

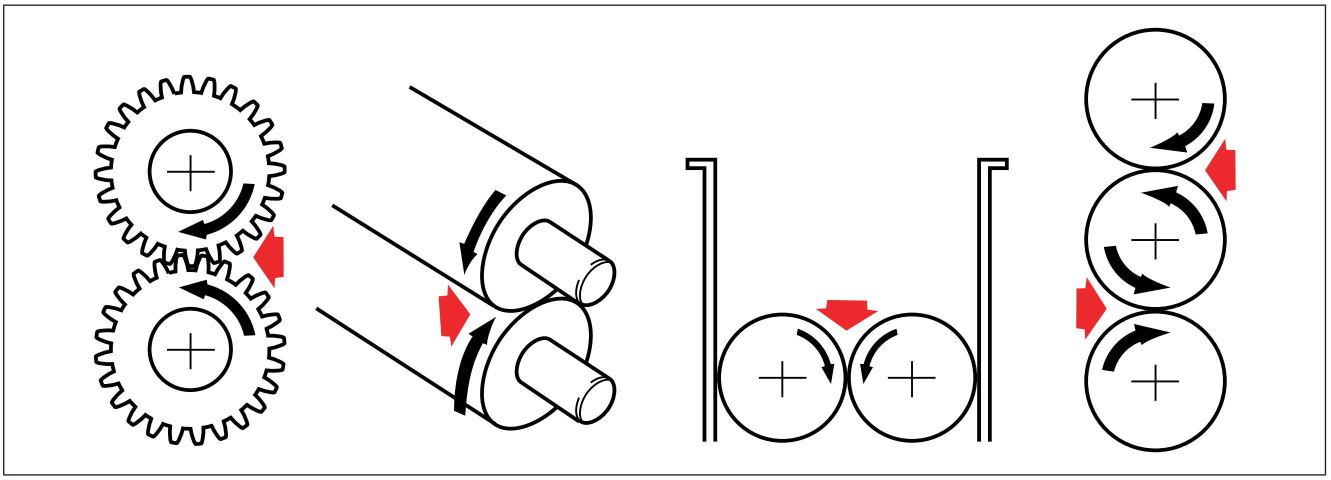
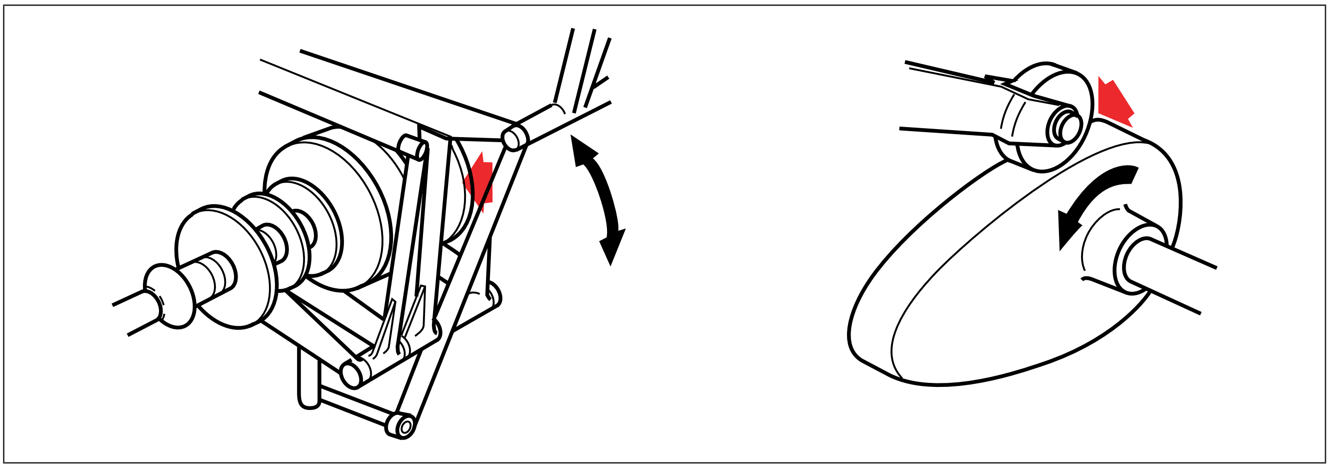


Figure 7 **Entanglement caused by catching between rotating and other moving parts** *(1 of 2)*



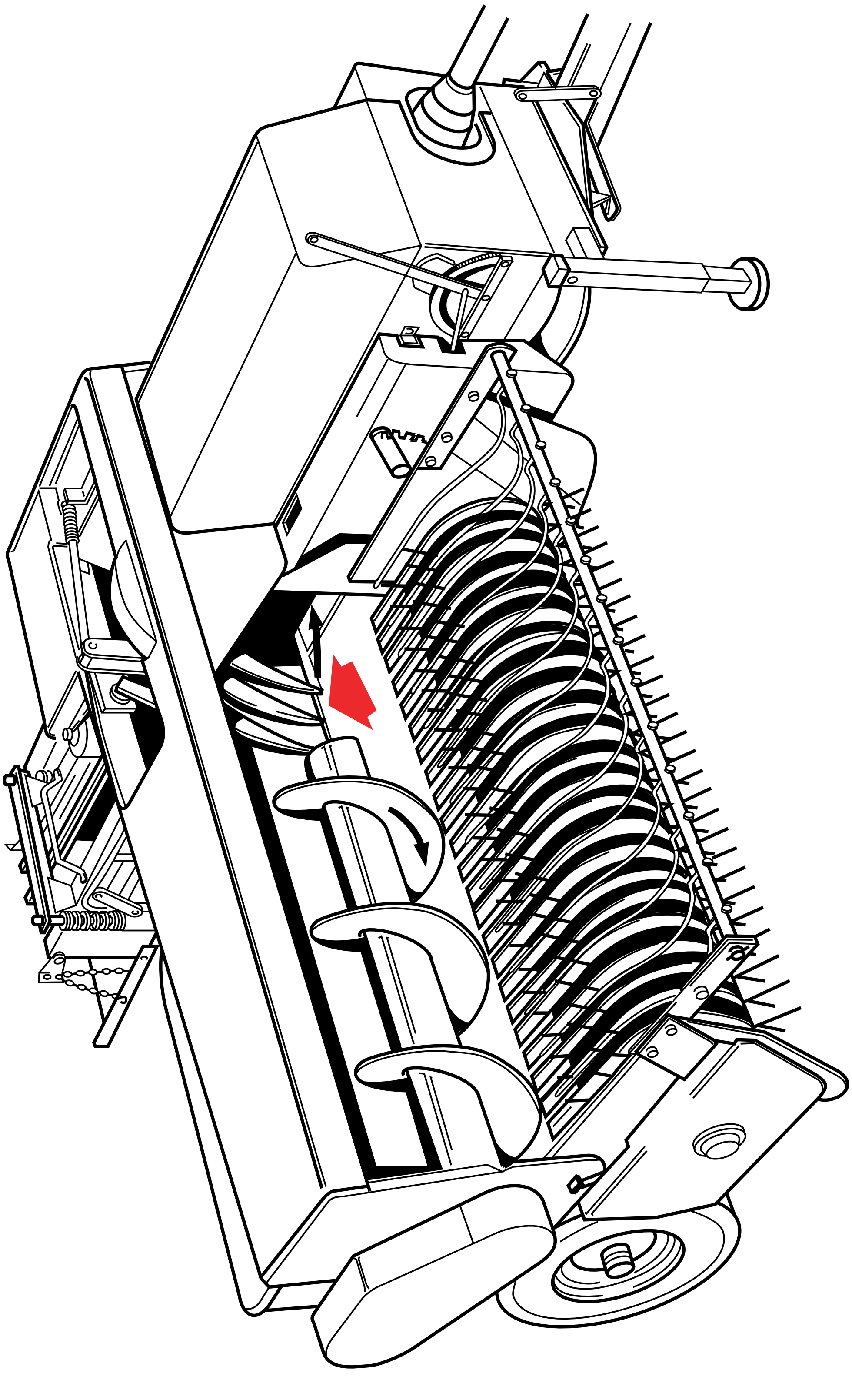


Figure 7 **Entanglement caused by catching between rotating and other moving parts** *(2 of 2)*

Figure 8 **Entanglement caused by catching between rotating and fixed parts**

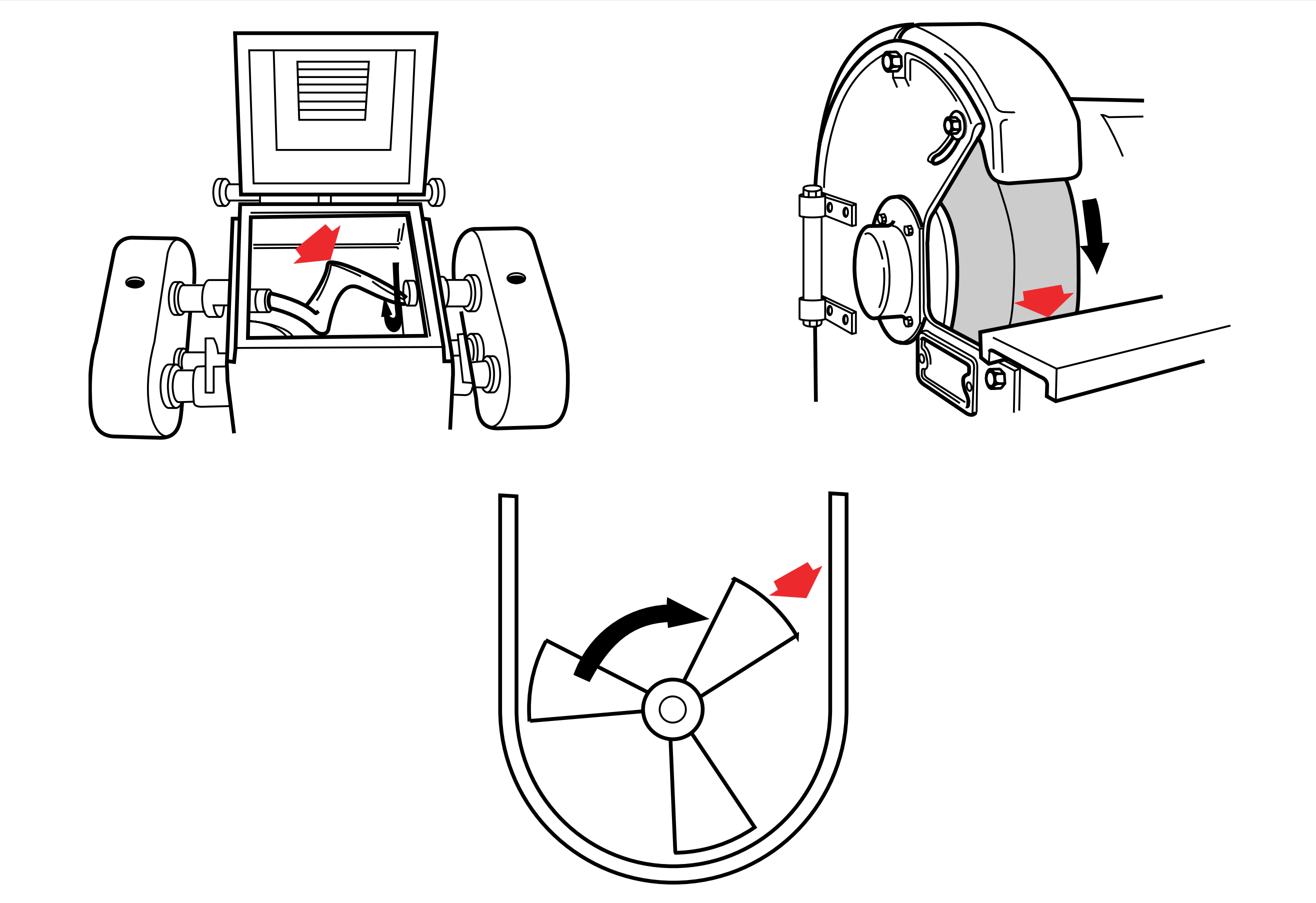
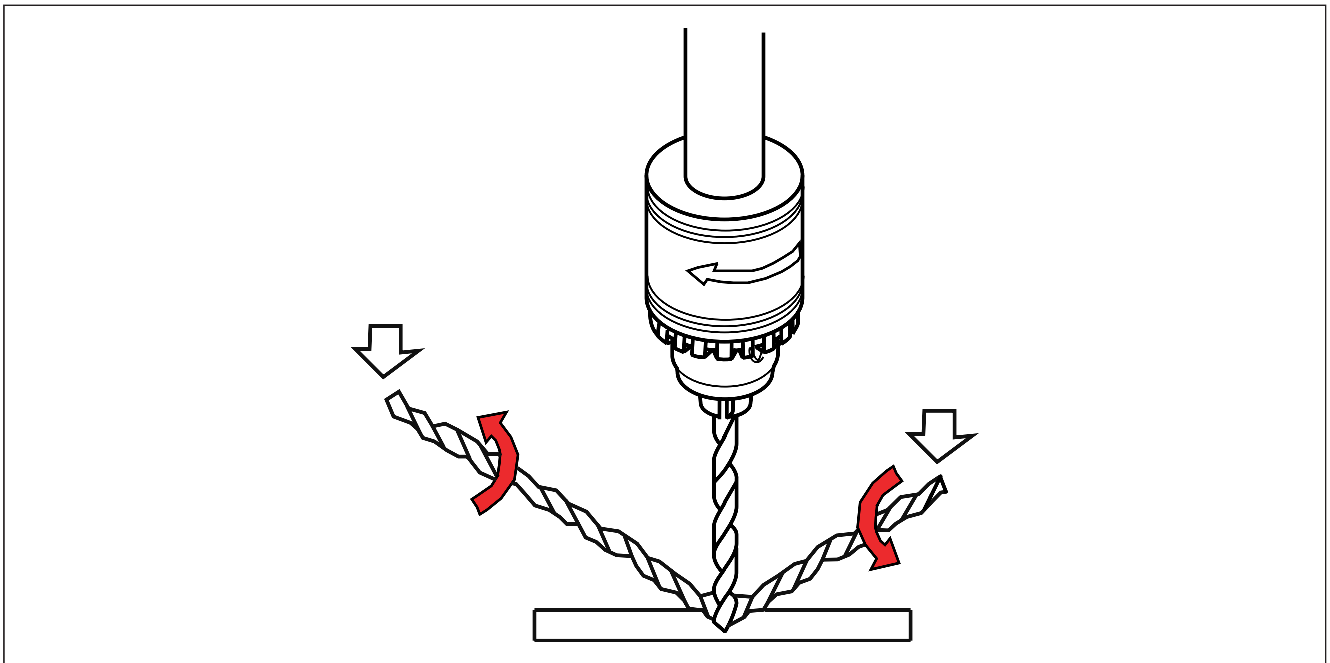


Figure 9 **Entanglement caused by catching in materials in motion (swarf)**

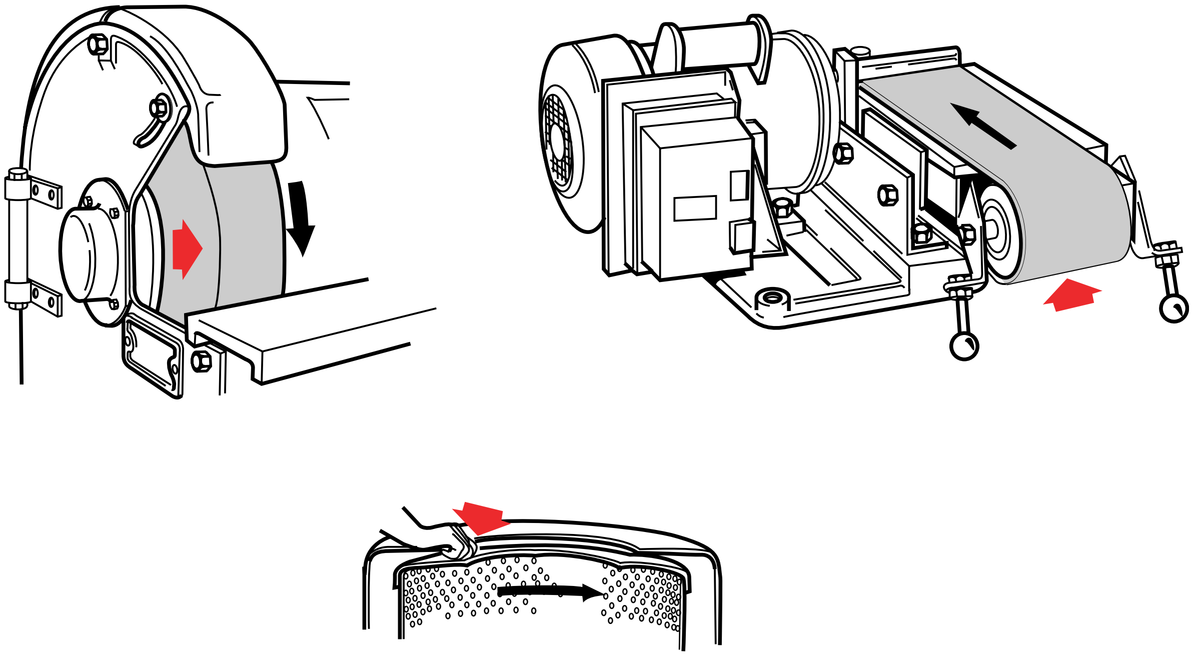


4.2.3 Friction and abrasion

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 10), material running onto a reel or shaft, a conveyor belt and its drums or pulleys (see **4.2.9** and Figure 20), and fast moving ropes or belts.

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

Figure 10 **Friction and abrasion hazards**



NOTE Not all hazards are shown. There can be others.

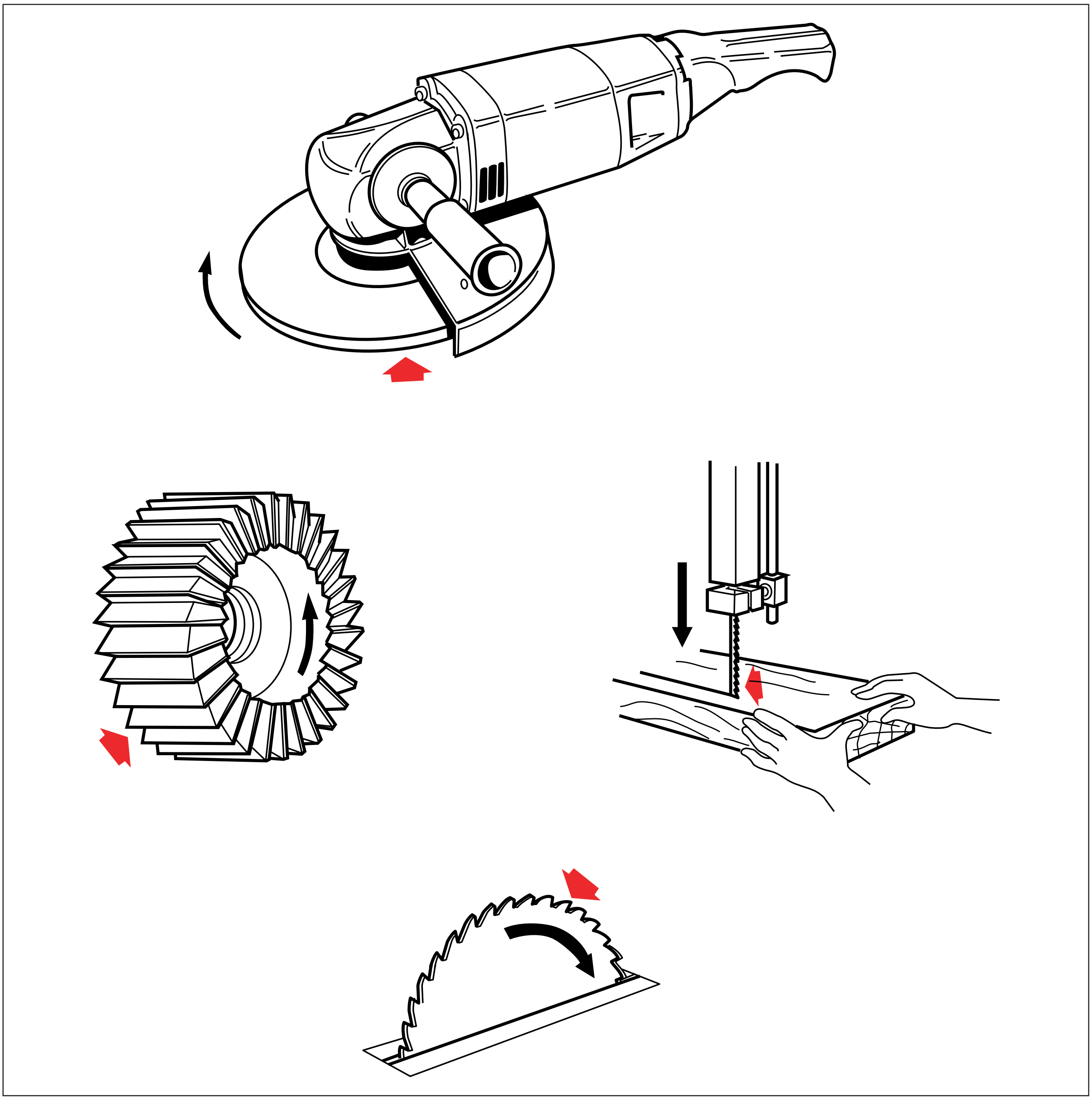
4.2.4 Cutting or severing

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

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

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

Figure 11 **Cutting hazards**



4.2.5 Shearing

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

a) between two machine parts (see Figure 12), for example, the table of a metal planing machine and its bed, the blade of a guillotine and the material to be cut, nip points between connecting rods or links and rotating wheels, or oscillating pendulum movements; or

b) between a machinery part and a workpiece (see Figure 13), for example, transfer mechanisms, the tool of a broaching machine.

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

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

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

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

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

Figure 12 **Shear hazards between two machine parts**

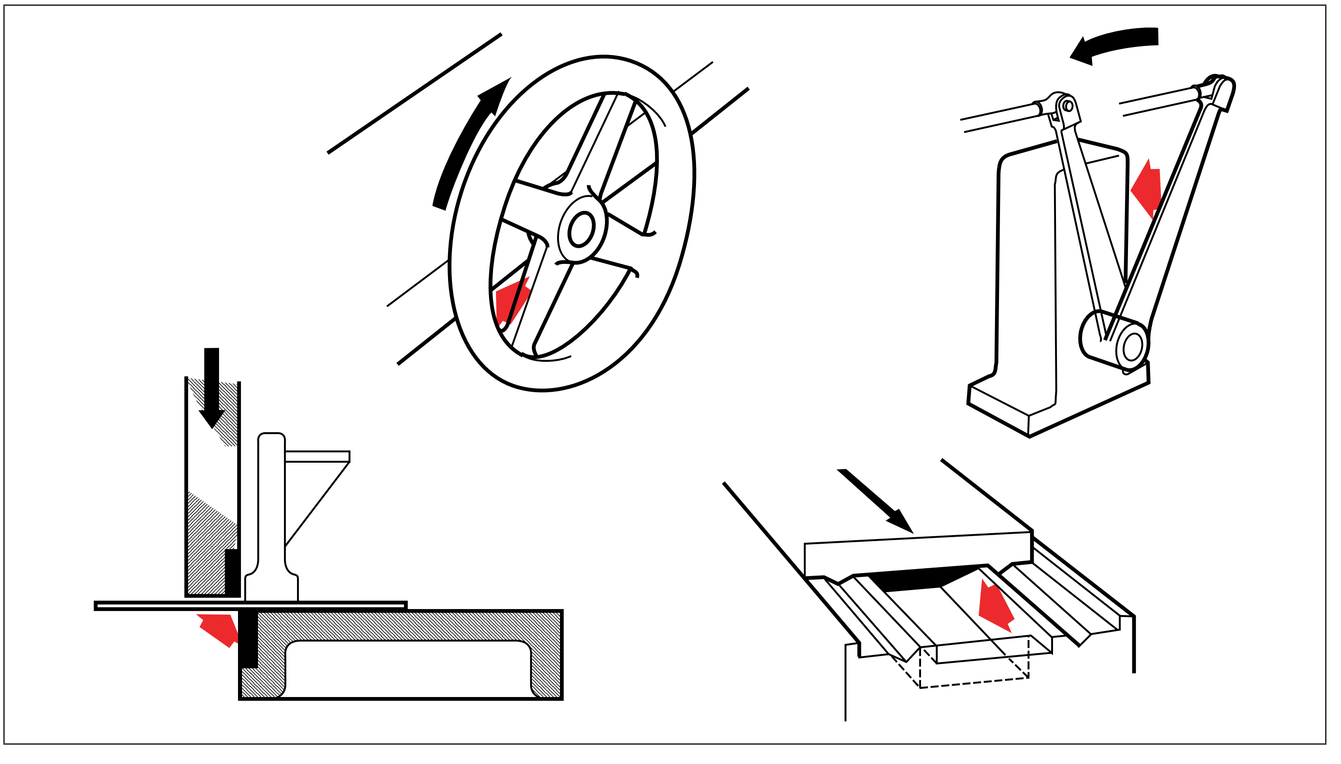


Figure 13 **Shear hazards between a machinery part and a workpiece**

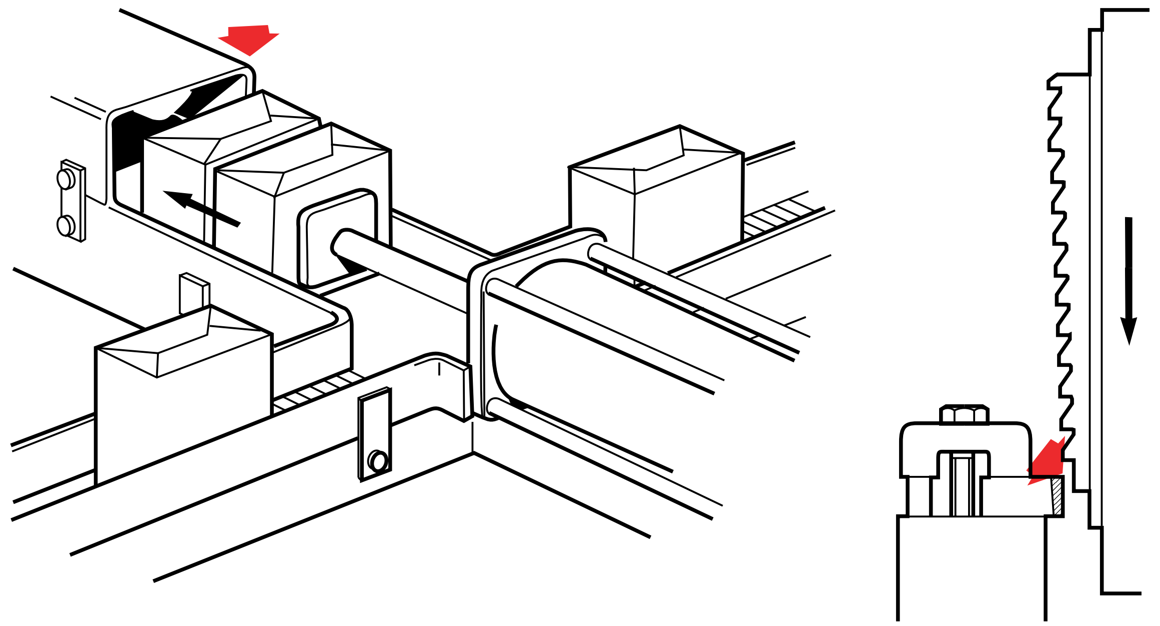
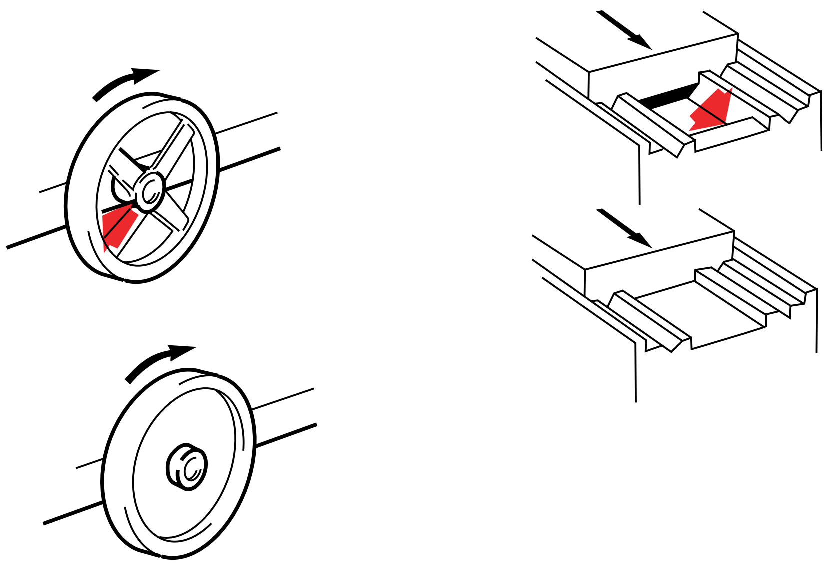
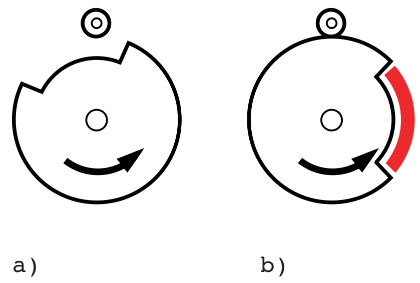


Figure 14 **Removal of shear trap by design**



NOTE Two examples of how shear traps have been eliminated by design.

Figure 15 **Gap cover to prevent shear trap**



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.

4.2.6 Stabbing or puncture

The body can be penetrated by:

a) flying objects (see Figure 16):

   1) ejection of parts of machinery, for example, the flying shuttle of a loom, a loose cutter on a vertical spindle moulding machine, broken tooling on a press, or the bursting of an abrasive wheel;

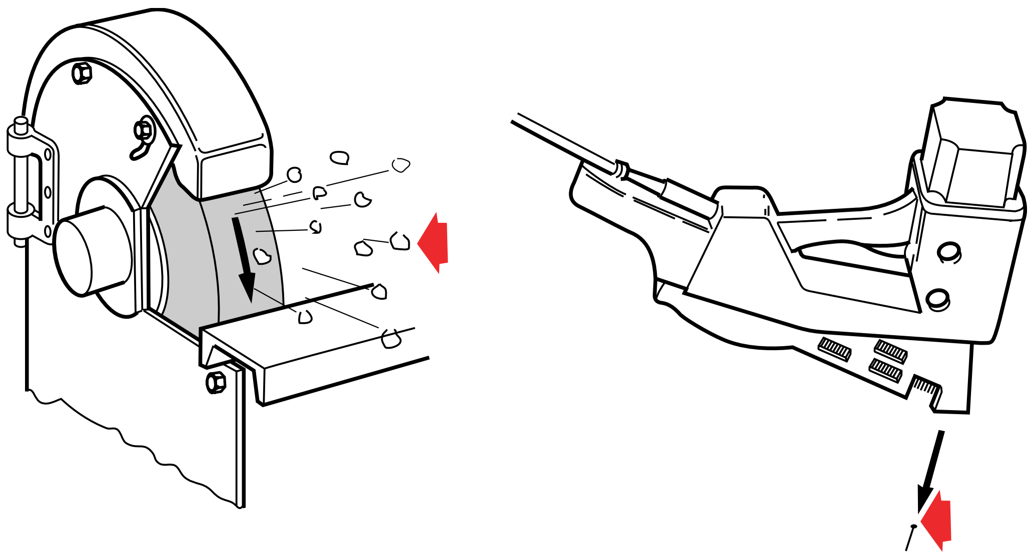
   2) ejection of material, for example, flying swarf, ejection of a workpiece, molten metal ejection from a diecasting machine, sparks generated in a welding process, cartridge tools, debris from rotary mowers and hedge-cutters, or particles blown by compressed air during cleaning;

b) rapidly moving parts of machinery or pieces of material (see Figure 17), for example, 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.

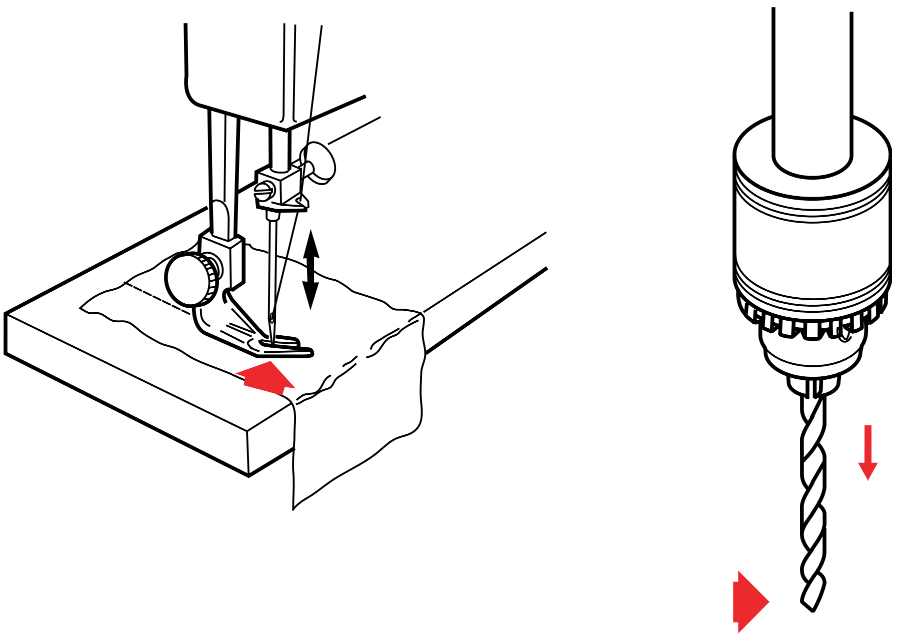
Where there is a risk of small or sharp ejected objects penetrating the skin, the use of sheet material instead of mesh should be considered for guards.

Figure 16 **Stabbing and puncture by flying objects**



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

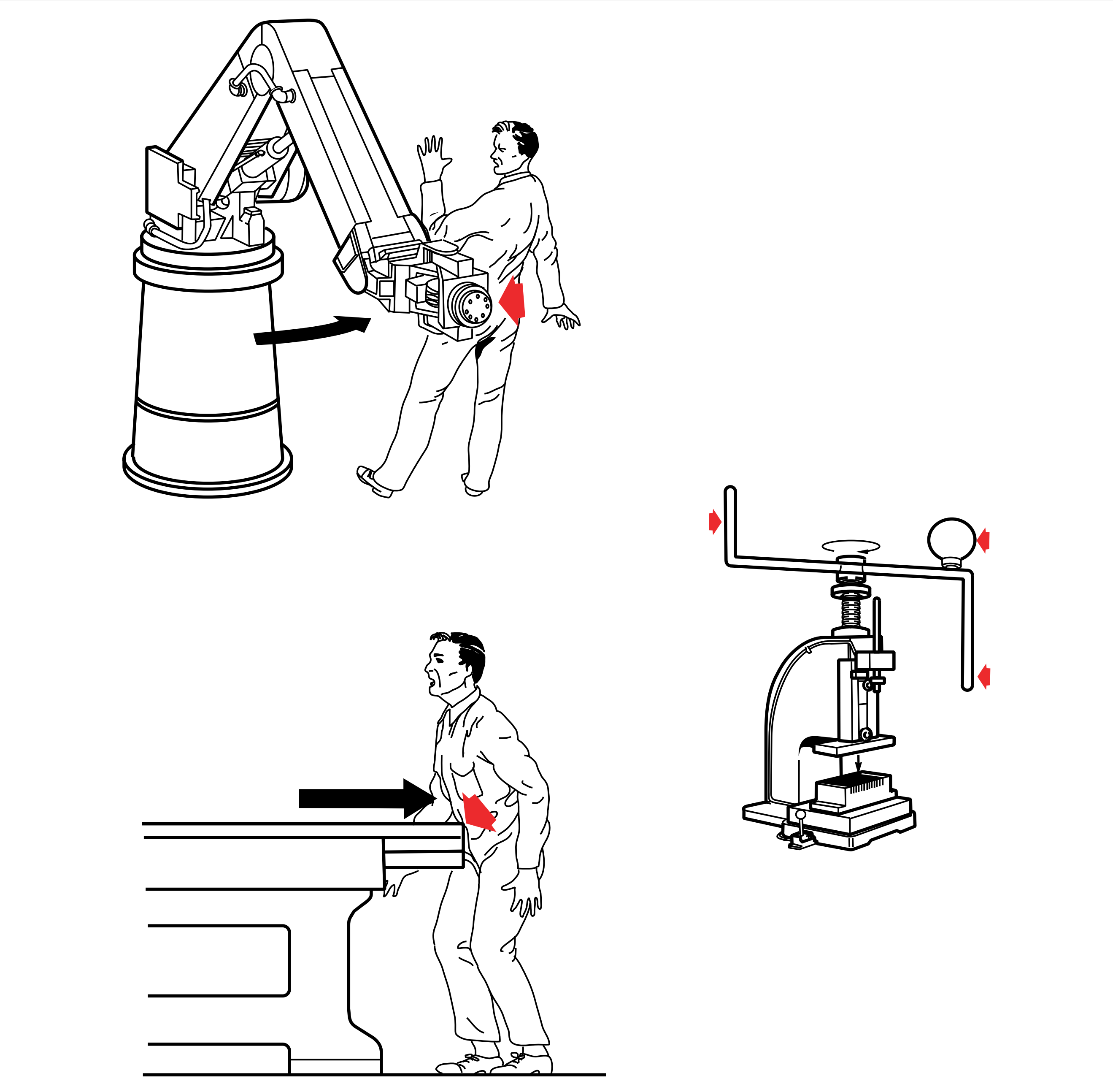
Figure 17 **Stabbing and puncture by rapidly moving parts of machinery or pieces of material**



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 18), for example, the traversing motion of a machinery part, oscillating pendulum movements, striking by projections or moving counterweights. The considerations for impact injuries are much the same as for stabbing or penetration injuries.

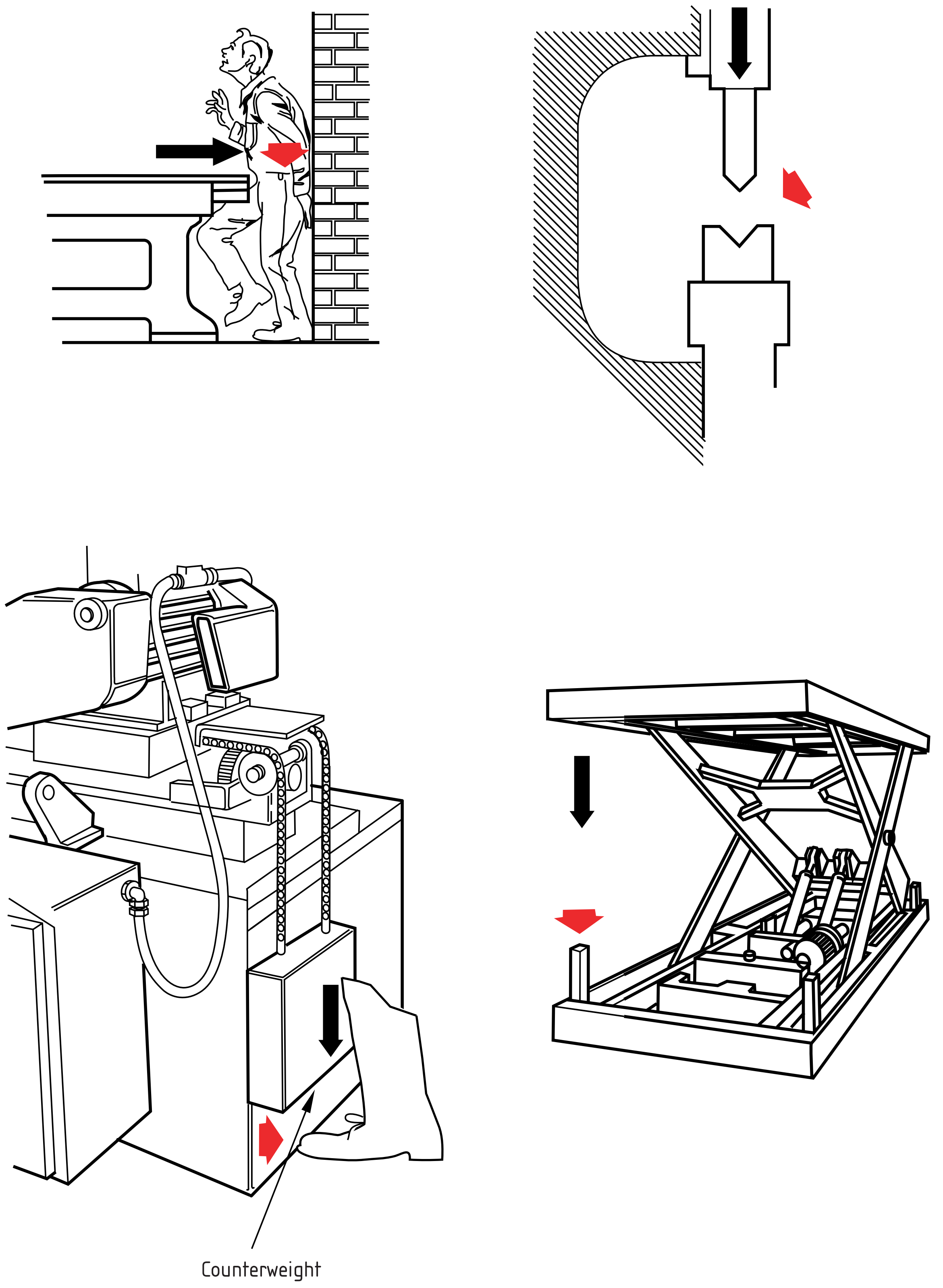
Figure 18 **Impact hazards**



4.2.8 Crushing

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

Figure 19 **Crushing hazards**



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:

a) in-running nips between two counter-rotating parts (see Figure 6), for example, meshing gears, rolling mills, mixing rolls, press rolls, reel and carriage rolls, dough brakes and moulders or calenders;

b) in-running nips between a rotating surface and a tangentially moving surface (see Figure 20), for example, power transmission belt and pulley, chain and chain wheel, rack and pinion; and

c) running nips between a rotating surface and a tangentially moving surface where material, for example, metal, paper, cable and rope, runs on to a reel, drum or shaft.

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

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

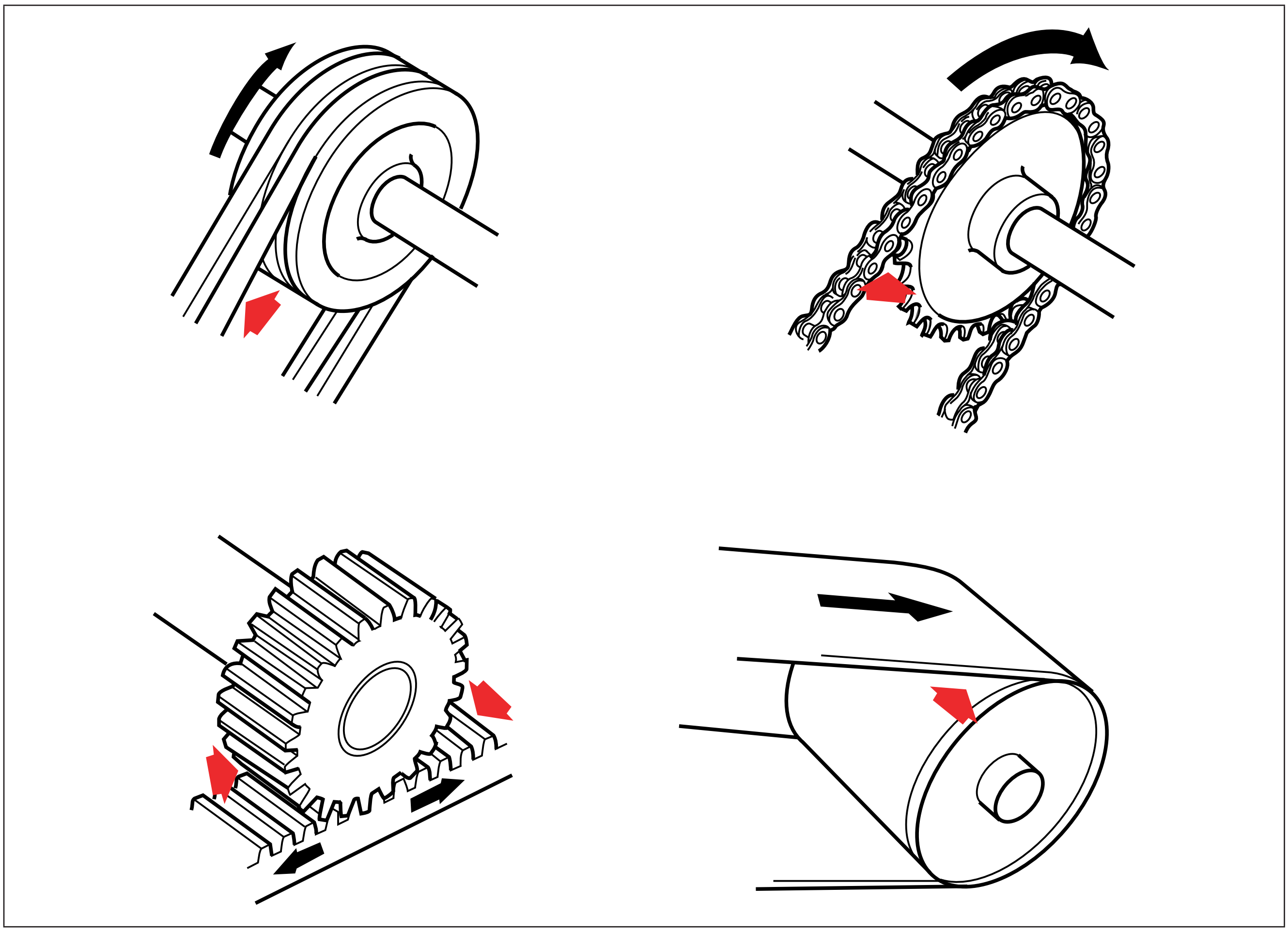
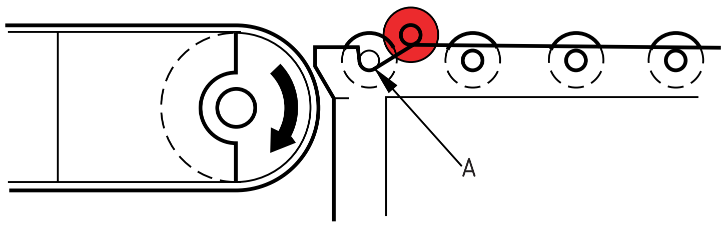


Figure 21 **Roller conveyor: first idle roller free to prevent drawing-in**



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.

4.2.10 Injury by compressed air or high-pressure fluid injection

Injection of fluids through the skin can cause serious tissue damage. Examples of equipment and processes that can cause this type of injury include compressed air jets, diesel injectors, paint sprayers, high-pressure water jetting and high-pressure hydraulic systems (see also **4.2.6**).

4.3 Non-mechanical hazards

4.3.1 General

Machinery can present other, non-mechanical hazards that require protective measures to be taken to prevent harm. The nature of these measures depends on the type of hazard. Where measures taken for one hazard could conflict with those taken for another, the aim should be to minimize possible risk. This normally means that precedence is given to dealing with the hazard creating the greatest risk, irrespective of the nature of the hazard. Designers and suppliers ought to have considered all hazards in accordance with BS EN ISO 12100. The nature of these hazards and examples of the availability of advice, together with examples of protective measures and safeguards that could be adopted, are given in **4.3.2** to **4.3.10**, but more generally in Clause **5**.

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 with (or approach to, in the case of high voltage equipment) (normally) live parts or parts which have become live under fault conditions or have become charged with static electricity;

b) thermal radiation and projection of arc products (including chemical effects) arising from short circuits, or overloading, or processes such as electric arc welding; and

c) risk of ignition of flammable substances due to use of unsuitable electrical equipment or the generation of static electricity by the machine or the process.

General requirements for the electrical equipment of machines are specified in BS EN 60204-1 (and BS EN 60204-11 in the case of high voltage). Hazards due to static electricity are discussed in PD CLC/TR 50404. Modifications arising, for example, from change of use, should be in accordance with BS EN 60204-1 and PD CLC/TR 50404.

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

4.3.3 Thermal

Thermal hazards include:

a) contact with parts or materials operating at extremes of temperature (hot or cold);

b) flames or explosions and radiation from heat sources; and

c) hot or cold working environment.

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

4.3.4 Noise

Exposure to excessive noise can result in:

a) permanent hearing loss;

b) tinnitus;

c) tiredness;

d) stress;

e) loss of balance and loss of awareness; or

f) interference with speech communication and awareness of auditory signals.

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

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

Where noise reduction at source is not practicable, persons can be protected against the effects of excessive noise by the use of personal protective equipment (see **12.5.5**).

4.3.5 Radiation

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

Types of non-ionizing radiation include:

a) electromagnetic radiation (for example, in the frequency ranges from low frequency through radio frequencies up into microwave); and

b) light, including infra-red, visible, ultra violet and laser light radiation.

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

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

Protective measures include the use of, for example:

1) filtering and absorption; and

2) attenuating screens or guards.

NOTE Attention is drawn to the Ionising Radiation Regulations 1999 [7] and BS EN 12198 for non-ionizing radiation.

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 machinery, can give rise to hazards such as:

a) fire and explosion;

b) harm arising from ingestion, contact with the skin, eyes and mucous membranes or inhalation of fluids, gases, mists, fumes, fibres, dusts or aerosols (e.g. toxic, corrosive, teratogenic, carcinogenic, mutagenic, irritant or sensitizing effect); and

c) biological (mould) and micro-biological (viral or bacterial).

Protective measures include:

1) complete enclosure with means to maintain a negative pressure differential with the surroundings;

2) local exhaust ventilation with filtration;

3) wetting with liquids; and

4) special ventilation in the area of the machine (air curtains, cabins for operators).

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

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

4.3.8 Poor ergonomics

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

a) physiological effects (e.g. musculo-skeletal disorders) resulting, for example, from unhealthy postures, excessive or repetitive efforts;

b) psycho-physiological effects generated by, for example, mental overload or underload, or stress arising from the operation, supervision or maintenance of the machine; or

c) human errors.

Advice on ergonomic principles is given in BS EN ISO 12100 (see also **7.4** and Annex A).

4.3.9 Inadequate access

Inadequate (e.g. poorly designed or maintained) access can give rise to injuries from slips, trips and falls (protective measures are discussed in **5.23.3** and **11.3.3**).

4.3.10 Environment

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

4.3.11 Hygiene

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

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

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

5.1 Design for safe use

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

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

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

5.2 Checks by user

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

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

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

5.3 Further considerations for safeguards

5.3.1 General

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

5.3.2 Corrosion

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

5.3.3 Coolant and swarf

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

5.3.4 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.

5.3.5 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 [8] regarding acceptable levels of exposure to mist, fumes and dust and occupational exposure limits and occupational exposure standards. These are given in HSE Guidance Note EH40/2005 [9].

5.4 Controls

5.4.1 Position

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

The controls should be positioned and spaced for safe and easy operation. There should be sufficient clearance between each control and also between controls and other parts of the machinery such that their operation does not cause additional risk [see BS EN ISO 12100:2010, **6.2.8**f)]. 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 the possibility of inadvertent operation is minimized.

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

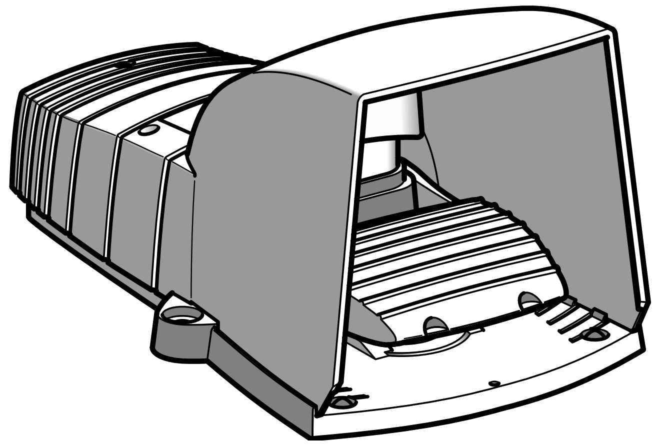
Where a machine has more than one control station, measures should be provided to ensure that commands from different control stations do not lead to a hazardous situation. This can be achieved by providing unambiguous control circuit selection at a master control station overriding all other controls, so that the start control can be transferred from one position to another. These and other methods are discussed in further detail in BS EN 60204-1 and BS EN 61310-3 (see also **5.14**).

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

Two-hand controls should be so placed, separated and protected as to prevent them from being operated by any means other than with two hands (see **8.5** and BS EN 574).

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

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



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.

5.4.2 Identification

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

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

Emergency stop and emergency switching off controls should be coloured red, with a yellow background where one exists, in accordance with BS EN 60204-1:2006+A1:2009, **10.7**, and BS EN ISO 13850:2008, **4.4.5** (see also **8.8.2**).

5.4.3 Operation

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

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

5.4.4 Controls for machinery setting or adjustment and for feeding material

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

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

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

a) a protective device requiring sustained action [e.g. hold-to-run control (see **8.3**), enabling device (see **8.4**)];

b) reducing speed;

c) reducing torque;

d) limited movement device (inch or jog); and

e) identifying and providing safe position(s) and safe access to perform troubleshooting tasks

The enabling device shall be of three-position type (see BS EN 60204-1:2006+A1:2009, **9.2.6.3**).

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

5.4.5 Handles and hand-wheels

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

5.4.6 Warning signals

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

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

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

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

5.4.7 Program or sequence control

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

Assurance of the integrity of control systems, including programmable electronic systems, is described in **10.3**. Programmable systems are described in **5.24**.

5.5 Indicators

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

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 about the state of the equipment, e.g. an indicator light and/or audible alarm. See BS EN 60204-1 and BS EN 61310-1 for recommended colours of indicator lamps.

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

5.6 Unexpected/unintended start-up

Unexpected/unintended start-up (see **1.3.21**) is one of the most common causes of accidents at machinery. Therefore, preventing unexpected/unintended start-up whilst persons are present in hazardous areas is one of the most important requirements for the safe use of machinery. Machinery should have adequate means to prevent unexpected/unintended start-up (see also BS EN 1037 and BS EN 60204-1:2006+A1:2009, **5.4**).

Means for isolation and energy dissipation are recognized ways of preventing unexpected/unintended start-up. Activities that require, for example, the dismantling of machine parts or alterations to, or testing of, power circuits, generally require this (for electrical equipment, see **12.3.3** and BS EN 60204-1:2006+A1:2009, **5.5** and **5.6**). The user should ensure by a safe system of work that the means provided are properly used.

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

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

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

a) inspections;

b) adjustments;

c) work on electrical equipment where:

    1) there is no hazard arising from electric shock and burn;

    2) the means of switching off remains effective throughout the work; and

    3) the work is of a minor nature (for example, replacement of plug-in devices without disturbing existing wiring); and

d) work on fluid power systems where:

    1) there is no hazard arising from release of pressurized fluid;

    2) the means of switching off remains effective throughout the work; and

    3) the work is of a minor nature.

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

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

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

5.7 Measures for the escape and rescue of trapped persons

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

a) escape routes and shelters in installations generating operator trapping hazards;

b) escape doors in guards;

c) arrangements for operating some machine elements by hand;

d) arrangements for reversing the direction of operation of some machine elements;

e) anchorage points for descender devices; and

f) means of communication to enable trapped persons to call for help.

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

5.8 Clutches

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

5.9 Braking systems

5.9.1 General

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

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

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

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

5.9.2 Mechanical (friction) braking systems

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

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

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

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

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

a) selecting an appropriate friction material;

b) providing an effective housing to prevent ingress; and

c) monitoring braking efficiency and supplying control systems that prevent motion when efficiency is below the acceptable level.

When springs are used, they should be of the compression type, adequately rated and of sufficient strength to secure prompt and effective brake application. Any set of springs used on a brake should be closely uniform in dimension, quality and rating. A single spring should not be relied upon unless equivalent safety is assured by other means. The means for loading the springs should be such that, when correctly adjusted, the spring anchorages can be locked to prevent risk of slackening-back.

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

1) the length to which the spring(s) can be compressed; and

2) the setting of the operating mechanism.

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

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

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

5.9.3 Electrodynamic braking systems

5.9.3.1 General

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

5.9.3.2 Reverse plugging

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

5.9.3.3 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 **5.9.3.2**) 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.

5.9.3.4 Capacitor regenerative braking for a.c. motors

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

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

b) Improving the braking effect during the final stages of deceleration by short-circuiting the motor terminals.

5.9.3.5 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 d.c. power supply.

5.9.3.6 Motor controllers (variable speed drive)

Motor controllers incorporating electronic and computer control technology are often used to control motor speed. Their capacity for speed control includes the ability to perform electrodynamic (regenerative) braking. The electrical, thermal and energy safety requirements of these controllers are specified in BS EN 61800-5-1. Requirements for their functional safety performance are specified in BS EN 61800-5-2.

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

Where risk of injury could arise, a protective device should be incorporated in the design to restrain any moving machinery part which can, for example:

a) overrun beyond its normal stopping position;

b) runback due to gravity; or

c) fall due to gravity, such as the failure of a counterweight system (see **5.11**).

5.11 Counterweights and similar devices

Counterweights which could fall upon or trap persons should be suitably safeguarded (see Figure 19). The movement of the counterweights should be safeguarded as far as necessary to provide complete protection against injury, particularly in the event of a power system failure.

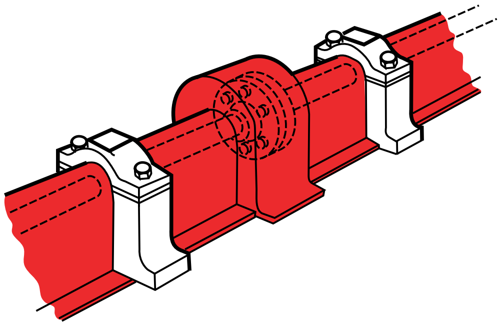
Duplication of the flexible connections (chain or cable) between the mass and its balance weight(s) is good practice, provided each connection is sufficiently strong to take the full load.

Similar precautions are necessary on other weights, for example, 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.

5.12 Rotating shafts, spindles and couplings

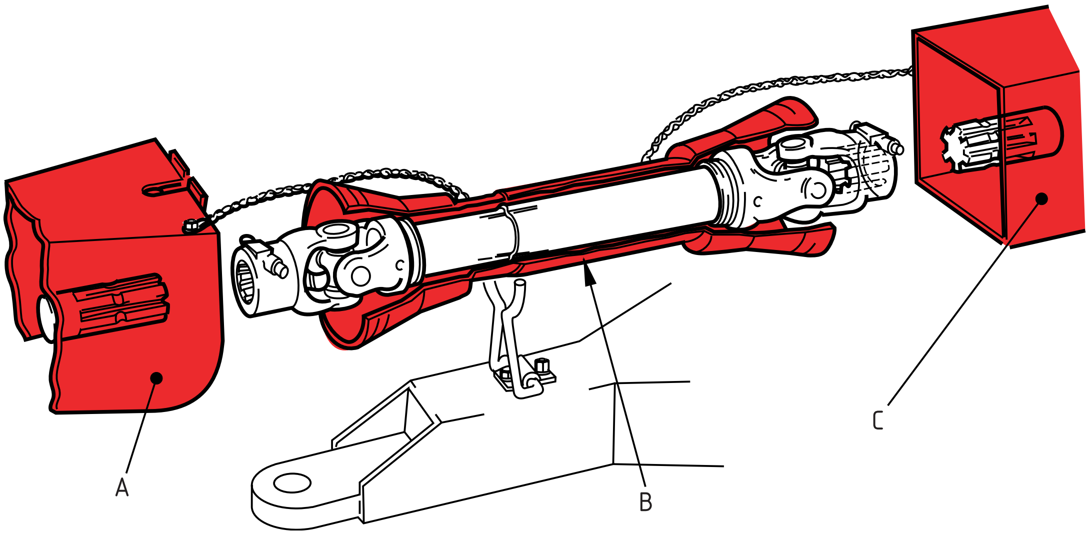
Every projection, such as a setscrew, bolt or key, on any exposed revolving part of machinery should be shrouded or otherwise effectively guarded. Guards for rotating shafts should ideally be fixed or moveable interlocking guards of solid construction (see Figure 23 and Figure 24). However, guards of the bellows type or telescopic construction can also be used in some applications (see Figure 25).

Figure 23 **Guarding of shafts and couplings: Fixed guard for a transmission shaft and coupling**



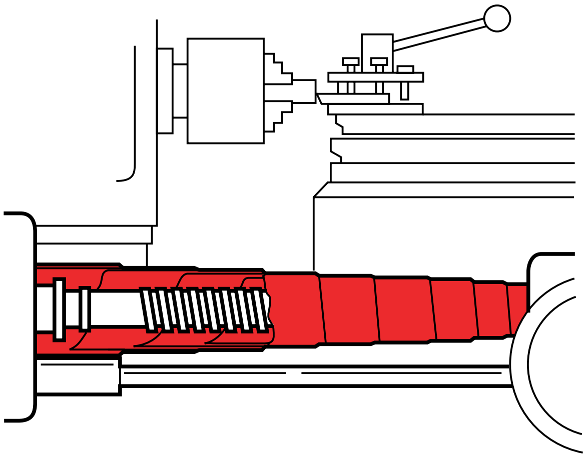
The fixed guard for a transmission shaft and coupling is made of sheet metal and is of U-section, with flanges for fixing to the structure on which the bearings are mounted.

Figure 24 **Tractor power take-off drives**



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 25 **Telescopic type guard**



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.

5.13 Feeding and take-off devices

The use of equipment to move components, materials and substances into and out of machine tools and process machinery 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 of such equipment are robots, chutes, slides, indexing tables, transfer mechanisms, automatic feeds, magazines, suction or magnetic devices, push rods and air blast.

The addition of automatic feeding and removal devices can create additional hazards as a result of their interaction with the machinery, and a new risk assessment should be carried out. Additional safeguarding should be provided if required.

5.14 Hydraulic and pneumatic systems

Hydraulic and pneumatic equipment used should conform to the safety requirements specified in BS EN ISO 4413 and BS EN ISO 4414 or the appropriate machine standard where one exists.

5.15 Electrical systems

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

5.16 Workholding devices

5.16.1 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, for example, the provision of a reserve power supply to ensure the workpiece remains clamped until the machine can reach a safe position. Requirements for the design and construction of work holding chucks are specified in BS EN 1550.

5.16.2 Workholding devices for automatic machinery

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

The clamping movement should either:

a) if accessible, not expose a gap of more than 6 mm; or

b) be guarded such that it is not possible to trap a hand or a finger.

Guidance is given in BS EN ISO 13857 and Annex A.

5.16.3 Prevention of inadvertent unclamping of the workpiece

The control system should 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 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 over-travel of the clamp could create a hazard.

5.17 Lifting, handling and transport

When machinery has to be moved or transported and this cannot be done manually, it 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 ought to 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 [10], 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 avoid mismatching.

5.18 Static and dynamic stability

Machines should be stable (see BS EN ISO 12100:2010, **6.2.6** and **6.3.2.6**), so they are not likely to fall over during foreseeable operation or be unintentionally moved by vibration, wind pressure, impact, overloading or other foreseeable external forces. If this cannot be achieved by design then protective measures should be used. For example, movements of parts of the machine could be restricted, indicators, alarms to warn of impending instability or interlocks to prevent tipping could be provided, or the machine could be securely anchored to a foundation.

If special protective measures are required, a warning (that may include operating procedures) should be provided on the machine and in the instructions for use.

5.19 Lubrication

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 **5.23.3**).

5.20 Lighting

The work area should be adequately illuminated for the hazard-free and efficient operation of the machine. When this is not the case, local lighting should be provided on the machine for the illumination of the work area. Where necessary, local lighting should also be provided in areas where routine maintenance is required, such as the inside of certain electrical panels. Such lighting should conform to 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.

5.21 Hygiene and guard design

Machinery used in certain industries, in particular for the processing of food and pharmaceuticals, should be designed so that it can be readily cleaned without risk of harm (see **4.3.11**).

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 guard which is not detachable, 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 ISO 13857 and Annex A).

Materials used for guards 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.

5.22 Safety markings, signs (pictograms) and written warnings

Clearly visible and unambiguous safety markings, signs and written warnings should be applied as necessary for safe use. They can indicate, for example, maximum permissible speed of rotating parts, maximum working load, presence of a laser product or presence of electrical equipment under a cover, and the necessity of wearing personal protective equipment. BS EN 981 and BS EN 61310 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 12100:2010, **6.4.4**).

5.23 Access (see also Section 11)

5.23.1 Operating stations

Safe access to operating stations should be provided. Stations should be positioned so that the operator has adequate visibility for control of the process being carried out. This can necessitate the provision of extra measures to aid visibility and easy access for the operator. Where an operator needs to stand or sit on machinery when it is being operated, a platform or seat should be provided that is designed and situated to protect the operator from any fixed or moving part which can cause injury.

Seats should be constructed to provide adequate support and be fitted with back rests or shaped to protect an operator against slipping from the seat. Suitable restraint systems (such as seat belts) and footrests should be provided where necessary.

5.23.2 Platforms, steps and ladders

Where work platforms are used, they should be designed to provide safe access, with 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, hoops, or a stairway with handrails or some other suitable means should be provided to give safe and convenient access.

Requirements for the design and general construction of factory stairways, ladders and handrails are specified in BS EN ISO 14122.

5.23.3 Access for adjustment, lubrication and maintenance

Machinery should be designed to enable all routine adjustments, lubrication and maintenance to be carried out without removing safeguards and without extensive dismantling. Positions where an external action is required, such as filling with lubricant or actuation of a lever, should be easily accessible and situated so as not to present a hazard.

Where necessary, machines should have built-in platforms, ladders or other facilities to provide safe access for any adjustment, lubrication or maintenance, but users should check that such platforms or ladders do not give access to hazardous parts of machinery (see also **5.23.2**).

Where practicable, lubrication and routine maintenance facilities should be located outside hazardous areas. Where access for lubrication is difficult, facilities for lubrication from a remote point or self-lubricating bearings should be provided.

5.24 Programmable systems

Modifications to programmable systems can present safety problems. The implications of such modifications might not be immediately apparent and could have unforeseen consequences, particularly in modern complex systems (see also **10.3**). Programmable systems can incorporate:

a) disc, cam or drum arrangements, operating switches, valves or linkages;

b) selector switches or valves affecting otherwise “hard-wired” logic;

c) punched card readers;

d) punched tape readers;

e) magnetic tapes or discs; and/or

f) electronic or optical storage.

These devices may be used in conjunction with a variety of control media, in control, interlocking and/or emergency systems. The effects of inadvertent or deliberate alteration of the stored program should be considered. Where these effects have safety implications, the reliability and security of the system should be assured by, for example, the use of one or more of the following:

1) pinned cams;

2) program storage in read only memory (ROM);

3) locks restricting access; and

4) password access to software.

NOTE See Section 12 for guidance on safe working practices.

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Section 6: Selection of safeguards

6.1 General

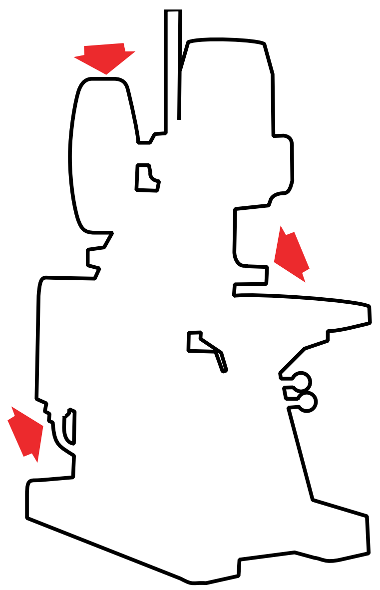
Safeguards (guards and protective devices) can, when suitably designed/selected, provide protection against mechanical (see **4.2**) and non-mechanical hazards (see **4.3**). They should be used where it is not practicable to remove hazards or sufficiently reduce risks by inherently safe design.

Fundamental considerations involved in safeguarding a machine are shown in Figure 26. In selecting an appropriate safeguard for a particular type of machinery or hazardous area, a fixed guard is simple and should be used where access to the hazardous area is not required during operation of the machinery or for cleaning, setting or other routine activities. If the removal of a fixed guard is required, this should be done in accordance with a safe system of work that ensures the machine remains in a safe state.

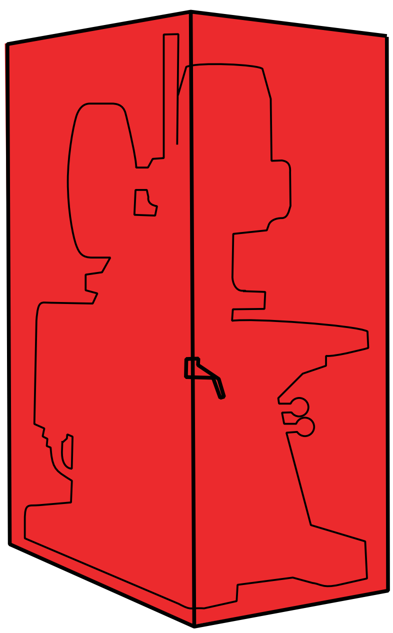
As the requirement for access increases in frequency, fixed guards might no longer be appropriate and other protective devices, such as interlocking guards, should be used. The requirements of safe systems of work and/or interlocking become more stringent as the risk increases (see Section 3 and Section 9).

In practice, a combination of safeguards might be required. For example, a fixed guard, an interlocked guard at the access point and a presence-sensing device in the hazardous area (see Figure 62 and Figure 66).

Figure 26 **Fundamental considerations involved in guarding a machine** *(1 of 3)*

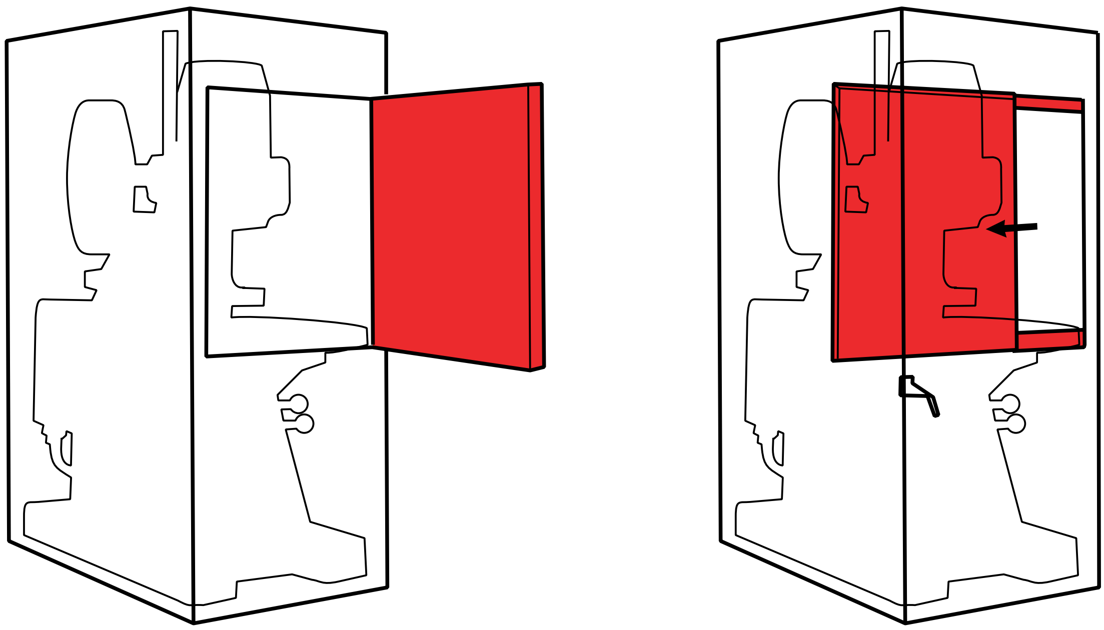


a) This shows a hypothetical machine in which, because of its design, several hazards are present.

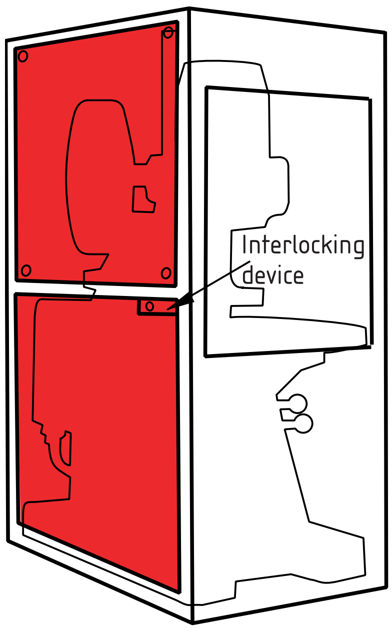


b) This shows the same machine where usage does not require access. A fixed box has been placed around the machine giving complete protection from the hazards. If an operator requires access to the machine, however, a box would of course be impracticable.

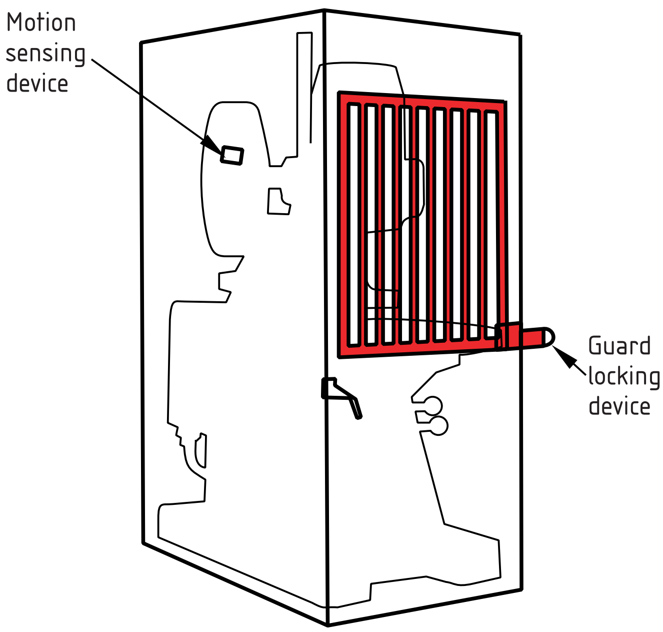
Figure 26 **Fundamental considerations involved in guarding a machine** *(2 of 3)*



c) To provide access from in front of the machine an opening in the box has been provided. This is covered by a hinged or horizontal sliding guard which interlocks the hazardous parts and their power supply by one or other of the methods described and illustrated in Section 9.

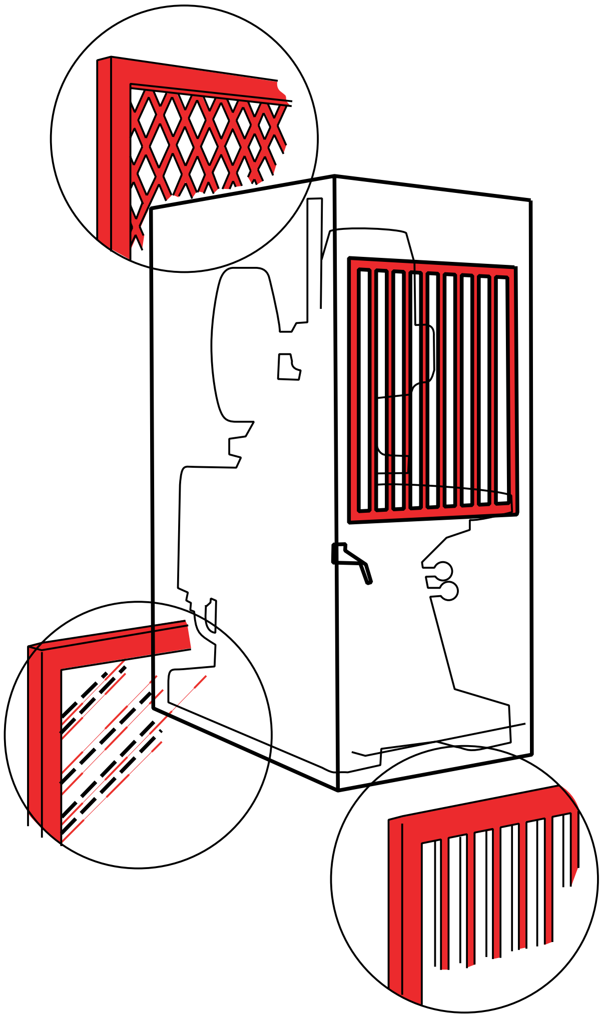


d) Fixed and interlocking guards have been provided at the side of the machine for maintenance or inspection purposes, showing alternative methods of attaching them. The top fixed guard is shown securely bolted in position. Opening the lower interlocking guard interrupts the power supply to the motor.



e) When hazardous movement would be possible after the power has been interrupted, e.g. by opening an interlocking guard, a guard locking feature is required (see **9.4**). The unlocking can be controlled by means of a motion-sensing device or timing device in conjunction with the guard locking device.

Figure 26 **Fundamental considerations involved in guarding a machine** *(3 of 3)*



f) The choice of guard materials and construction requires consideration, in particular the need for strength and visibility through the guard (see **7.3**).

6.2 Where access to the hazard zone is not required during normal operation

Where access to the hazard zone is not required during normal operation of the machinery, safeguards should be selected from the following.

a) Fixed enclosing guard (see **7.2.1.2**), including, where necessary, feeding and take-off devices (see **5.13**) or a false table (see **7.2.7**). Openings in the guard should be in accordance with BS EN ISO 13857 and Annex A.

b) Fixed distance guard (see **7.2.1.3**), including a barrier of adequate height or a tunnel guard in accordance with BS EN ISO 13857 and Annex A.

6.3 Where access to the hazardous area can be required during normal operation

Where access to the hazardous area can be required during normal operation of the machinery, safeguards should be selected from the following.

a) Interlocking guard with or without guard locking (see **7.2.3** and Section 9).

b) Self-adjusting (self-closing) guard (see **7.2.6**), where the adjustment is controlled by the workpiece and the hazardous area is enclosed by the guard before and after the operation and during the operation by the guard and/or the workpiece.

c) Sensitive protective equipment, e.g. electro-sensitive protective equipment, such as light beams or light curtain (see **8.1.3.2**) and pressure-sensitive mats or floors (see **8.1.4**).

6.4 Where access to the hazard zone is required during normal operation

Where access to the hazardous area is required during normal operation, safeguards should be selected from the following.

a) Interlocking guard with or without guard locking (see **7.2.3**).

b) Sensitive protective equipment, e.g. electro-sensitive protective equipment, such as light beam devices or light curtains (see **8.1.3.2**) and pressure-sensitive mats or floors (see **8.1.4**).

c) Interlocking guard with start function (control guard) (see **7.2.3.4**).

d) Self-adjusting (self-closing) guard (see **7.2.6**), where the adjustment is controlled by the workpiece and the hazardous area is enclosed by the guard before and after the operation and during the operation by the guard and/or the workpiece.

e) Adjustable guard (see **7.2.5**), fitted where the hazardous area cannot always be completely enclosed, for example, on certain machine tools such as horizontal and vertical milling machines, grinding machines and woodworking machines.

f) Two-hand control (see **8.5**) should be considered only where the forms of safeguarding detailed in a) to e) cannot provide suitable protection. It protects only the person operating the control device and does not prevent others in the vicinity from gaining access to the hazardous zone.

It should be noted that push-away guards are no longer accepted as safeguards (see **7.2.4**).

6.5 Access to the hazardous area for infrequent operation

When access is needed to the hazardous area, for example, for machine setting, process correction or maintenance, safeguards provided for operation might not fully protect persons who:

a) need to temporarily disable the safeguards provided in order to carry out their work; or

b) could be out of sight and therefore exposed to risk of harm if the machinery is switched on.

In these circumstances safe systems of work including, for example, the use of suitable isolation/immobilization procedures, should be used, augmented where necessary with additional safeguards, for example, lockout/tagout. The use of such systems requires planning and discipline by all concerned. Further information on safe systems of work is given in Section 12.

Section 7: Guard design and construction

7.1 General

The construction of fixed and movable guards should be in accordance with BS EN 953 (see also BS EN ISO 12100:2010, **6.3.3**).

The design and construction of guards should take account of the mechanical and other hazards present (for example, a fixed guard preventing access to a zone where a mechanical hazard is present can also be designed and arranged to reduce the exposure to noise level, toxic emissions, etc.).

Guards should be designed and constructed so as not to give rise to any additional hazard (for example, crushing by a power-operated guard). Guards should provide the minimum interference with activities during operation and other phases of machine life, in order to reduce any incentive to defeat them.

Guard can be used either individually or in combination to provide protection from hazards. For example, many typical guarding systems include both fixed and interlocking guards.

Where possible, guards should prevent persons remaining in the guarded area (for example, between the guard and the hazard) during machine operation. Where this is not possible, for example during maintenance or because of machine layout, additional protective measures are required to protect personnel within the hazardous area. These could be safeguards and/or safe systems of work.

7.2 Types of guard

7.2.1 Fixed guard (see Figure 27 to Figure 36)

7.2.1.1 General

A fixed guard should be held in place in such a manner (for example, by screws, nuts, welding) that it can only be opened or removed by the use of tools or by destruction of the affixing means.

The guard should prevent access to the hazardous parts of the machinery. It should be of robust construction, and sufficient to withstand the stresses of the process and environmental conditions.

If the guard is capable of being opened or removed, fastenings should be of the captive type to reduce the risk of their loss and/or non-replacement. The guard should be securely fixed in position when the machinery is in operation or is likely to be in operation. Where guards have to be removed periodically for such purposes as setting or cleaning, good design reduces the time required for their removal and replacement to a minimum. For example, a fixed guard can be hinged to assist its opening and the removal of a single fixing with the appropriate tool can give the access required (see Figure 29).

Fixed guards for preventing access to in-running nips are shown in Figure 29 to Figure 34.

7.2.1.2 Fixed enclosing guards

A fixed enclosing guard is a fixed guard which, when in position, prevents access to a hazard zone by enclosure (see Figure 27).

When it is necessary for a workpiece to be fed through the guard, openings should be sufficient to allow the passage of material without allowing access to the hazardous parts, but should not create a trapping hazard between the material and the guard. If access to the hazardous parts cannot be prevented by the use of a fixed enclosing guard with a plain opening, then a tunnel of sufficient length should be provided (see **7.4.2**, Figure 37, Figure 38 and Figure 39).

7.2.1.3 Fixed distance guard

A fixed distance guard is a fixed guard which reduces access to a hazard by its physical dimensions and its distance from the hazard (see Figure 40).

A distance guard which surrounds machinery can also be called a perimeter guard, fence-type guard, etc. (see Figure 41 and Figure 42). Its dimensions should be in accordance with BS EN ISO 13857 (see Annex A).

Figure 27 **Fixed enclosing guard constructed of wire mesh and angle section preventing access to transmission machinery from all directions**

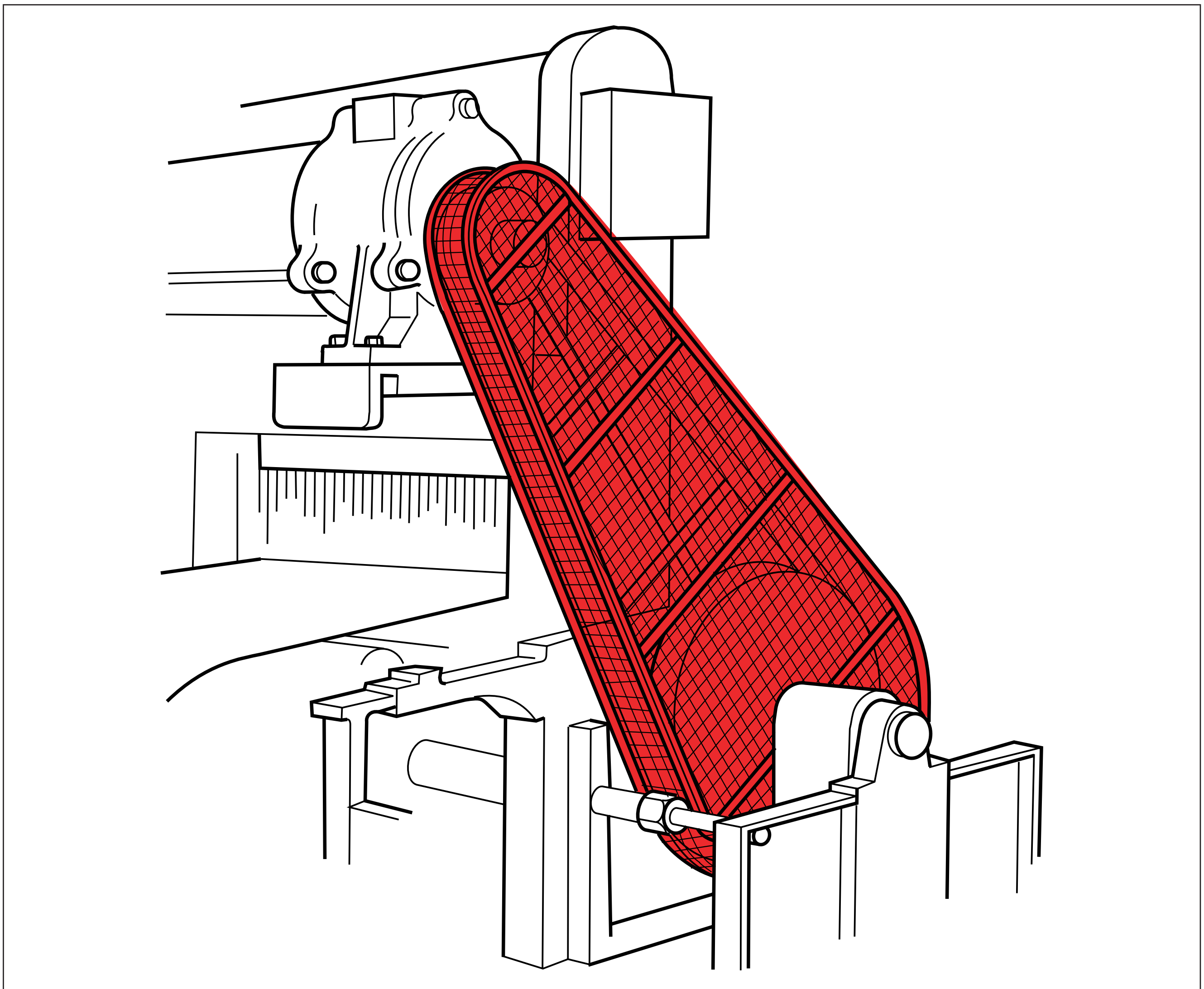
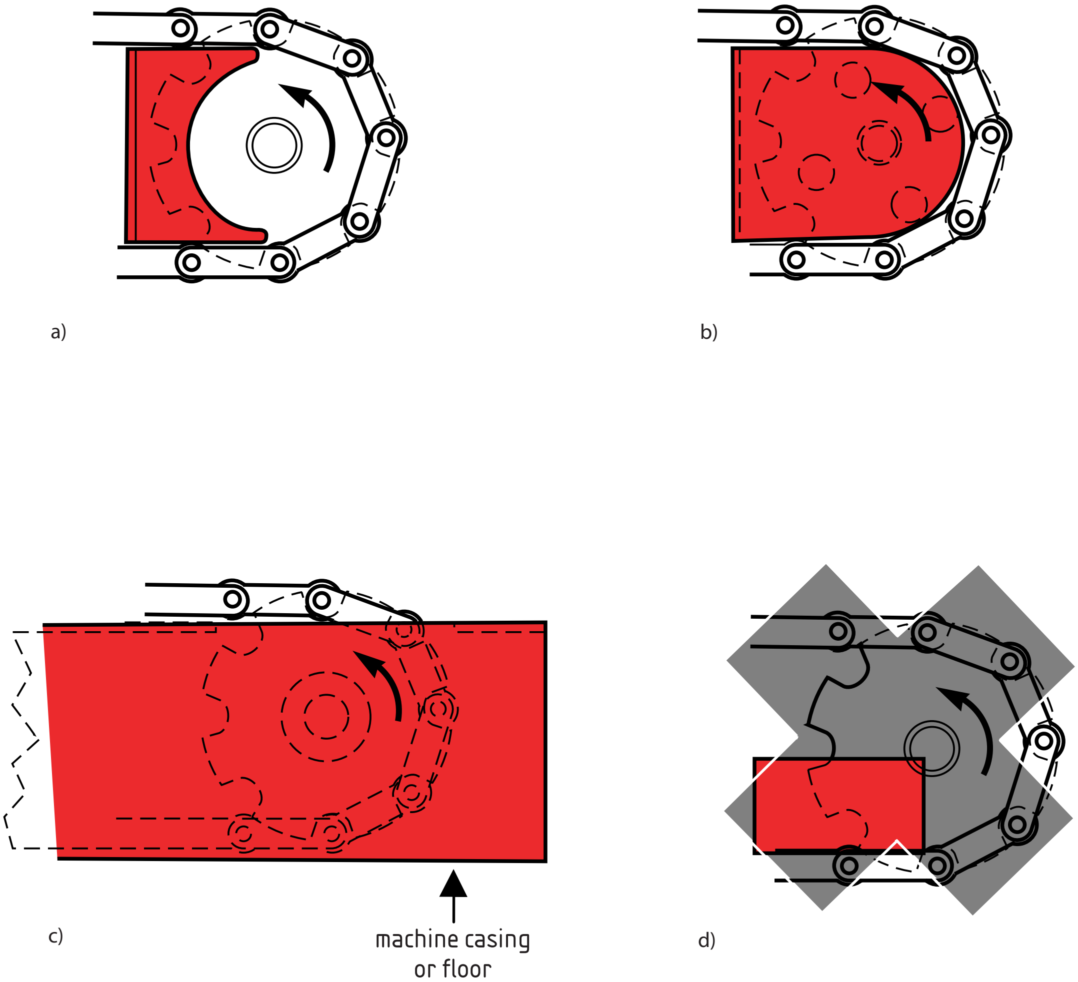
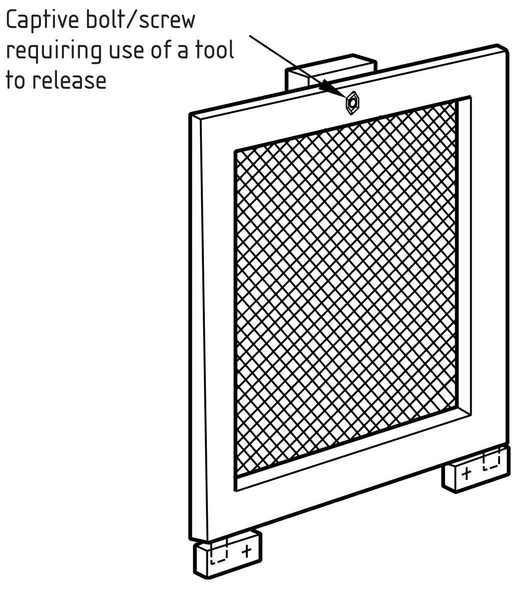


Figure 28 **Fixed guards for chains and chain wheels**



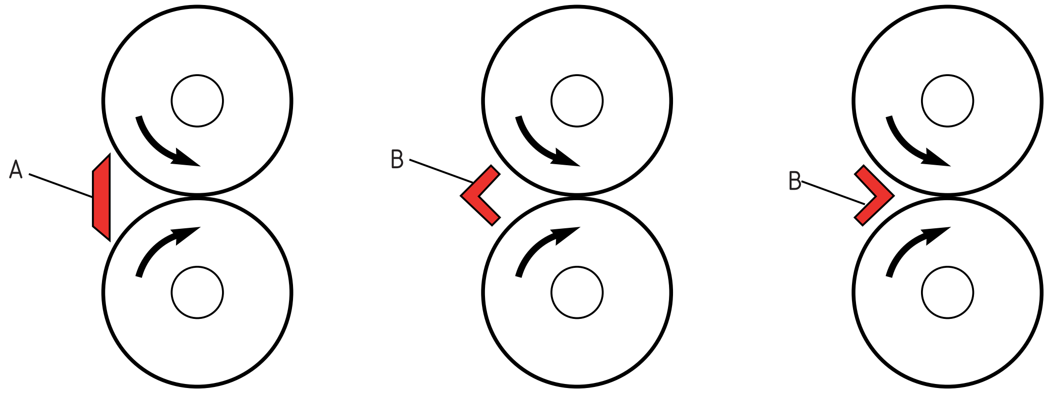
To prevent entanglement with the chain and chain wheel, they should, unless safe by position, be completely enclosed. Where this is not practicable measures to reduce the risk are shown in a), b) and c). The guard should fill the gap between the forward and return parts of the chain, and extend inwards beyond the roots of the teeth a). Where there are spokes or openings in a chain wheel, the guard should also prevent access to the shear points which they create b). Protection can also be provided by enclosing the chain wheels in a machine casing or under the floor c).
A guard which covers only the nip but leaves exposed a trap between the teeth and the guard d) is unsatisfactory.

Figure 29 **Example of a quick release fixed guard**



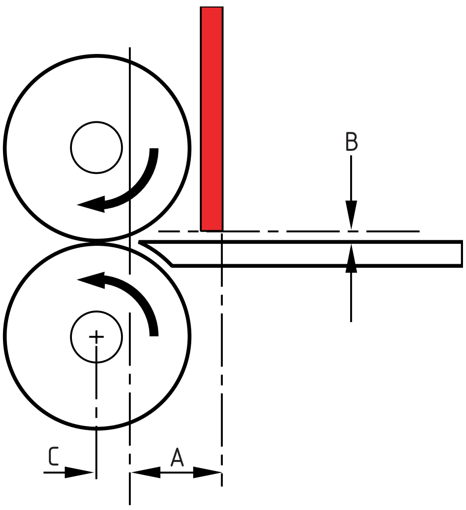
The guard is located by a single captive bolt or screw together with two pins locating in fixed blocks on the machine. Release of the bolt or screw allows the guard to be removed. Removal and replacement of fixed guards should only be carried out as part of a safe system of work.

Figure 30 **Use of flat plate or angle section to prevent access to in-running nips**



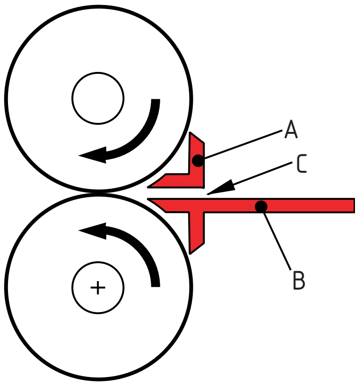
Access to in-running nips (see **4.2.9**) can be prevented by means of a flat plate A or angle section B as shown.

Figure 31 **Feeding material to a pair of rollers**



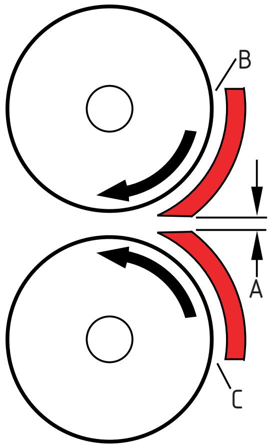
When material such as cardboard has to be fed to a pair of rollers, and a gap, B, is necessary to permit the free flow of the material, the relationship of distance, A, to gap, B, should be in accordance with BS EN ISO 13857 (see Annex A), so that a person cannot reach the intake. The dimension, C, varies with the size of the rollers. As the roller diameter increases, C needs to be increased.

Figure 32 **Small horizontal table, stiffened to prevent deflection, spanning the full width of a calender**



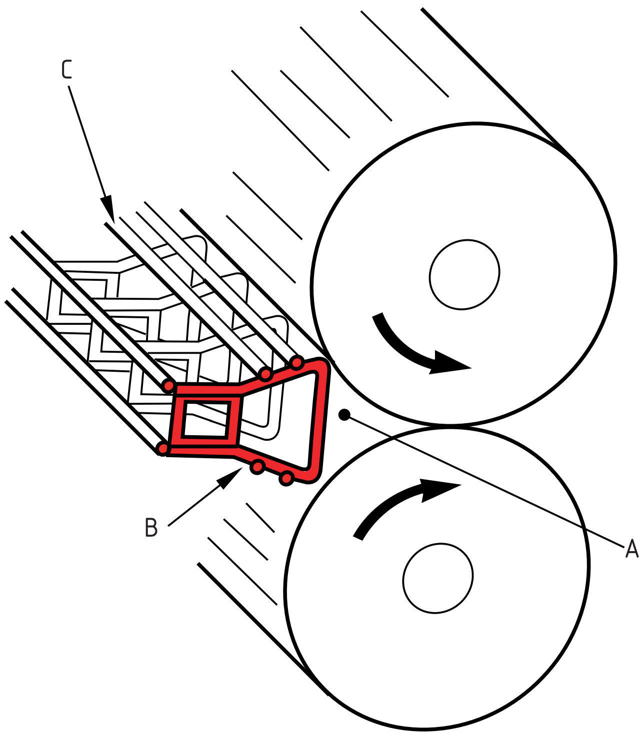
The angle bar, A, above the table, B, forms the guard, which should be set at the smallest distance above the table consistent with feeding the material through the narrow slot, C, and keeping the in-running nip (see **4.2.9**) inaccessible.

Figure 33 **Use of fixed curve metal plates to prevent access to in-running nips**



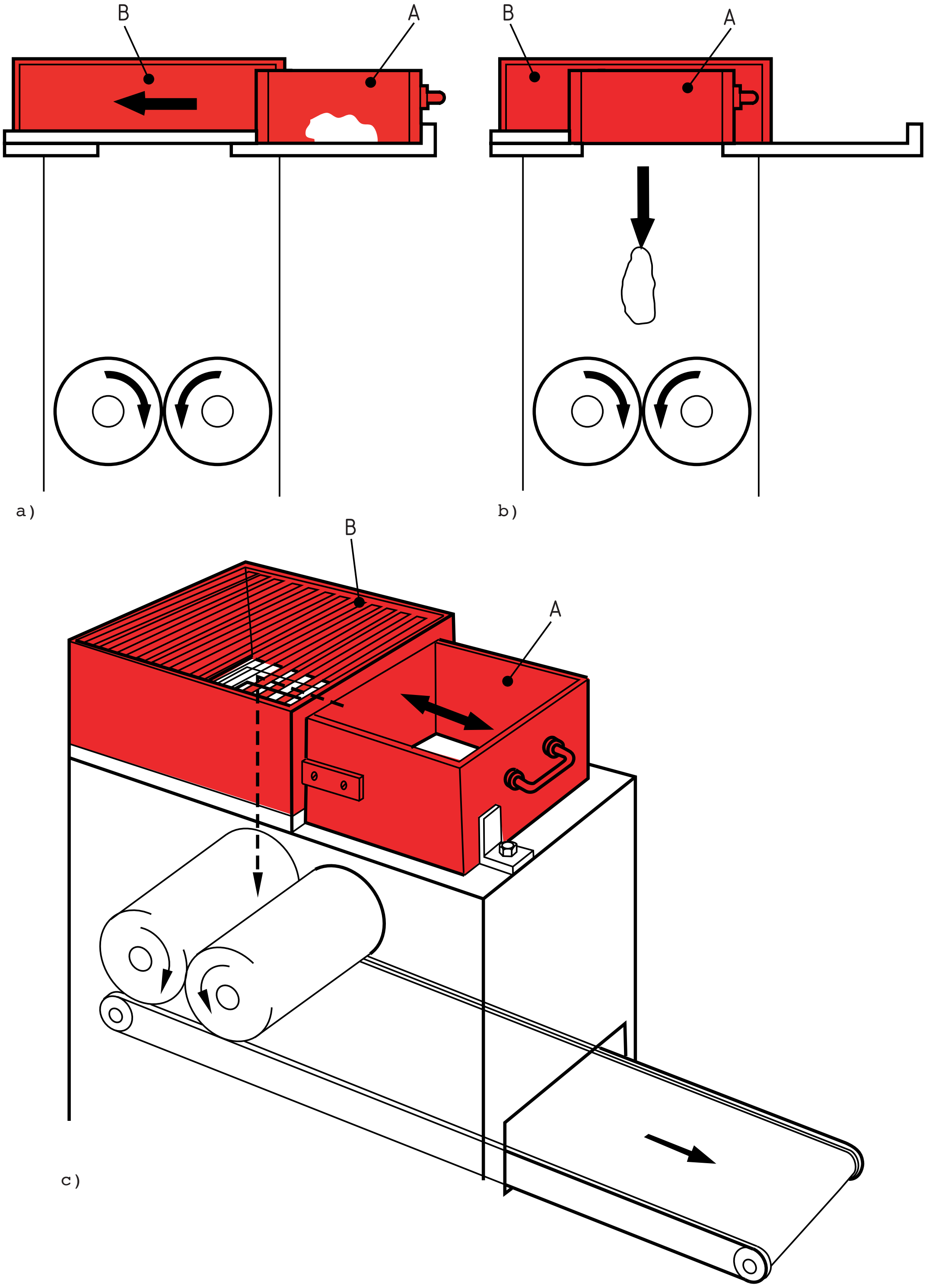
A guard consisting of two fixed curved metal plates provides a narrow gap, A, for feeding materials while effectively preventing access to the nip between the rolls (see **4.2.9**). The clearances at A, B and C, and at similar gaps shown in Figure 30 and Figure 31, should be small enough to prevent access.

Figure 34 **Fixed guard that allows continuous observation of the in-running nip point**



Access to the in-running nip at A is prevented by a fixed guard consisting of a number of closely spaced loops, B, which are connected by transverse rods, C. This type of guard permits clear visibility of the in-running nip.

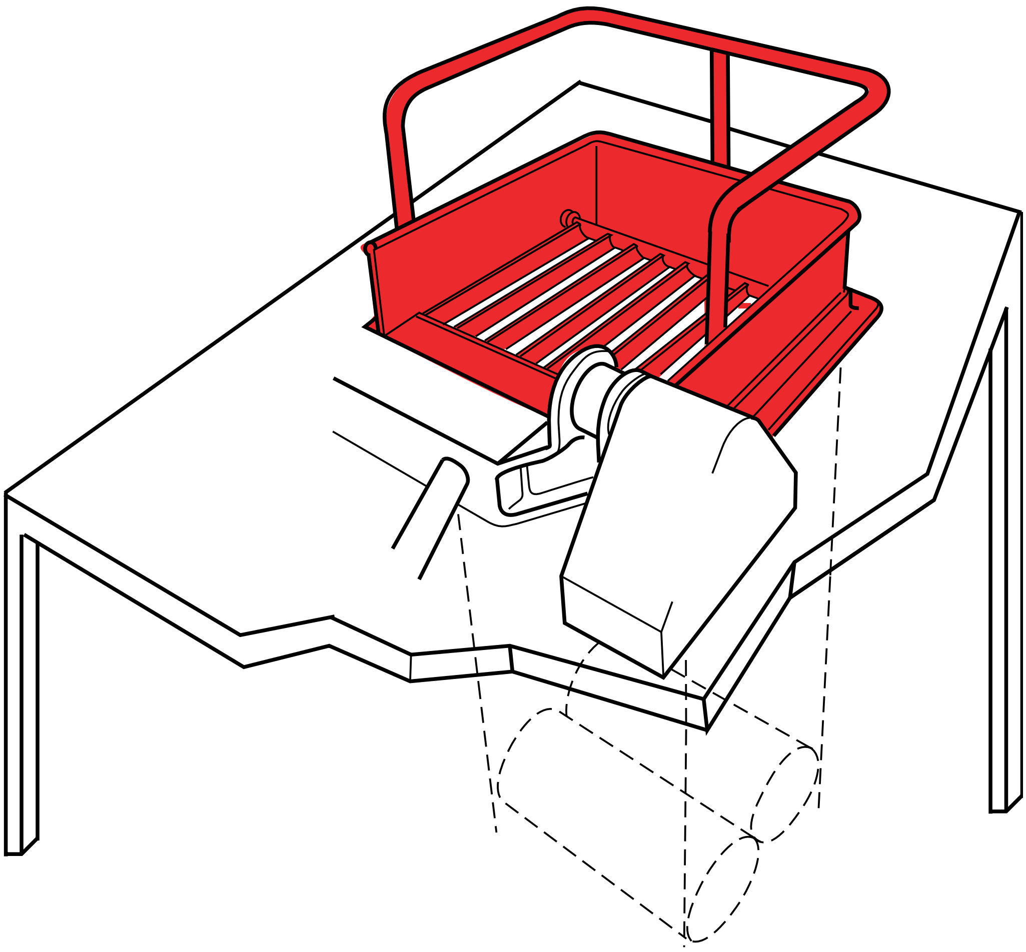
Figure 35 **Captive drawer**



The captive drawer, A, slides beneath fixed guard, B, mounted on top of the hopper. The material is loaded when the drawer is in position shown in a) and then falls onto the roll nip below by pushing the drawer into position as shown in b).

A typical trapped drawer system on a bun moulder is shown in c).

Figure 36 **Feeding of bulk material from the floor above the machine**



Where the layout of the plant permits, bulk material can be fed to a pair of in-running rolls or other hazardous parts within casings safely from the floor above the machine (see **4.2.9**). In the example illustrated, bulk material is fed through the grid into the machine below. The dimensions and spacing of the grid bars depend on the nature of the material being processed. For viscous material, the bars are so shaped that they cut the material and thereby assist the flow into the machine. If the grid has to be opened for cleaning, it should be interlocked with the power supply to the rolls. The grid bars should be positioned in accordance with BS EN ISO 13857 (see Annex A).

Figure 37 **Transparent tunnel guard with conveyor belt**

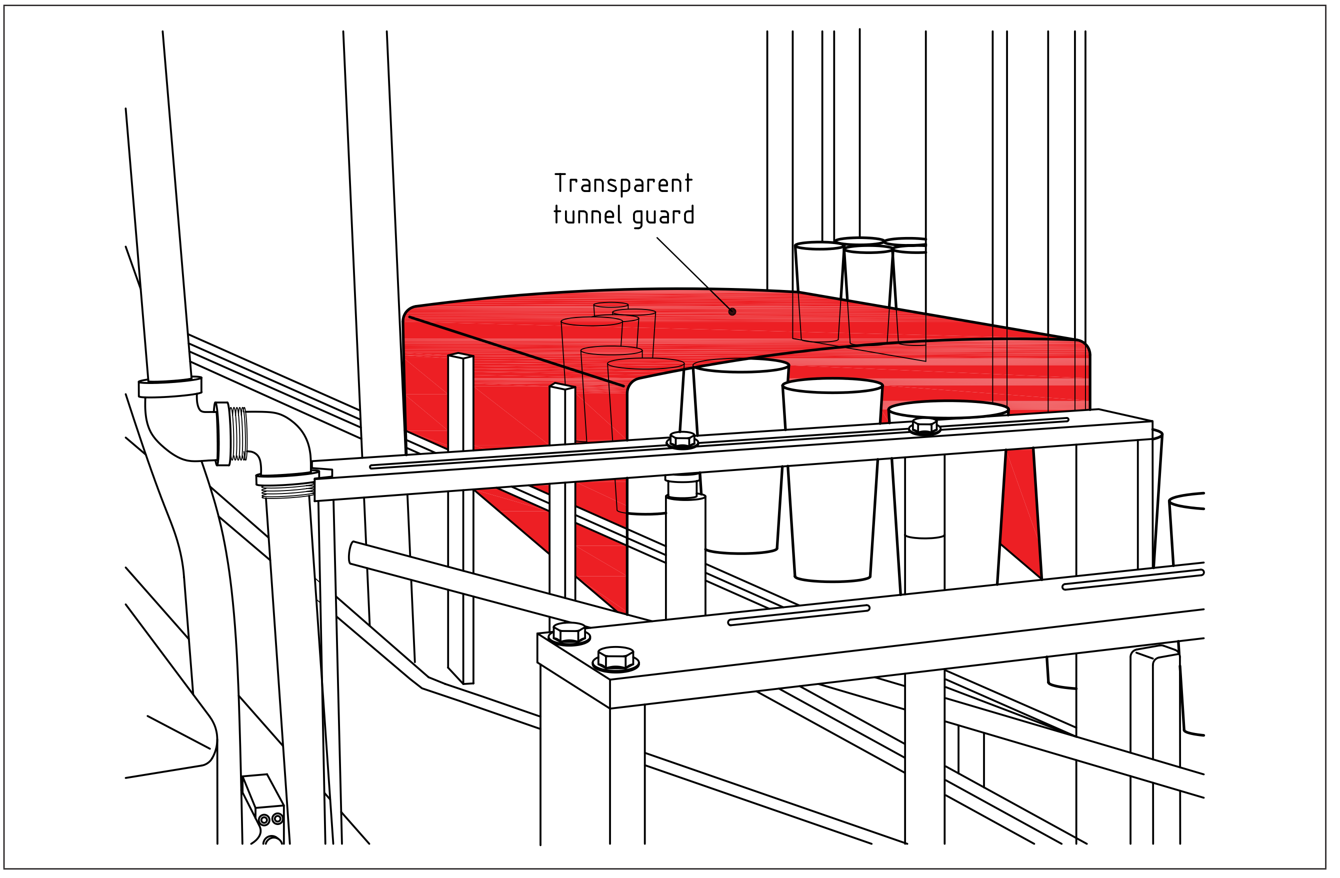
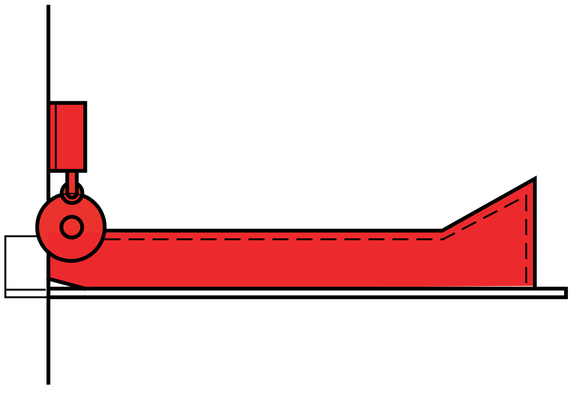
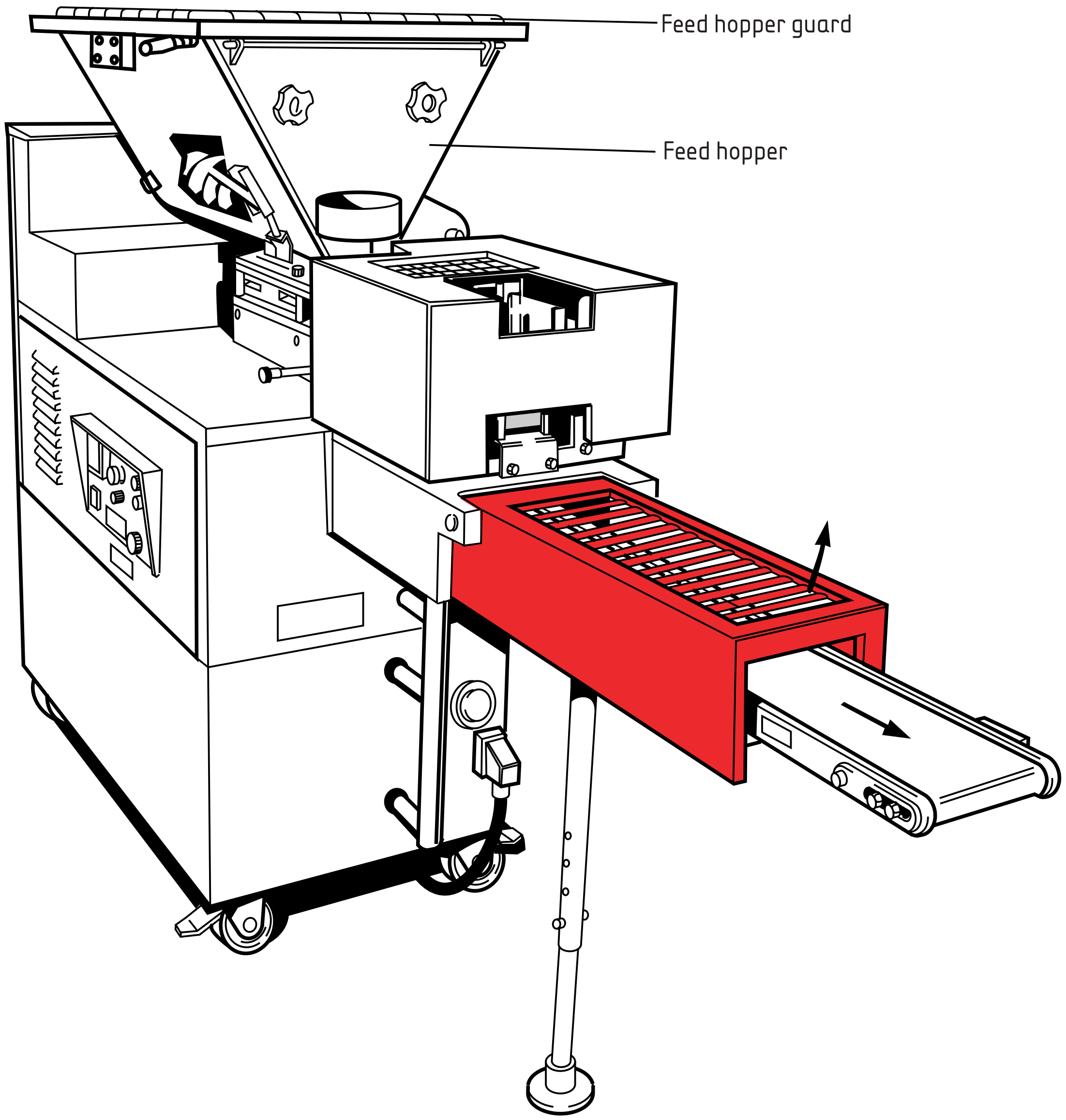


Figure 38 **Example of interlocked tunnel guard**



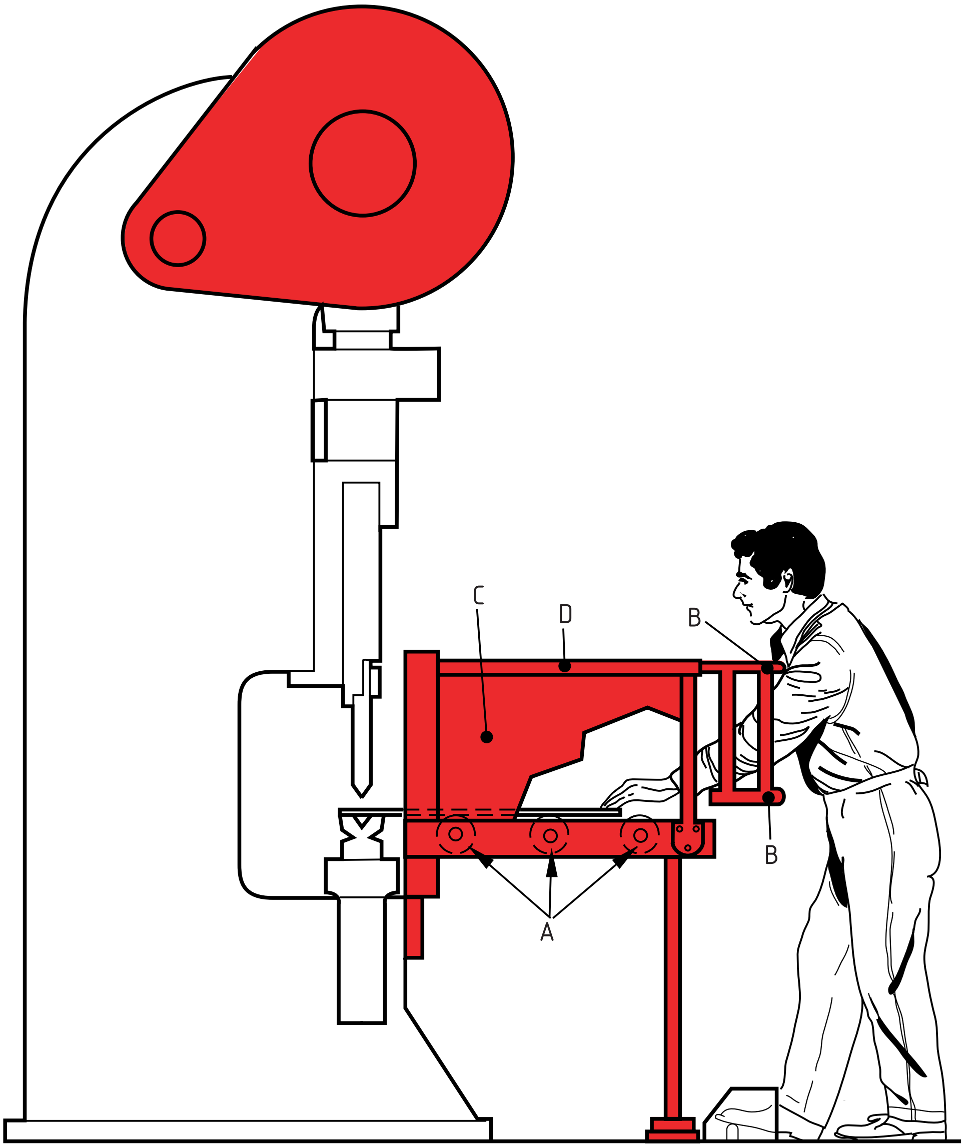
Where it is necessary for the passage of material to leave openings in the feeding and delivery sides of a machine, access for the operator to the hazard can be prevented by the use of a tunnel guard.

Figure 39 **Example of interlocking tunnel guard on food preparation machinery**



The passage of material can be assisted by using a conveyor as the base of the tunnel. The tunnel guard should either be bolted to the machine or, if arranged so as to hinge out of position for cleaning, interlocked so that the machine cannot be run unless the tunnel guard is in place (see Figure 38). The provision of bars or a vision panel in the top of the tunnel assists visibility. BS EN 1672-2 specifies requirements on food processing machinery hygiene.

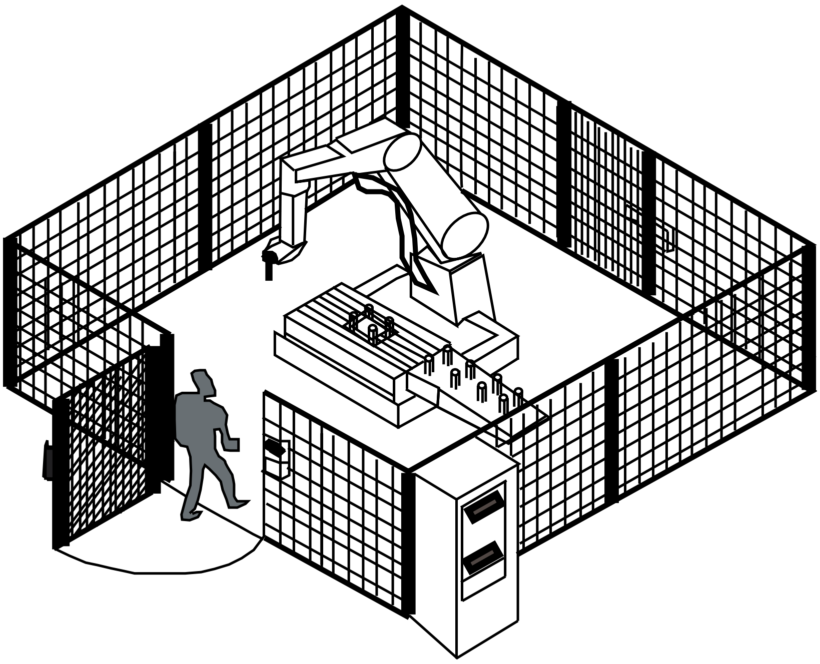
Figure 40 **Fixed distance guard fitted to a press brake**



The guard consists of a pair of side frames in the lower parts of which rollers A are fitted, together with a pair of tubular rails, B, running across the front of the machine and supported by the side frames. The position of the front frame is so arranged that fingers cannot reach the hazardous area. Safety details are given in BS EN ISO 13857 (see Annex A). The side frames are filled with solid guarding, C. The upper front rail can be made to telescope within the upper tubes, D, of the side frames so that the guard can be moved further from the dies to accommodate larger sheets. Rear and side guards are not fully shown in the illustration.

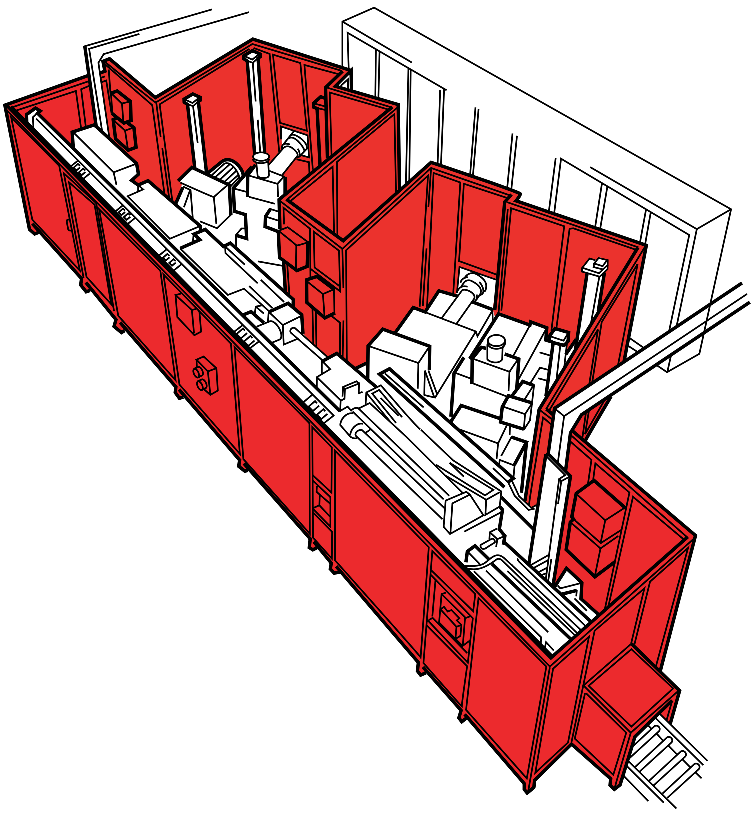
This type of guard is found on some older machines, but is no longer considered to be a suitable protective measure for this type of machine. Users, when relocating or considering change of use or reviewing the safety of such machines, should consider the feasibility of replacing such guards. For example, where the machine can be reliably and consistently stopped in a suitably short time at any point in its operating cycle, the arrangement shown in Figure 62 could be used.

Figure 41 **Example of guarding an industrial robot with a perimeter fence type guard**



The guard consists of fixed fencing and interlocked access gates. Additional safety measures might be needed to protect personnel within the guard (see **12.3.3.6**). See BS EN ISO 10218-2 for advice on the safety of industrial robots.

Figure 42 **Close contour perimeter fence guard**



The guard is in the form of a fence which follows the contours of the machinery, thereby limiting the space between the guard and the machinery.

7.2.2 Movable guard

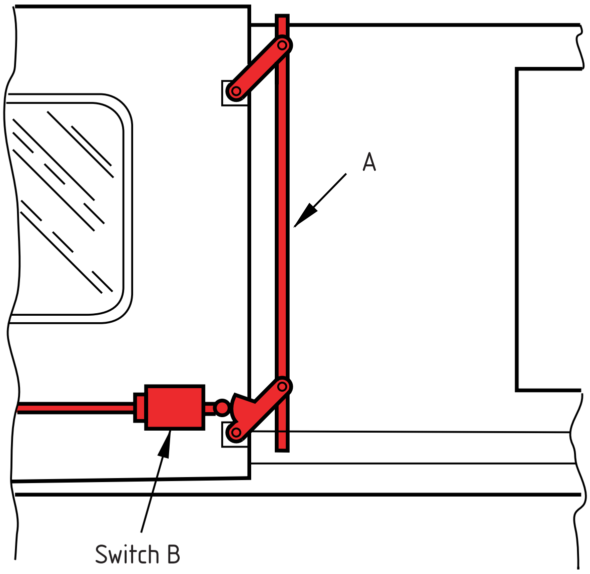
A movable guard is a guard which can be opened without the use of tools. It can be hinged, sliding or completely removable. Examples of movable guards are chuck guards or belt guards on manually-operated lathes and inspection hatches.

Movable guards, where practicable, should be interlocking guards (see **7.2.3**). The design of interlocked guards that are completely removable should ensure that the interlocking device cannot be actuated unless the guard is in its intended closed position.

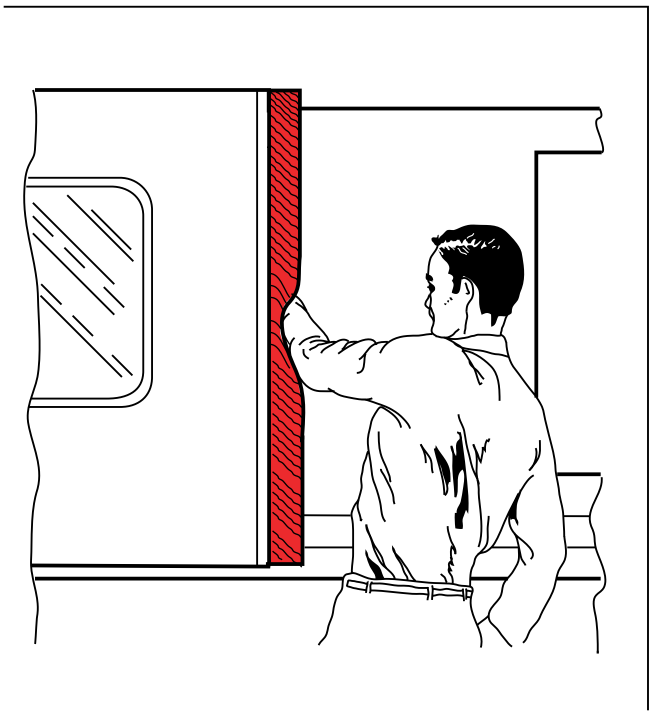
For power-driven movable guards steps should be taken to avoid harm arising from movement of the guard (see Figure 43).

Rise and fall guards which are capable of inflicting harm in the event of their falling under gravity should be provided with a suitable anti-fall device (see Figure 44 and Figure 45).

Figure 43 **Power-operated guards and doors**

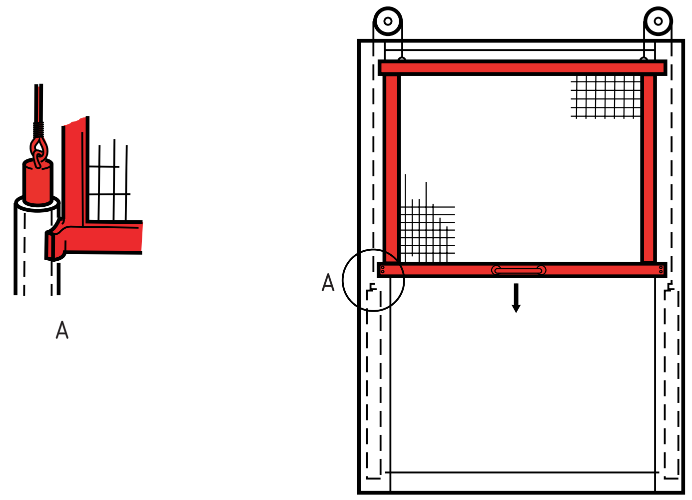


a) At large machines it can be necessary to use power-operated guards, but these can create a trapping hazard as they move towards a fixed part of the machine. A method of overcoming this is to fit a pressure-sensitive trip bar, A, to the leading edge of the guard as shown here. If the bar is obstructed by the operator, it is deflected about its pivots and operates a pneumatic valve or an electrical switch, B, so as to either stop or reverse the direction of movement of the guard. The free movement of the trip bar, A, has to be sufficient to prevent trapping due to overrun of the guard after the power to its drive has been interrupted by actuating the trip bar. The guard and trip bar should be designed so that a trap is not formed between the leading edge of the guard and the rear edge of the bar. Large guards should also be provided with buffers to absorb the impact at the ends of their movement or be arranged to decelerate in a controlled manner. Alternatively, a pressure-sensitive edge as shown in b) could be used.



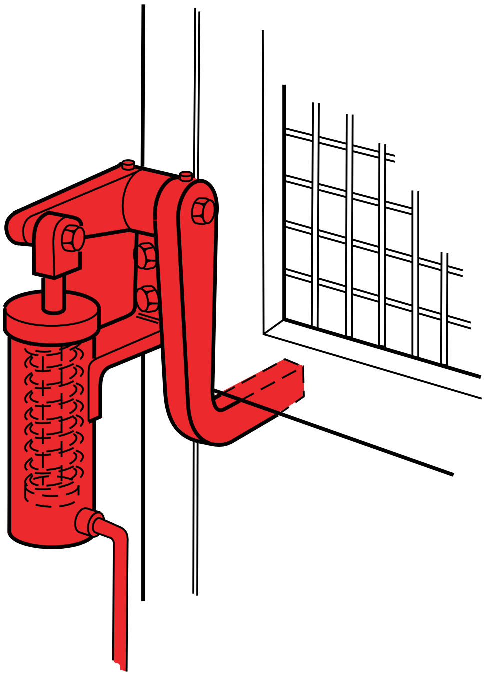
b) See BS EN ISO 13856-2 for information on pressure-sensitive edges and pressure-sensitive bars.

Figure 44 **Balance weights to reduce the effort required to open a rise and fall guard**



To ensure that the balance weights are not obstructed, they should be enclosed as shown.

Figure 45 **Latch (restraint) to protect against gravity fall of an air-operated guard which has no balance weight**



The hook is actuated by a single-acting spring return air cylinder, air pressure being used to disengage the hook, and the return spring to engage it.

7.2.3 Interlocking guard

7.2.3.1 General

An interlocking guard is a guard associated with an interlocking device, so that if the guard is opened while the hazardous machine functions are operating a stop command is given and maintained while the guard remains open (see Section 9).

An interlocking guard with guard locking is a guard associated with an interlocking device and a guard locking device, so that the guard remains closed and locked until the risk of injury from the hazardous machine functions has ceased.

NOTE The interlocking device and the guard locking device can be combined, as in a solenoid locking interlock switch, or separate, as in a trapped-key system that requires the transfer of a key from an isolator to a guard locking device.

An interlocking guard with start function (control guard, see **7.2.3.4**) and a sensing guard (see Figure 46) are particular forms of interlocking guard.

An interlocking guard should be configured so that:

a) the hazardous machine functions covered by the guard cannot operate until the guard is closed; and

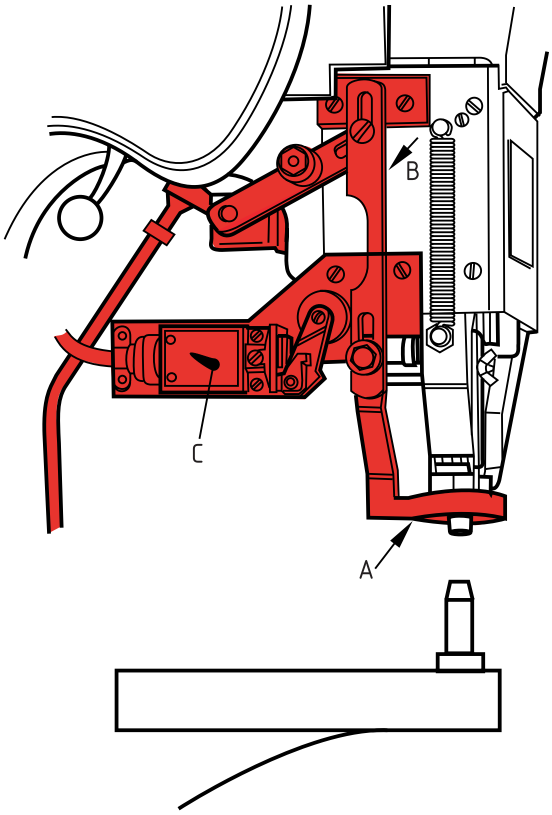
b) either the guard remains closed and locked until the risk of harm due to the hazardous machine functions covered by the guard has ceased or opening the guard causes the hazardous machine functions to cease before access is possible.

The interlocking system may be either mechanical, electrical, pneumatic, hydraulic or any combination of these. The type and mode of operation of the interlock should be considered in relation to the process to which it is applied (see Section 9). The interlocking system should be designed to minimize the risk of failure and the possibility of deliberate bypassing.

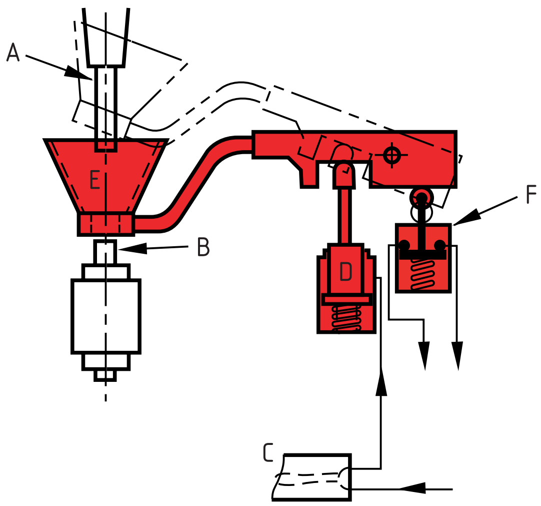
An interlocking guard for preventing access to hazardous area (in-running nip) is shown in Figure 47.

Interlocking considerations are covered in greater detail in Section 9 (see also Figure 73 to Figure 96).

Figure 46 **Sensing guard fitted to a riveting gun**

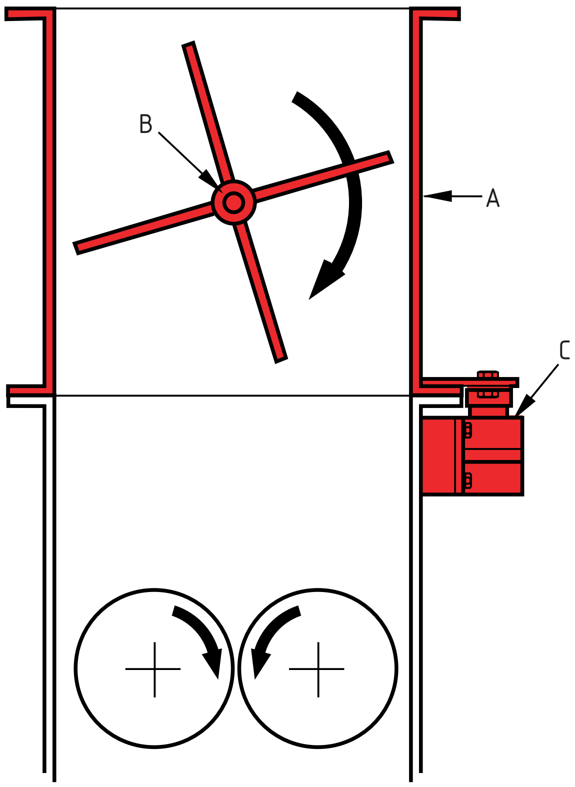


a) The guarding of a riveting machine presents a particular difficulty in that the operator has to hold the workpiece on the anvil while the tool descends. Complete enclosure by means of a fixed guard or a conventional interlocking guard is therefore usually impracticable. The illustration shows a guard consisting of a sensing ring, A, which surrounds the tool and which offers no obstruction, either physical or visual, to the operator while locating and holding the workpiece on the anvil. Depression of the operating pedal lowers the sensing guard to the working position, which is adjustable so that the lower edge of the guard is just clear of the workpiece. Provided the guard is not obstructed by the operator's fingers, as it descends, linear cam B allows position switch C to operate and a solenoid-operated clutch to engage and cause the tool to descend under power. If the sensing guard is obstructed by a finger, or otherwise fails to reach the preset position, the machine does not operate. In some sensing guards electrical control is replaced by either a mechanical linkage or a pneumatic system.



b) A indicates the rivet plunger and B the anvil. Depression of shrouded pedal C admits air to the piston, D, which allows sensing guard E to fall to its preset operating position. This allows the contacts in switch F to close and initiate a stroke of the rivet plunger. Any obstruction such as a finger interposed between the sensing guard, E, and the anvil prevents switch F from closing and the plunger, A, from descending.

Figure 47 **Example of interlock on a hopper extension**



The hopper extension, A, is provided with a magnetic switch, C, which automatically cuts off power to the rolls if the extension is removed for cleaning purposes (see also **4.3.11**). Supported within the hopper extension, A, is a free-rotating gate, B. Material loaded into the hopper extension falls on to the gate causing it to rotate and discharge the material into the nip below.

7.2.3.2 Interlocking enclosure guard

An interlocking enclosure guard is an interlocking guard which, when in position, prevents access to a hazard or hazardous area by enclosure. The recommendations for feeding work through the guard and for tunnel openings given in **7.2.1.2** apply.

7.2.3.3 Interlocking distance guard

An interlocking distance guard is an interlocking guard which does not completely enclose a hazardous area but reduces access by its physical dimensions and its distance from the hazardous area, e.g. an interlocking access gate or a removable section in a perimeter fence type guard (see also **12.3.3.6**).

An interlocking distance guard can be in the form of a barrier located at a safe distance from the nearest hazard point. The barrier itself can take a variety of forms. Initial movement of the barrier actuates the stopping mechanism of the machine. The means employed could be mechanical, electric, pneumatic or hydraulic (see Figure 56 and Figure 58).

7.2.3.4 Interlocking guard with a start function (control guard)

A control guard is a special form of interlocking guard which, once it has reached its closed position, gives a command to initiate the hazardous machine function(s) without the use of a separate start control, and which interfaces with the machinery controls so that:

a) the hazardous machine functions covered by the guard cannot operate until the guard is closed;

b) the act of closing the guard initiates operation of the machinery; and

c) the guard is locked closed during hazardous operation.

Such a guard (see BS EN ISO 12100:2010, **6.3.3.2.5**) should only be used when:

1) the machinery cycle is of short duration such as with a small pneumatic or hydraulic press;

2) the maximum guard open time is set to a low value (for example, equal to the machine cycle time), after which the hazardous functions cannot be initiated by closing the guard and resetting is needed before the machine can be restarted;

3) the dimensions or shape of the machine do not allow a person, or part of a person, to stay in the hazardous area or between the hazardous area and the guard while the guard is closed (see BS EN 953);

4) all other guards, whether fixed (removable type) or movable, are interlocking guards;

5) the associated interlocking device is arranged (by, for example, use of redundancy, monitoring, diversity), so that the probability of a failure within it leading to an unintended/unexpected start-up is sufficiently low; or

6) the guard when open is prevented from closing (for example, by use of springs or counterweights) and hence initiating an unintended/unexpected start-up.

7.2.4 Push-away guard

A push-away guard is found on some older machines, but is no longer considered to be a suitable protective measure. When relocating, changing the use or reviewing the safety of such machines, users should replace these guards.

This type of guard is moved into position by the machine, thereby removing any part of a person from the hazardous area. In some applications this type of guard is known as a "sweep away guard".

A push-away guard operates by physically removing from the hazardous area any part of a person exposed to a hazard. It should only be used where there is adequate time and space for such removal to take place without introducing any further hazard.

The guard should be securely fastened to the machinery so that it cannot be adjusted or detached without the aid of tools.

7.2.5 Adjustable guard (see Figure 48, Figure 49 and Figure 50)

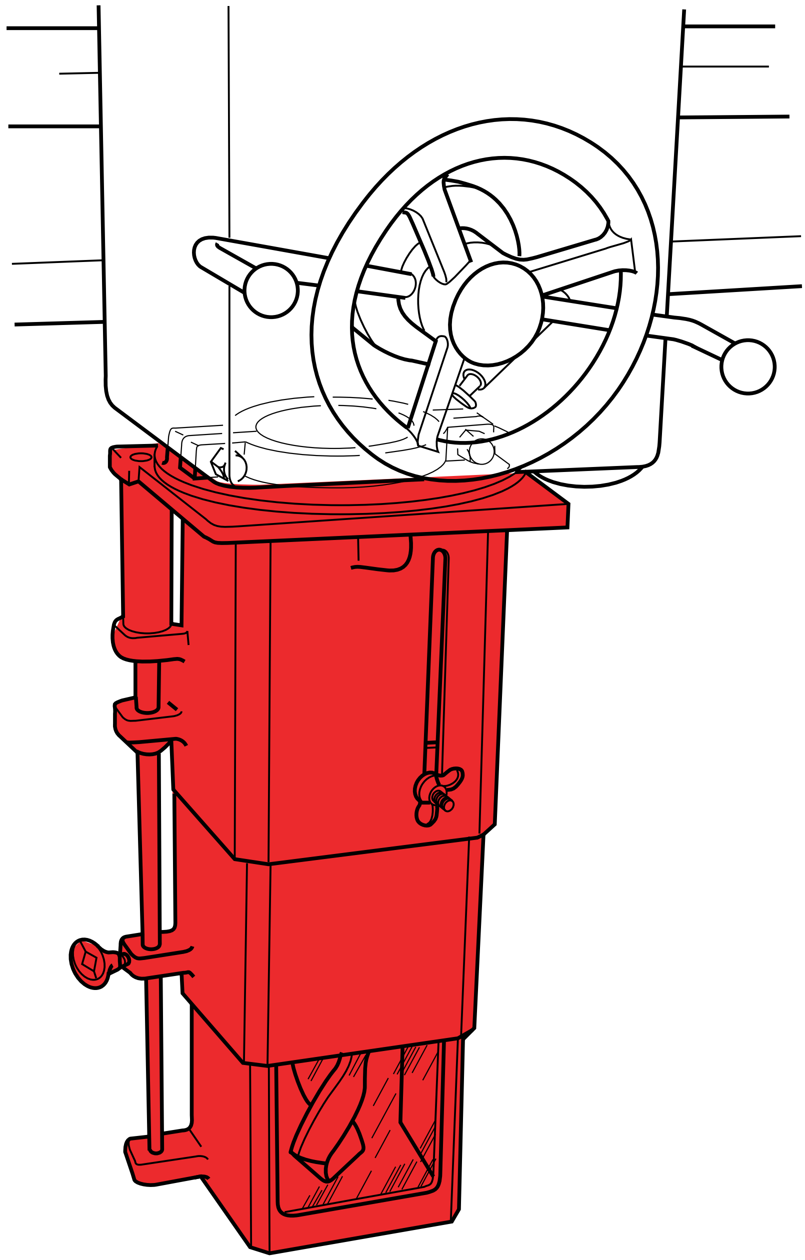
An adjustable guard is a fixed or movable guard which is adjustable as a whole or which incorporates an adjustable part or parts. The adjustment remains fixed during a particular operation.

Where it is impracticable to prevent access to the hazardous parts because they are unavoidably exposed during use, for example, the cutters on milling machines and the cutters of some woodworking machines, an adjustable guard may be used in conjunction with other closely supervised conditions, for example, a sound floor, good lighting and adequate training of the operator.

An adjustable guard provides an opening to the machinery through which material can be fed, the whole guard or part of it being capable of adjustment in order that the opening can be varied in height and width to suit the dimension of the workpiece in hand. It is essential in such cases that the adjustment is carefully carried out by a suitably trained person (see Section 12). Regular maintenance of the fixing arrangements is necessary to ensure that the adjustable element of the guard remains firmly in place when once positioned. The guard ought to be designed so that the adjustable parts cannot easily become detached and mislaid.

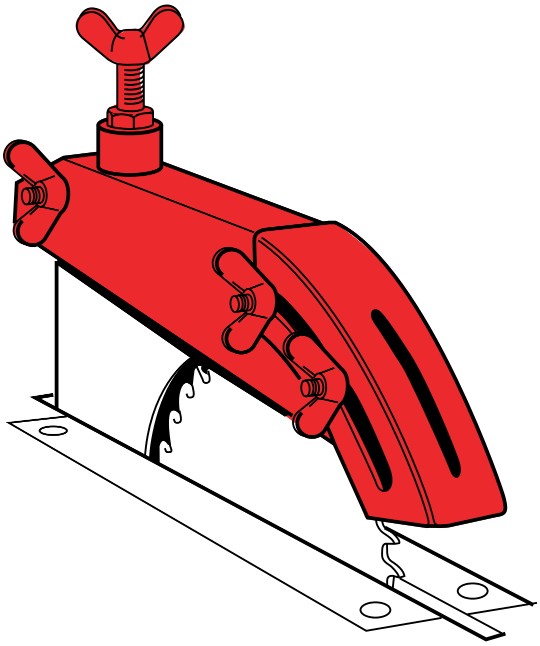
Consideration should be given to the use of feeding and take-off devices, jigs and fixtures when this type of guard is used.

Figure 48 **Adjustable guard for a radial or pedestal drilling machine**



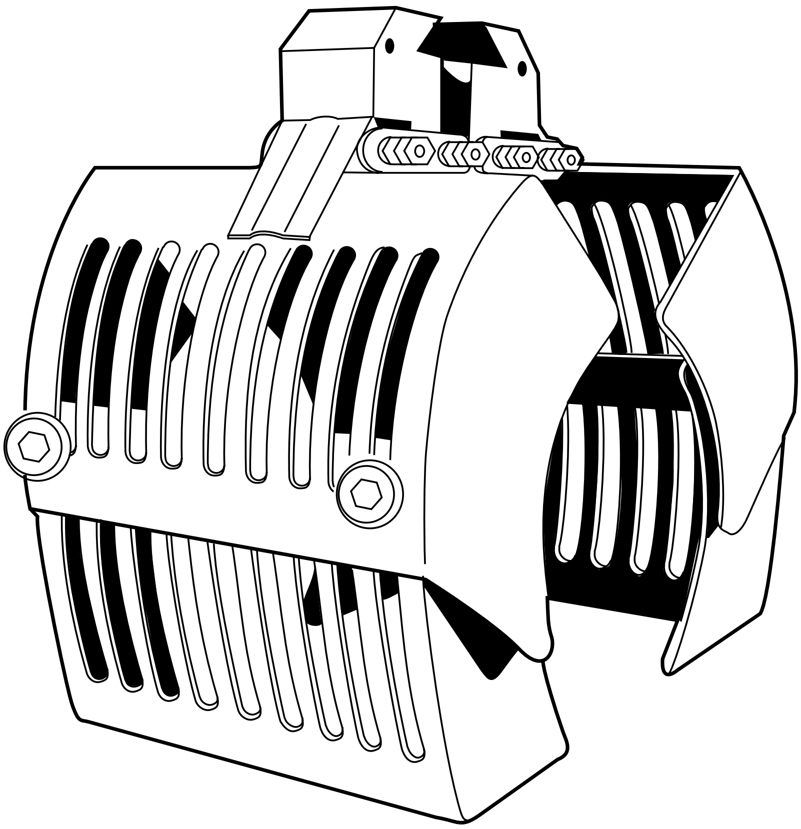
The guard is telescopic to provide ready adjustment to the surface of the workpiece and is attached to a vertical hinge to permit access to the spindle for drill changing.

Figure 49 **Adjustable guard on a circular sawing machine**



A groove in the extension piece indicates the line of cut.

Figure 50 **Adjustable guard for the cutters of horizontal milling machines**



The guard, which is clamped to the arbour support, has a wide range of adjustment to suit cutters of different diameters. Slots provide adequate visibility of the cutter and allow the application of coolant.

When used in conjunction with a false table (see **7.2.7**), the guard affords a high standard of protection.

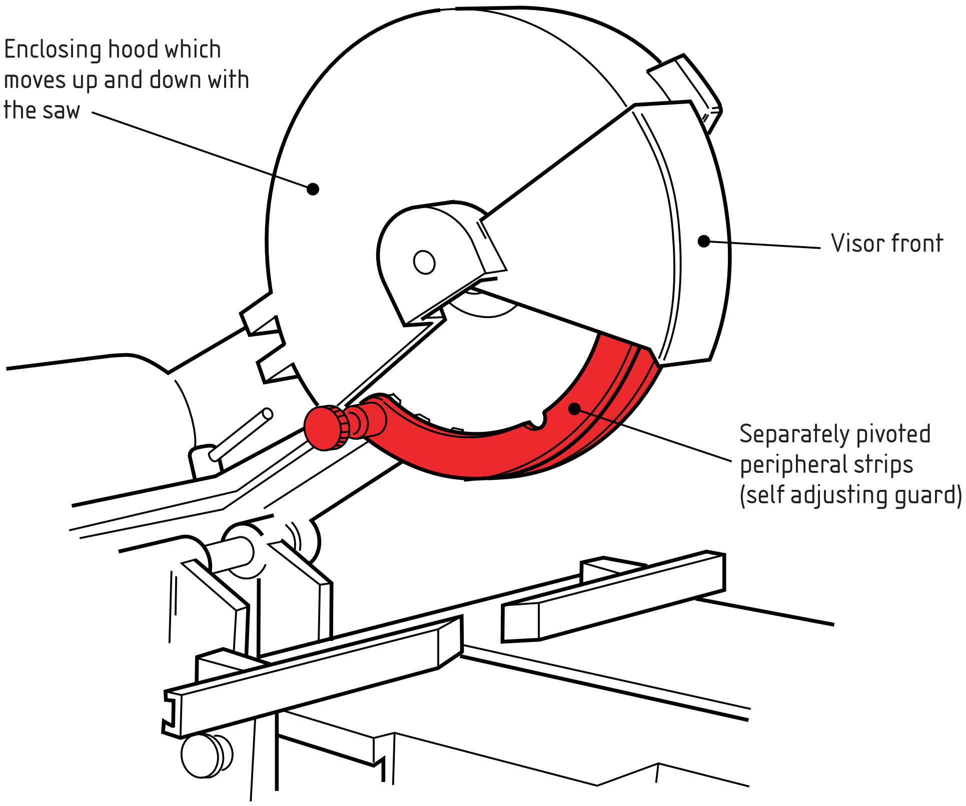
7.2.6 Self-adjusting guard

A self-adjusting guard is a fixed or movable guard which, either in whole or in part, adjusts itself to accommodate the passage of material, etc. (see Figure 51).

This type of protection is designed to prevent access to the hazardous part(s) until actuated by the movement of the workpiece, that is, it is opened by the passage of the workpiece at the beginning of the operation and closes automatically (by means of gravity, a spring or other external power) on completion of the operation.

Consideration should be given to the use of feeding and take-off devices, jigs and fixtures when this type of guard is used.

Figure 51 **Self-adjusting guard arrangements for snipper cross-cut sawing machine**



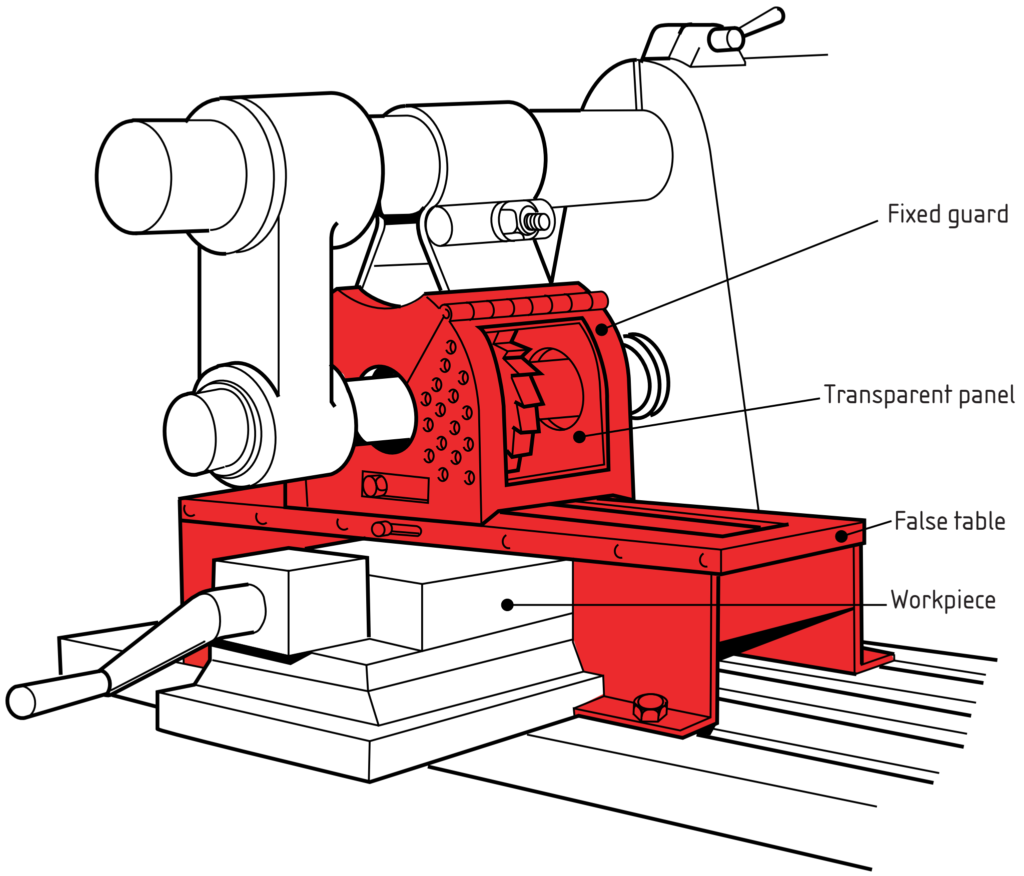
The guard is lifted by the workpiece as the saw is lowered and rests on top of the material throughout the cut. It falls back automatically by means of gravity or a spring, when the saw is raised.

7.2.7 False table (see Figure 52 and Figure 53)

A particular difficulty in preventing access to hazardous parts of machinery arises when a power-operated feed table, which could have either traversing or rotary motion, carries material to the operating point of the machine. A guard provided in front of the operating point has to leave an opening for the material to pass through, which presents the risks of a person gaining access to the hazardous area or being trapped between the material or work holder and the edge of the opening as the feed table moves forward.

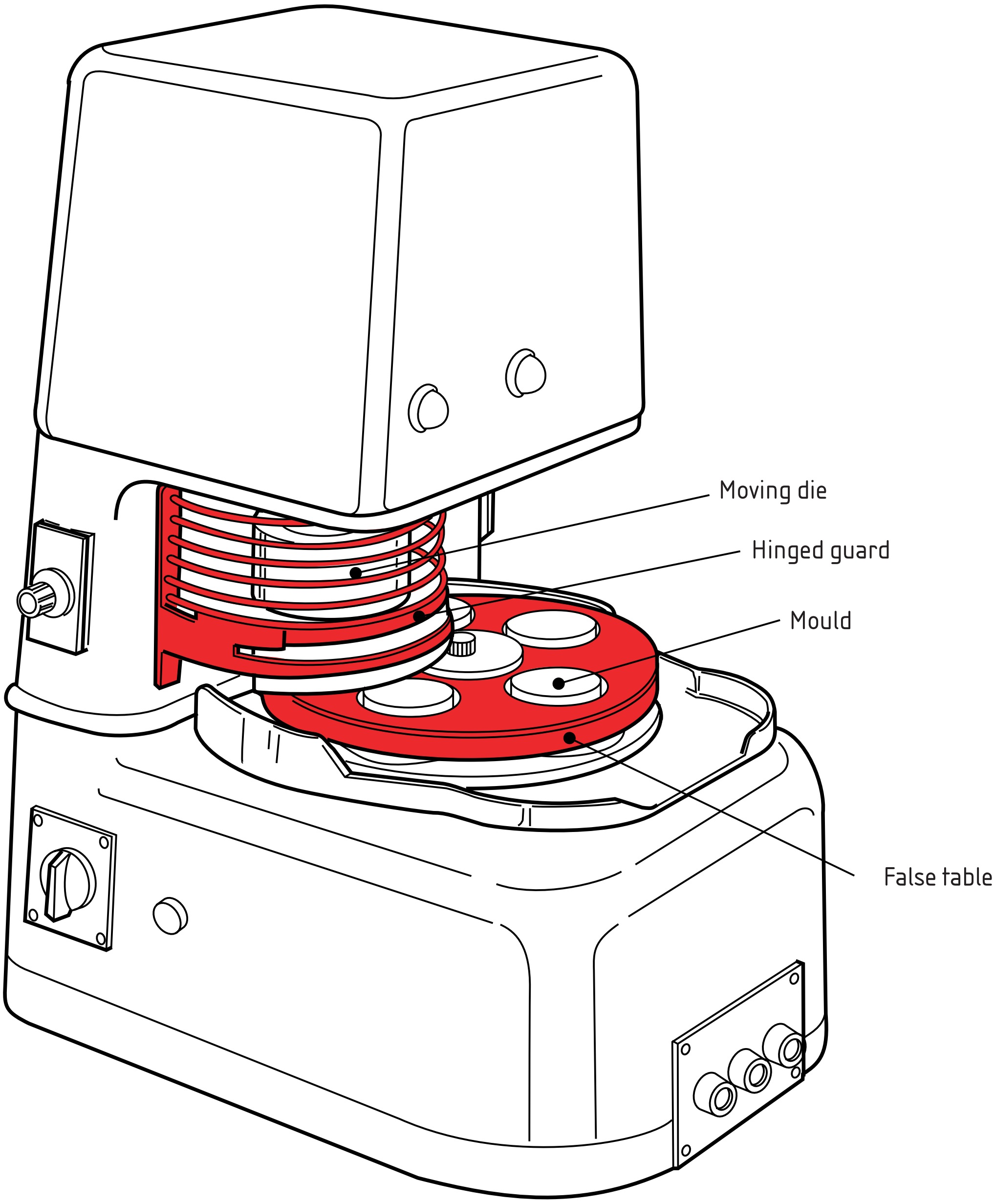
The use of a false table has the effect of filling the spaces between the workpieces on a rotary feed table, or, in the case of a single workpiece mounted on a traversing table, filling the space between the workpiece and the extremity of its travel through the guard. By means of a false table, therefore, the opening in the guard remains blanked off while the machine is in operation.

Figure 52 **False table and fixed guard applied to a milling machine**



The false table is supported on the traversing table and is shaped so that the component can be readily clamped in the vice well away from the cutter, access to which is prevented by a fixed guard. A transparent panel in the guard permits observation of the milling operation and the gaps beneath the false table permit clearance of swarf.

Figure 53 **False table and interlocking guard applied to a rotating table pie and tart machine**



The false table fills the gaps between the moulds, preventing access to the trap between the die and mould from beneath the hinged interlocking guard. This guard should also be designed to act as a trip device. This prevents injury by stopping the machine if the operator gets caught between the mould and the guard.

7.3 Guard construction

7.3.1 General

The construction of fixed and movable guards should be in accordance with BS EN 953.

Any guard selected should not itself present a hazard, such as trapping or shear points, rough or sharp edges, or other hazards likely to cause injury.

Guard mountings should be compatible with the strength and duty of the guard.

Power-operated guards should be designed and constructed so that a hazard is not created (see Figure 43).

7.3.2 Material

7.3.2.1 General

In selecting the material to be used for the construction of a guard, consideration should be given to the following.

a) Its ability to withstand the force of ejection of part of the machinery or material being processed, where this is a foreseeable hazard.

b) Its ability to provide protection against hazards identified (see Section 4). In many cases, the guard can fulfil a combination of functions, such as prevention of access and containment of hazards. This could apply where the hazards include ejected particles, liquids, dust, fumes, radiation, noise, etc., and one or more of these considerations can govern the selection of guard materials.

c) Its weight and size in relation to the need to remove and replace it for routine maintenance.

d) Its compatibility with the material being processed. This is particularly important in the food processing industry where the guard material should not constitute a source of contamination of the product. BS EN 1672-2 specifies the basic concepts for the hygiene requirements of food processing machinery.

e) Its ability to maintain its physical and mechanical properties after coming into contact with potential contaminants, such as cutting fluids used in machining operations or cleaning and sterilizing agents used in food processing machinery.

7.3.2.2 Solid sheet metal

Metal has the advantages of strength and rigidity, and in solid sheet form is particularly suitable for guarding transmission systems and machinery at which adjustments are rarely needed and where there is no advantage in being able to see the working parts. However, care should be taken to ensure that, where necessary, sufficient ventilation is provided in the guard to prevent machinery overheating and that the guard does not create resonance.

7.3.2.3 Metal rod-type materials

Guards of metal rod-type materials are used in applications where, for example, observation of the operation and the spraying of lubricants or other fluids is required. They are also used where material needs to be fed, at different levels, through the guards.

7.3.2.4 Perforated and mesh material

Guards can be manufactured from perforated metal, woven mesh, welded wire, metal lattice and other similar materials, all of which enable some sight of the working parts and are unlikely to cause overheating. However, they are unlikely to be suitable where hygiene (see **5.21**) or the ejection of material are considerations. The perforation of the mesh should be such that fingers cannot reach the hazard. If there are reasons for openings which would permit the entry of fingers, the distance of the guard from the hazard should be sufficient to prevent contact (see **7.4.2**, BS EN ISO 13857 and Annex A for information on safety distances).

7.3.2.5 Glass

Ordinary glass is unsuitable for guard manufacture due to its brittleness, but where an operation is required to be observed and the material is likely to be exposed to high temperatures or abrasive action [see **7.3.2.6**c)], safety glass could be suitable. Though intended for buildings, BS EN ISO 12543 (all parts) provides useful information on laminated glass.

7.3.2.6 Plastics

Transparent plastics sheet materials may be used in guarding as an alternative to sheet metal, rods or mesh. These materials are particularly suitable where observation is required during the operation of machinery.

Plastics materials available for guarding purposes include polycarbonate, polyvinyl chloride (PVC), cellulose acetate and acrylic sheet.

The mechanical properties of most plastics can be adversely affected by contamination, such as can be found in cutting fluids or cleaning and sterilizing agents, by incorrect cold working and by continuous exposure to high temperatures. The material suppliers should be consulted to ensure that the material chosen is compatible with the intended application. The guard should then be checked and/or replaced at suitable intervals (see HSE Guidance [11]). Among the points to be considered are the following.

a) Plastics have differing impact strengths. When considering materials of equal thickness, polycarbonate and a type of modified PVC are the strongest, followed in descending order by rigid PVC, cellulose acetate and acrylic sheet. However, polycarbonate is more notch sensitive than some acrylics. Therefore, when all aspects of the application have been discussed with the supplier, it might be necessary to increase the thickness of the chosen material in order to achieve an acceptable impact strength.

b) Guards can be made from plastics sheet by fabrication (solvent welding), vacuum forming, heat application techniques or by mounting panels of the material in a suitable framework. Unless these processes are carried out in accordance with the instructions from the material supplier, the mechanical properties are likely to deteriorate considerably. When rivets or screws are used to secure the panels, care should be taken to ensure that the radial stresses induced are not sufficient to crack the material. Such panels should not be fitted without a method of clamping which provides sufficient area to prevent the panel(s) ejecting under stress.

c) Continuous exposure to high temperature (polycarbonate 135 °C, acrylic sheet 90 °C, cellulose acetate 70 °C, PVC 60 °C) causes softening and consequent lowering of impact strength.

d) The transparency of plastics is likely to reduce with use due to scratching, although remedial action using polishing compounds might be practicable in some cases.

   NOTE Although there are known exceptions, in general the greater resistance a material has to scratching the lower its resistance to impact.

e) Most plastics have an ability to hold an electrostatic charge, which can create a risk of electrostatic ignition of flammable materials and can also attract dust. This characteristic can be mitigated by the use of an anti-static preparation.

7.3.2.7 Other materials

Timber is sometimes suitable for guard construction and is frequently employed in the woodworking industry. Where flexibility is required, chain mail, leather, rubber or flexible plastics may be used.

7.3.3 Supports

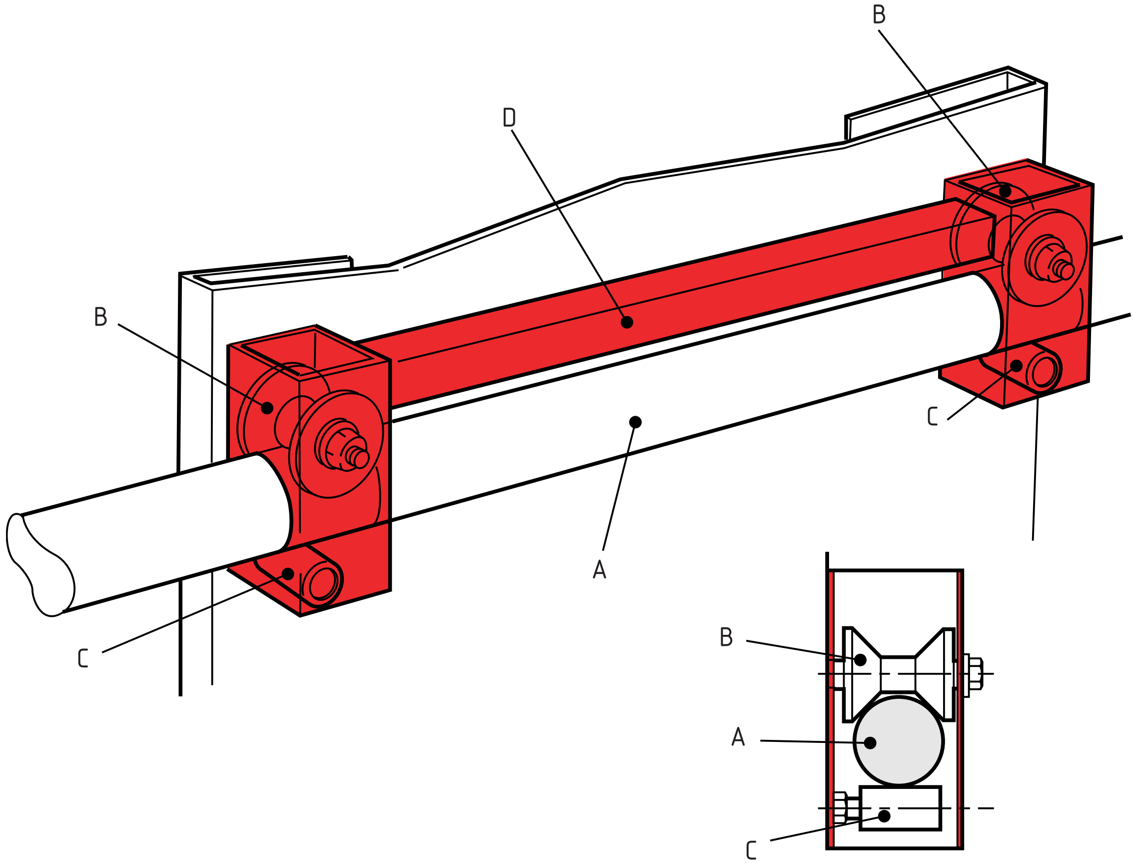
Guards may be fastened to independent supports or to the machinery itself. The number and spacing of the fixing points should be adequate to ensure stability and rigidity of the guard.

Where necessary, there should be clearance under the guard for cleaning spillage, swarf, etc., provided this clearance does not allow access to the hazardous parts.

Gaps between guards or between guards and supports should not exceed those given in BS EN ISO 13857.

A support for a horizontally sliding guard is shown in Figure 54.

Figure 54 **Support for a horizontally sliding guard**



Many accidents have been caused by the misalignment or failure of guard support rollers and tracks. The illustration shows a robust and efficient method of supporting and guiding a horizontally sliding guard. Track A is circular in cross section and the rollers, B, sit on the track as shown in the inset. This arrangement provides lateral as well as vertical support for the guard. A cylindrical roller, C, under the track retains rollers B in contact with track A and the roller housings are connected by angle section D.

7.3.4 Cover plates

Removable panels or cover plates may be incorporated into guards to provide easy access or improve visibility. They should be treated as part of the guarding system and considered as either fixed or interlocking guards depending upon the process requirement (see **7.2.1** and **7.2.2**).

Some removable panels, etc., which contain processes might not contain or prevent access to any hazards. In such cases the rules for securing and/or interlocking might not apply. Examples include tray wash and cooling in the food industry.

7.4 Anthropometric considerations

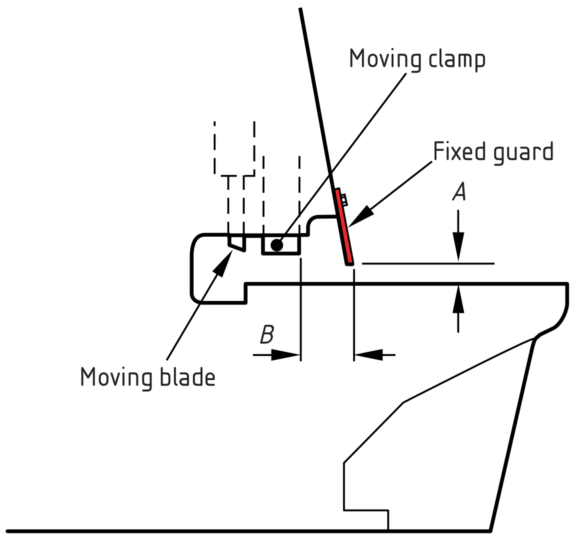
7.4.1 General

Guards ought to be designed and constructed with the object of preventing any part of a person's body from reaching a hazardous area. They should take account of the physical characteristics of the people involved [see BS EN 547 (all parts)], particularly their abilities to reach through openings, and over or around barriers or guards (see BS EN ISO 13857 and ISO 13854).

7.4.2 Openings in a guard

Where it is necessary to provide an opening in a guard, it should be at a sufficient distance to prevent any person from reaching the hazard. This could be achieved by positioning the guard at the required distance or by providing a tunnel which extends outwards from it (see **7.2.1.3**, Figure 37, Figure 38 and Figure 39). The effectiveness of a guard with an opening should be judged by a reach test carried out with the machinery at rest and in a safe condition. The relationship between the size of the guard opening and the distance of the opening from the hazard is illustrated in BS EN ISO 13857 (see Annex A and Figure 55). Access through a guard opening can often be prevented by the use of a false Table (see **7.2.7**, Figure 52 and Figure 53).

Figure 55 **Opening in a fixed guard at a metal cutting guillotine**



The relationship between the opening, A, between the guard and the blade and the minimum distance, B, of the guard from the nearest hazardous part, in this case the moving clamp, should conform to the dimensions specified in BS EN ISO 13857 (see also Annex A). Access to the rear and sides of the moving blade should be prevented by further fixed guards, which are not shown.

7.4.3 Barriers

Where it is not practicable to use enclosing guards, barriers may be used to prevent people reaching the hazardous area. These rely on a combination of height and distance to achieve their purpose. A height of 1.8 m is recommended for perimeter fencing. For specific applications refer to BS EN ISO 13857 (see also Annex A).

Section 8: Protective devices

NOTE Interlocking is dealt with in Section 9 and control systems in Section 10.

8.1 Trip devices (see Figure 56 to Figure 61)

8.1.1 General

A trip device causes machinery to stop or assume an otherwise safe condition in order to prevent harm when a person approaches a hazard or hazardous area beyond a safe limit. It also keeps the machine in this condition while the person remains within the hazardous area unless other means of fulfilling this presence-sensing function are provided (see **5.6**).

A trip device should be designed to ensure that an approach to a hazard or hazardous area beyond a safe limit causes the hazardous part(s) to cease operation before harm can occur (see BS EN ISO 13855). The sensitive trip bar fitted to radial drilling machines (see Figure 61) does not exactly fit this description, but when operated on minimal deflection and properly adjusted, it prevents serious injury. The effective performance of a trip device depends on the stopping characteristics of the machinery, which might change with, for example, age, type of use or level of maintenance. A brake might be necessary.

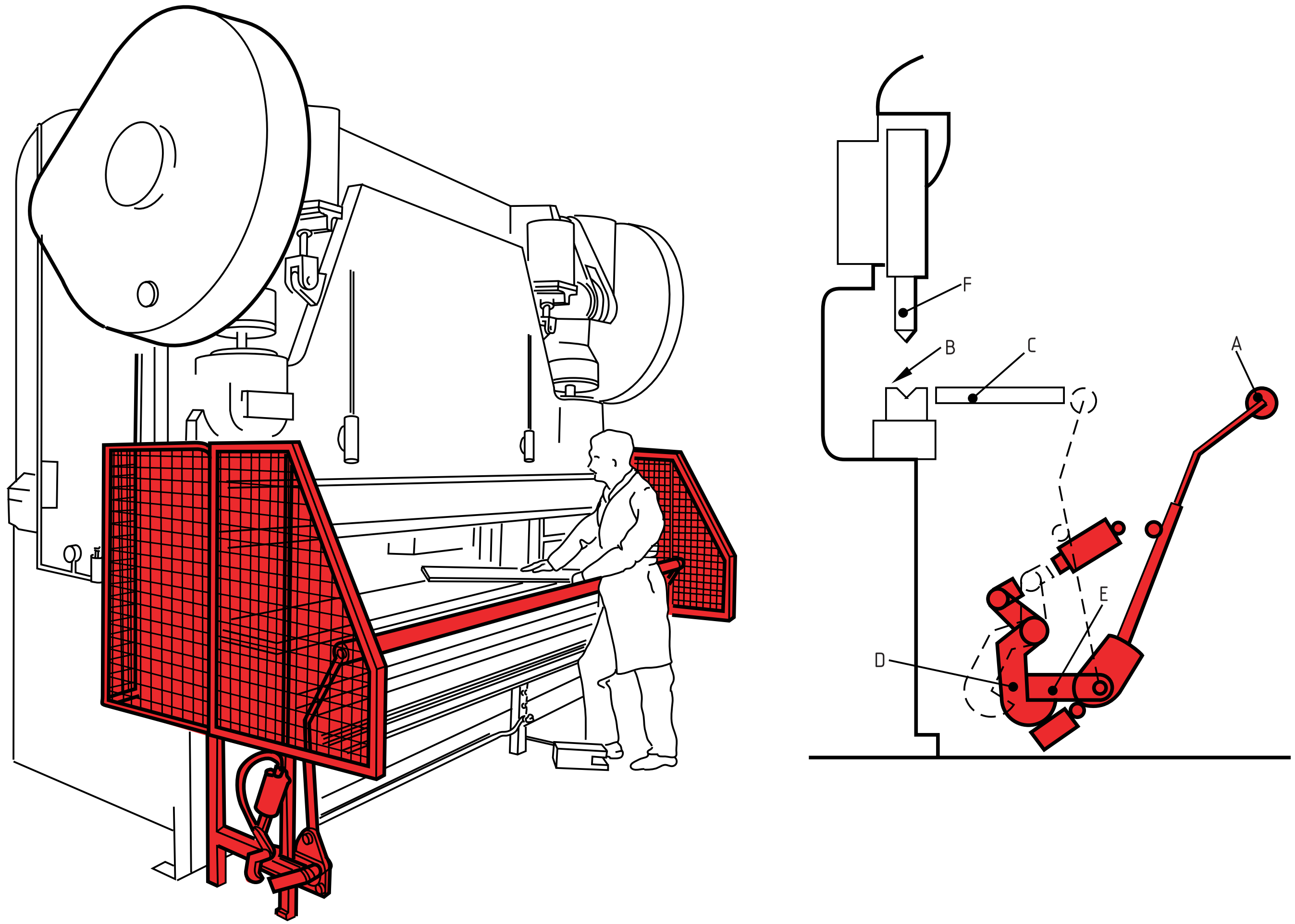
A trip device should be designed so that after it has been operated it is reset automatically or manually; restarting should then be by means of the normal start button. An electrical or electronic trip device should be designed so that its effective operation is not impaired by any function of the machinery or by extraneous influences.

A trip device is not suitable for machinery that cannot be stopped part way through a cycle of operation, for example, a full revolution mechanical power press.

8.1.2 Mechanical trip device

The essential element of a mechanical trip device is an actuator, e.g. trip bar, which is moved by part of the body as it approaches a hazardous area. This movement operates the device which can be electrical, mechanical, pneumatic or hydraulic.

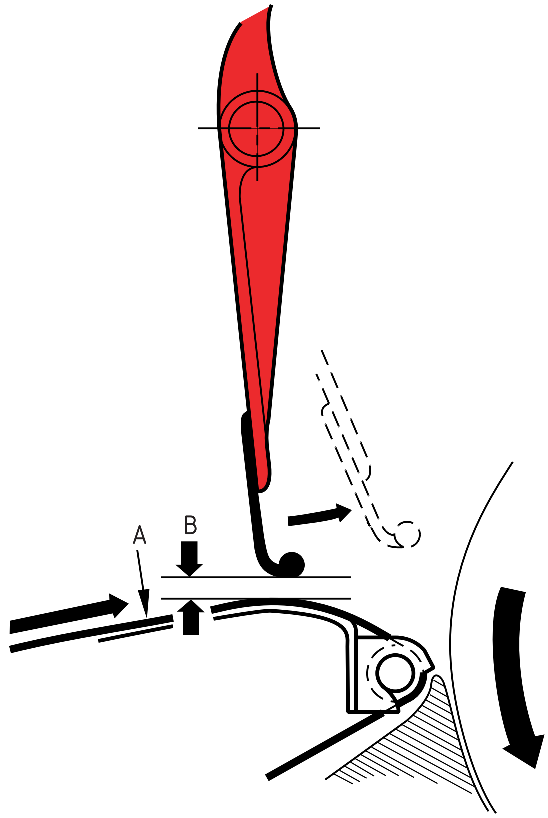
Figure 56 **Distance bar trip guard**



The trip bar, A, is connected to the machine controls such that it has to be moved out from the hazardous area, B, a specified distance before the machine can be operated. The illustration shows the guard fitted to a mechanical press brake, with a work Table C to assist work handling. The bar is locked in the safe (out) position by hook D which engages arm E, the hook being released when the beam, F, has returned to the top of its stroke. The bar is also pressure-sensitive so that leaning against it disengages the clutch and applies the brake. (For clarity, the guarding around the trip bar mechanism is not shown.)

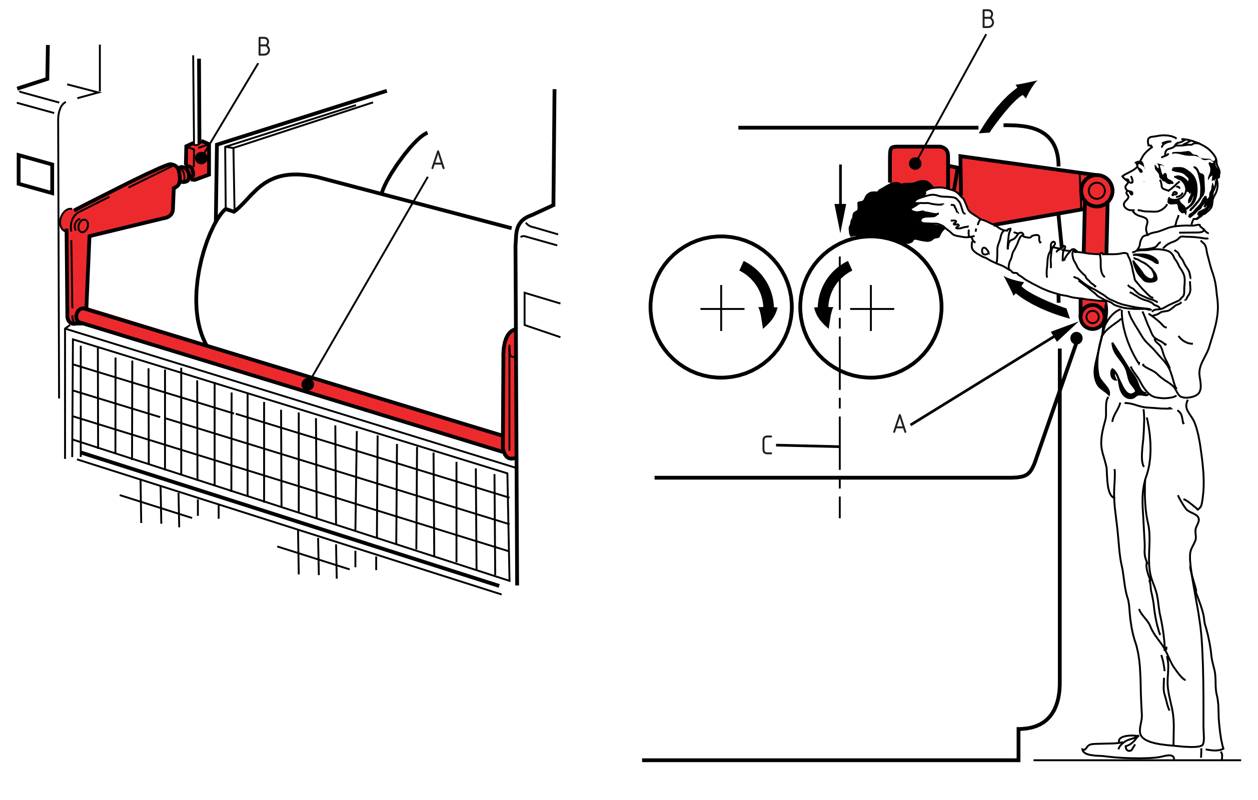
NOTE This type of guard is not suitable for guarding paper cutting guillotines.

Figure 57 **Trip device on a flat work ironing machine (calender) used in laundries**



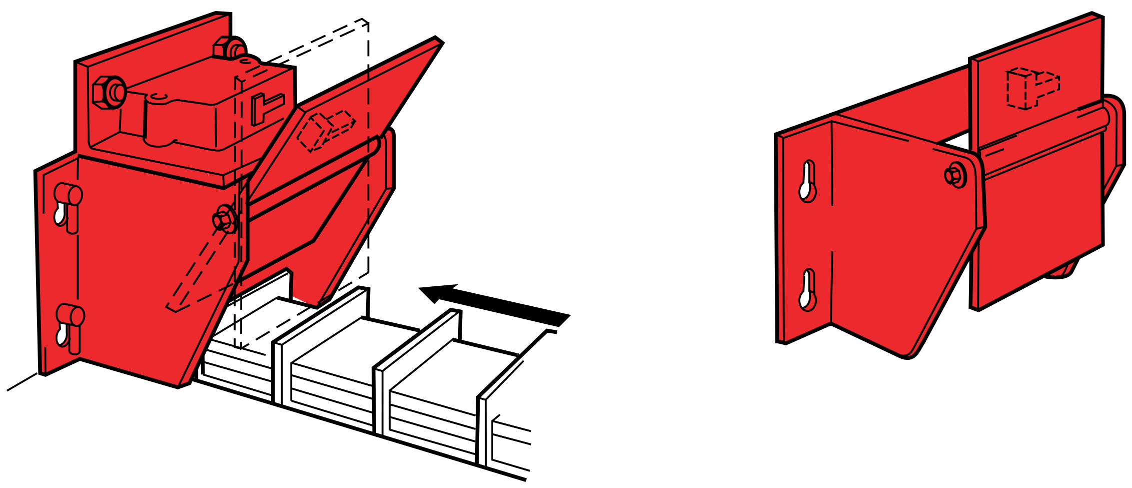
Access to the hazardous nip between the heated bed and the first roll (hazardous area) is prevented by means of a trip device. In this sectional view of the guard, the heavy lines show the normal position of the guard when the machine is in operation and the dotted lines show it after it has been tripped. The feed tapes, A, which are power-driven, carry the material into the nip. It is essential that the trip device operates quickly enough to stop the movement of the tapes and the roll before the operator's fingers can be carried into the nip, and that the gap, B, does not exceed the dimensions given in BS EN ISO 13857 (see Annex A). Safety requirements for industrial laundry machines are covered by BS EN ISO 10472.

Figure 58 **Trip device for horizontal two-roll mills used in the rubber industry**



Movement of the trip bar, A, towards the front roll switches off the drive to the rolls by means of position switches, B, and applies a brake. Each safety trip bar has two position switches, one mounted at each end of the bar. The position of the trip bar is important. Its height above the floor and its horizontal distance from the in-running nip should be such that the operator cannot reach the hazard without actuating the trip bar. After the trip bar, A, has been actuated, the brake should arrest the motion of the rolls before a hand can be drawn into the nip. BS EN 1417 specifies safety requirements for two-roll mills.

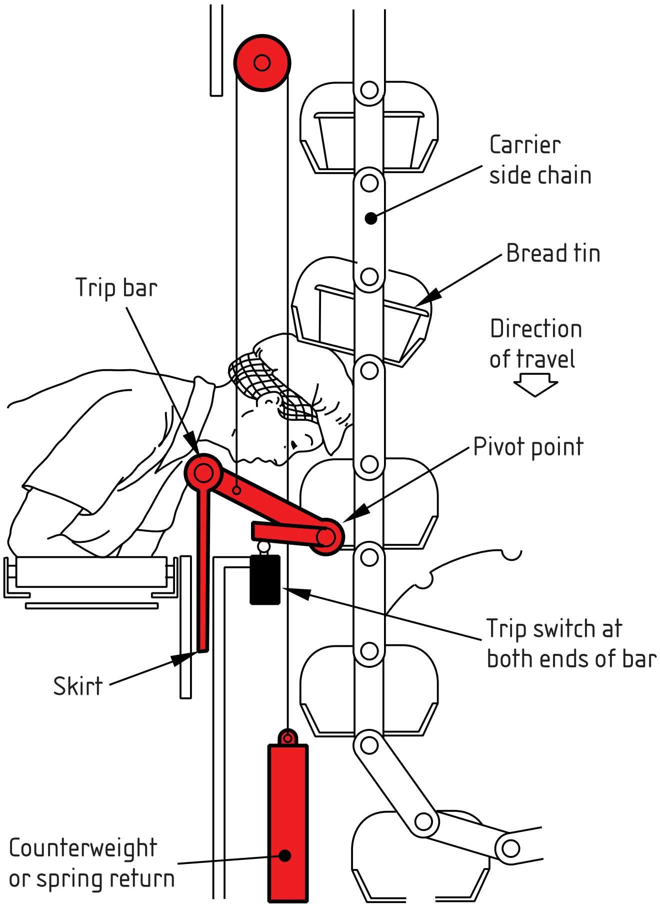
Figure 59 **Trip device that protects against the hazards associated with goods on a conveyor passing into wrapping machinery**



a) b)

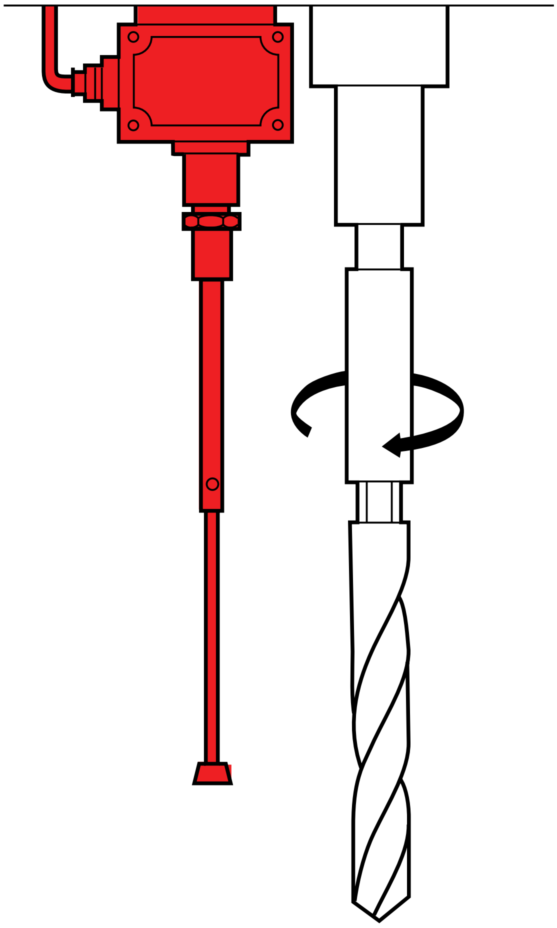
Injury is prevented by the operator's hand deflecting the trip guard and opening the contact of a switch and stopping the machine. The guard is removable for cleaning or the clearing of blockages [see b)], leaving the switch attached to the machine frame. A cam-operated position switch could be used in place of the magnetic switch illustrated if the guard does not have to be removed.

Figure 60 **Trip bar for mitigating the risk of trapping between a down-running conveyor and the casing of a final prover**



The trip device consists of a steel bar which spans the full width of the access opening. The bar is pivoted at each end and directly operates two trip switches when deflected. The bar is held in the up position by a counterweight and is fitted with a skirt to prevent the trip device from being wedged.

Figure 61 **Trip device for drilling machines**



At radial, heavy vertical and some other drilling machines there are sometimes serious practical difficulties in the use of a guard that encloses the drill and spindle. A common form of safeguard is the telescopic vertical trip probe suspended from the drilling head. When the bar is pivoted a few degrees from the vertical in any direction, a switch is operated and a brake is applied to the spindle. The recommended distance of the trip probe from the spindle is 75 mm (see HSE Guidance Note PM 83 [12]). However, experience has shown that heavy swarf generated by the drill is liable to deflect the probe and stop the machine unnecessarily. In this case, if chip-breaker tools do not eliminate the problem, the probe may be set between 75 mm and 150 mm from the side of the cutting tool and preferably towards the left front of the machine. The trip probe should be extended as far as the workpiece allows. The methods of braking which may be used with a vertical trip probe are described in **5.9**.

8.1.3 Electro-sensitive protective equipment

8.1.3.1 General

Electro-sensitive protective equipment (ESPE) (sometimes referred to as "intangible barriers") operates either as trip devices on the principle of detecting the approach of people or parts of persons into hazardous areas, or presence-sensing devices where, so long as a person or part of a people is detected, the hazardous parts cannot be set in motion. The means of detection can be active opto-electronic, activeopto-electronic responsive to diffuse reflection, passive infra-red, capacitance, inductive, microwave, radar, ultrasonic or vision-based.

The effectiveness of the complete installation depends not only on the integrity of the ESPE, but also on the electrical and mechanical integrity of the remaining installation and the location of the ESPE sensing device relative to the hazardous area. Where a high level of performance is required, the ESPE might have to monitor certain machine functions, such as the stopping performance and the performance of the devices controlling the hazardous operations (see BS EN 61496-1:2013, Annex A). BS EN 61496-1 specifies requirements for the design and testing of ESPE and defines three types, of which a Type 4 is the highest performance. The application guidance given in **8.1.3.2** to **8.1.3.5** is applicable to ESPEs.

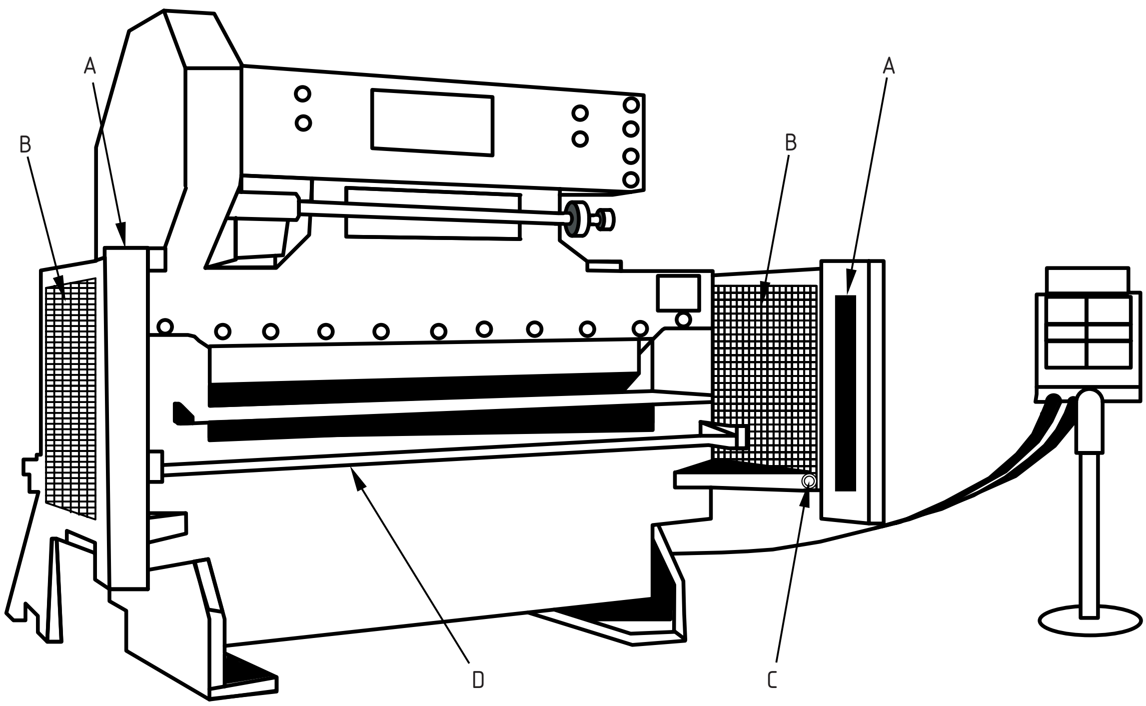
NOTE DD CLC/TS 62046 is being developed for ESPEs, using each sensing means described. As new parts of IEC 61496 are developed for additional sensing means, guidance will be included in future editions of DD CLC/TS 62046.

8.1.3.2 ESPEs using active opto-electronic protective devices (AOPDs) (see Figure 62, Figure 63 and Figure 64)

AOPDs operate on the principle of the detection of an obstruction in the path taken by one or more beams of light. The intangible barrier (sensing zone) formed by this system can consist of a single light beam device, a number of light beam devices, a light curtain or any combination of these as necessary to provide the required safeguard. The light curtain could be created by a scanning light beam or beams, or a number of fixed beams in the AOPD assembly. The light can be visible or invisible, e.g. infra-red, and might be continuous or pulsed.

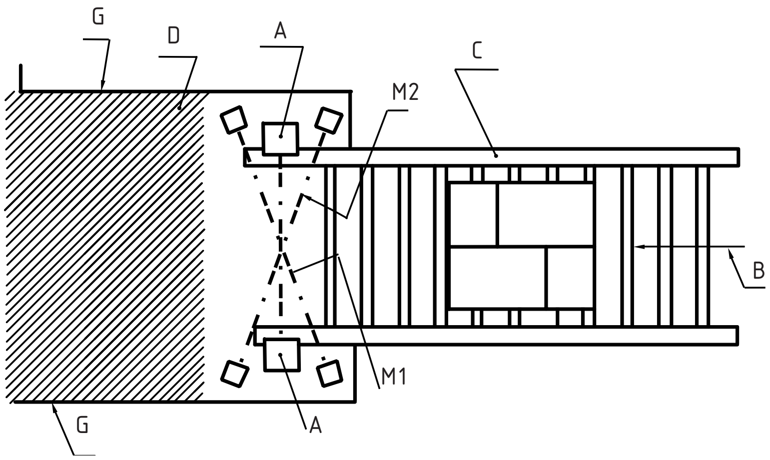
Requirements for the design and performance of ESPEs using AOPDs are specified in BS EN 61496-2 and guidance on their application is given in HSG 180 [13] and DD CLC/TS 62046.

Figure 62 **Electro-sensitive protective equipment using light curtains (AOPDs) as a trip and presence-sensing device at a press brake**



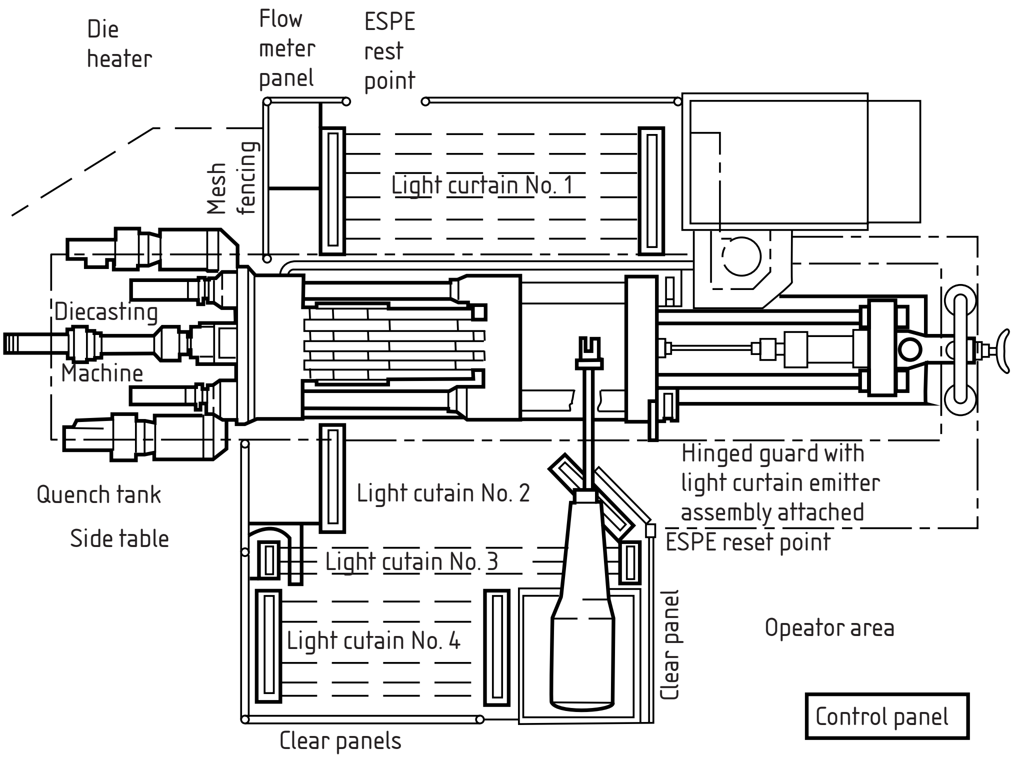
The arrangement consists of a vertical light curtain, A, positioned at a sufficient distance from the hazardous area to ensure hazardous operation has ceased before access can be gained from the front. Access from the side is prevented by the mesh side guards, B. In addition, measures to prevent someone standing between the light curtain and the hazardous area (front of the machine) are provided in the form of a single light beam device, C, and the projecting tool bed shelf, D. Hence A acts initially as a trip device and then, together with C, acts as a presence-sensing device.

Figure 63 **Electro-sensitive protective equipment using light curtains (AOPDs) as a trip device at a depalletizer**



The entry arrangement to the depalletizer is viewed from above. The light curtain, A, and the light beam devices, M1 and M2, are arranged so that pallets travelling through the opening in the machine enclosure, G, towards the machine on the conveyor, C, are detected by interrupting both beams of M1 and M2 before the pallet reaches the light curtain, A. This results in light curtain A being muted until the pallet is inside the machine and has cleared both light beams, M1 and M2. This arrangement depends upon the entry access being completely filled by the pallet conveyor, C, and the pallet as it enters the depalletizer. If a person attempts to enter the hazardous area, D, by the conveyor, light curtain A is intended to act as a trip device to stop machine operation. Further details are given in BS EN 415-4.

Figure 64 **Electro-sensitive protective equipment using light curtains (AOPDs) as presence-sensing devices at a robot-served pressure die casting machine**



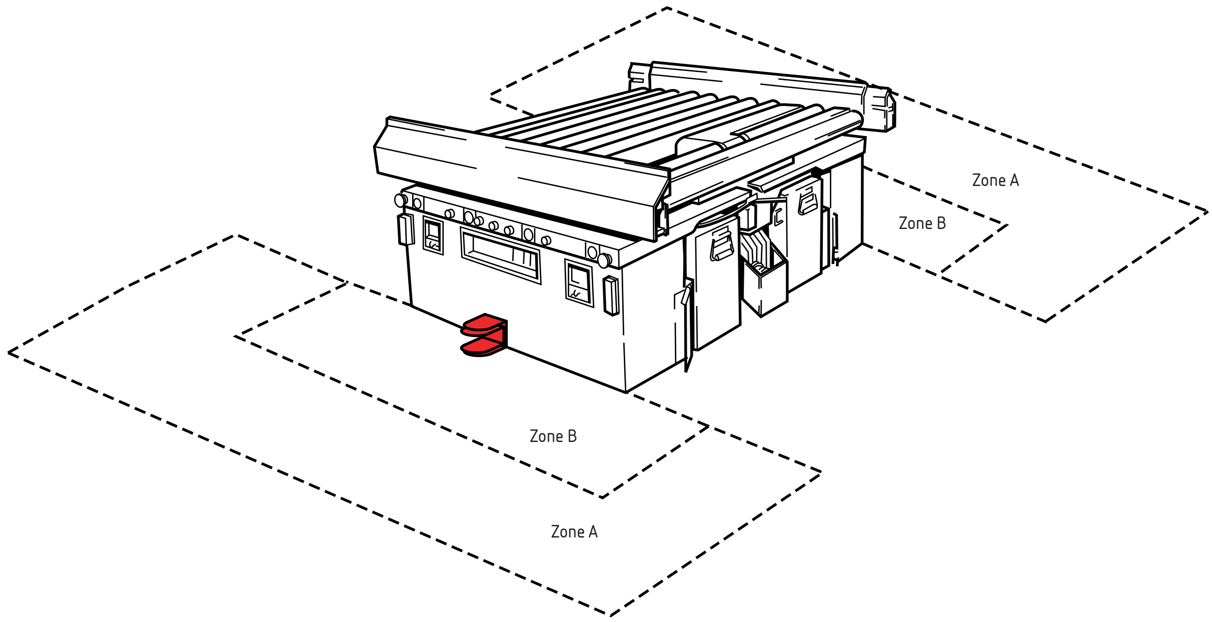
Light curtains 1, 2, 3 and 4 are positioned so that they scan the whole of the free space inside the distance guard. If a person is interrupting light curtains 3 and 4, motion of the robot is prevented. Interrupting light curtains 1 and 2 prevents motion of both the robot and the machine and injection of molten metal cannot take place unless all four light curtains are clear. To avoid the need for additional interlocks on the door giving access through the distance guard, the emitter assembly of light curtain 2 hinges with the door moving it out of alignment, with the respective receiver assembly producing the same effect as light curtain interruption.

8.1.3.3 ESPEs using active opto-electronic devices responsive to diffuse reflection (AOPDDRs)

AOPDDRs are devices that have a two-dimensional detection zone created by using infra-red radiation emitted by a transmitter element(s). When the emitted radiation impinges on an object, for example a person or part of a person, a portion of the emitted radiation is reflected to a receiving element(s) by diffuse reflection whereby the presence of an object can be detected.

Requirements for the design and performance of ESPEs using AOPDDRs are specified in BS EN 61496-3, and guidance on their application is given in DD CLC/TS 62046. Under certain circumstances limitations of the sensor in relation to its use need to be considered. Objects that generate mirror-like (specular) reflections might not be detected. AOPDDRs usually employ a scanning beam of radiation over angles typically of up to 180° (see Figure 65).

Figure 65 **Electro-sensitive protective equipment equipped with active opto-electronic devices responsive to diffuse reflection (AOPDDRs) used as trip and presence-sensing devices on an automated guided vehicle (AGV)**



An automated guided vehicle (AGV) can change direction without warning. The trip device shown is electro-sensitive protective equipment using an AOPDDR. In this example the devices are mounted at the front and rear of the vehicle and send a command to slow down the AGV and sound an alarm when a person (or obstruction) is detected some distance away (in Zone A). If the person does not move the AGV would then stop before actually coming into contact with the person (or obstruction) when they are detected in Zone B. Upon removal of the obstruction the AGV can re-start automatically (see BS EN 1525:1998, **5.9.5.4**). Designers and suppliers ought to have taken into account any need for other protective devices to prevent injury by contact with parts (e.g. the sides) of the vehicle not covered by this type of trip device.

8.1.3.4 ESPEs using passive infra-red detection devices (PIPDs)

There are no product standards for ESPEs using PIPDs. PIPDs are not considered to be suitable for the sole means of safeguarding at a machine.

8.1.3.5 Muting and blanking

8.1.3.5.1 Muting

Muting is the temporary automatic suspension of the ESPE's safety control function (see BS EN 61496-1:2004, **3.16**, and DD CLC/TS 62046). It can be used to allow access by persons or by materials:

- during a non-hazardous portion of the machine cycle; or
- when safety is maintained by other means (see Figure 63).

NOTE Muting may also be applied to other safety-related control systems.

8.1.3.5.2 Blanking

Blanking is an optional function of an ESPE that allows an object of a size greater than the detection capability to be present in the detection zone without causing the ESPE to operate. There are two types of blanking, namely fixed blanking and floating blanking. Fixed blanking is a technique where the locations of the blanked areas of the detection zone do not change during machine operation, and floating blanking is where the blanked area of the detection zone follows the location of a moving object(s) during operation. In both cases the detection capability of the other areas of the detection zone remain unchanged (see BS EN 61496-1:2013, **3.1**).

In order to prevent possible misuse, blanking should only be made available when necessary for the operation of the machine. Blanking may be used to allow the presence of parts of the workpiece or of the machine in the detection zone when safety is maintained by other measures, for example:

- the blanked area is continuously and entirely occupied by material, fixtures, fixed guards or removable interlocking guards;
- the light curtain (AOPD) operates in "opposite mode" for all fixed blanked beams, i.e. the ESPE goes to the off state if an area that is supposed to be obstructed becomes clear; or
- the separation distance is increased in accordance with BS EN ISO 13855 due to the modified detection capability.

  NOTE 1 Information on the modified detection capability is needed from the AOPD manufacturer.

The installation should be such as to minimize the possibility of loss of detection capability caused by reflective surfaces in the blanked zone.

NOTE 2 Blanking is only applicable to AOPDs.

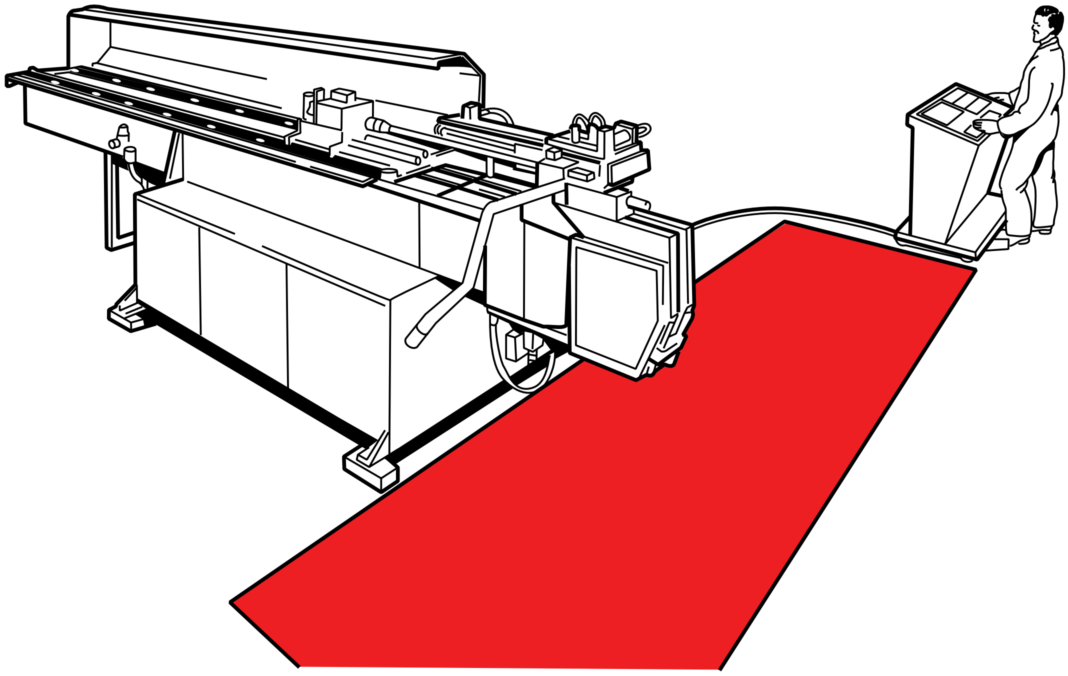
8.1.4 Pressure-sensitive mats (see Figure 66)

Pressure-sensitive mats contain sensors which operate when a person or object applies pressure to the mat or floor. By their nature pressure-sensitive mats are exposed to potential damage which could result in failure. Where there are electrical connections between the mat and the control box the circuit should operate at extra-low voltage.

The dimensions of a mat should take account of a person's speed of approach, length of stride, and the overall response time of the pressure-sensitive protective device. Guidance on the positioning of pressure-sensitive mats is given in BS EN ISO 13855. Care should be taken to ensure that access cannot be gained without actuating the mat or floor. Individual mats might have dead surfaces around their edges. Where a number of mats are used together, care should be taken to ensure that the junctions between them do not provide access to hazardous areas. Guidance on the application of pressure-sensitive mats is given in DD CLC/TS 62046.

A pressure-sensitive mat might be appropriate in circumstances where the use of a fixed guard or an interlocking guard is impracticable, and is particularly for use as a trip device, or a presence-sensing device as a means of protecting a person who could be inside machinery in conjunction with other forms of safeguard. Such protective devices should conform to BS EN ISO 13856-1.

Figure 66 **Pressure-sensitive mat safeguarding the clamping and bending jaws of an automatic horizontal tube bender**



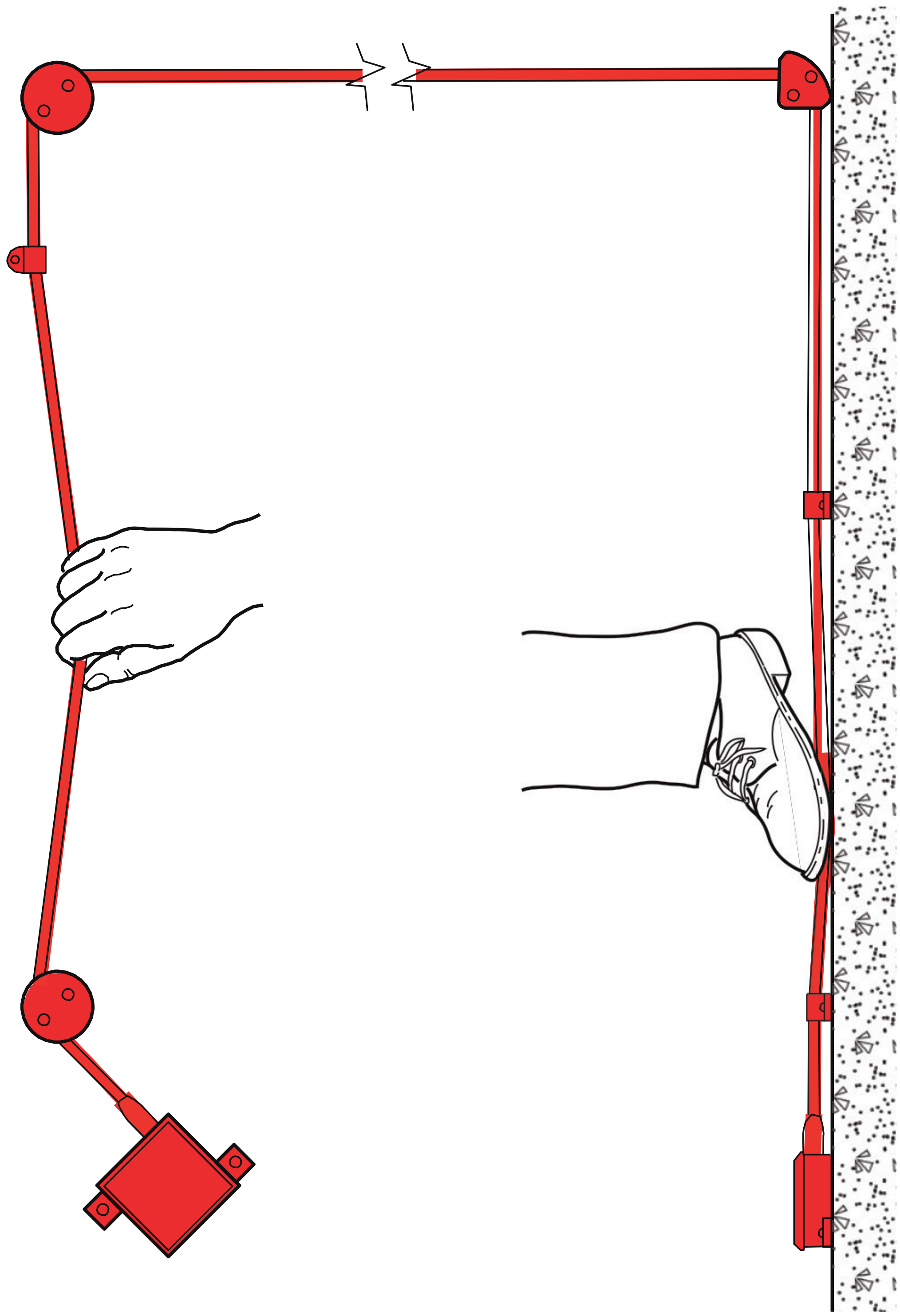
The machine cannot be set in motion until the operator and other people in the vicinity are standing clear of the mat. Pressure on the mat during any part of the machine cycle causes the machine to stop immediately. Additional safeguarding can be required to prevent access from the sides.

8.2 Pressure-sensitive cables (see Figure 67)

Pressure-sensitive cables are occasionally used in place of the electromechanical pull-cord system described in **8.8.4**. They are not a substitute for effective guarding and are not to be confused with the trip devices described in **8.1**. Such devices should be 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. They are sometimes more convenient than electromechanical pull-cord systems to install at conveyors or moving plant because they need not be restricted to straight runs, but can follow a complex route around machinery.

Pressure-sensitive cables are not currently considered to be suitable for use as emergency stop actuators (see BS EN ISO 13850).

Figure 67 **A typical pressure-sensitive cable installation used as a trip device**



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

8.3 Hold-to-run control

A hold-to-run control initiates machine operation and allows continued machine operation only as long as the control is held in a set position. The control returns automatically to the stop position when released.

A two-hand control (see **8.5**) can be used as a hold-to-run control, but it only protects 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.

A hold-to-run control may be used in conjunction with a safe system of work, for example, when a guard has to be displaced or removed and/or a protective device has to be disabled for setting, teaching, fault-finding or cleaning. In such cases, the speed of the machinery should be kept as low as practicable.

In addition to its value as a protective device during setting, a hold-to-run control, if placed at sufficient distance from the hazardous area, also provides a means of ensuring that a machinery operator is in a position of safety when the machinery is operating normally.

8.4 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 machine operation. In any other position, operation is stopped, or a start is prevented. Examples where enabling devices can be used include setting, teaching, fault-finding and cleaning.

NOTE Provisions for enabling devices are given in BS EN 60204-1.

8.5 Two-hand control device (see Figure 68)

Where other forms of safeguarding [see **6.4**f)] are impracticable, two-hand control offers a means of protecting the hands of the machine operator. It could also be used as a hold-to-run control (see **8.3**). There are very few cases where the use of a two-hand control alone, without other complementary safety measures (e.g. an ESPE), can be justified. When used alone it should be a Type III two-hand control device [see **8.5**b) and **8.5**c) and BS EN 60204-1:2006+A1:2009, **9.2.6.2**].

A two-hand control device requires both hands to operate the machinery controls, thus affording a measure of protection to the machinery operator only. It ought to have been designed and installed in accordance with the following (see also BS EN 574).

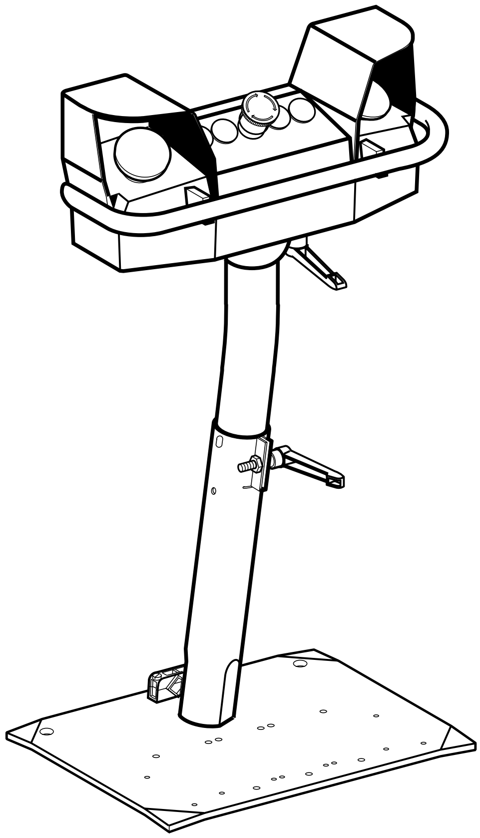
a) The two-hand control device actuators should be so placed, separated and protected as to prevent spanning with one hand only, being operated with one hand and another part of the body, or being readily bridged.

b) It should not be possible to initiate machine operation unless both control device actuators are operated within approximately 0.5 s of each other. After initiating machine operation, it should not be possible to do so again until both control device actuators have been returned to their "off" position. This effectively discourages two people operating the machine together by coordinating their actions and also prevents the operator from locking one control device actuator in the start position, allowing operation of the machinery by means of the other control device actuator leaving one hand free.

c) Hazardous operation should stop when one or both control device actuators are released.

d) The two-hand control device actuators should be situated at such a distance from the hazardous area that, on releasing the controls, it is not possible for the operator to reach the hazardous area before the operation of the hazardous parts has been arrested or, where appropriate, arrested and reversed (see BS EN ISO 13855).

Figure 68 **Two-hand control device**



The provision of a two-hand control device is intended to ensure that the operator has both hands in a safe position while hazardous operation takes place. To protect against accidental operation the buttons are shrouded.

8.6 Limiting and limited movement control devices

8.6.1 General

A limiting device prevents a machine or hazardous machine condition(s) from exceeding a design limit (e.g. space limit, pressure limit, load moment limit – see BS EN ISO 12100:2010, **3.28.8**).

A limited movement control device (inch or jog) is one which, after a single actuation, initiates only a limited amount of operation (e.g. movement of a machine element for a predetermined distance). Further movement of the machinery is precluded until there is a subsequent and separate operation of the control.

Such devices are used, for example, during maintenance and setting.

The fitting of a limited movement device inevitably results in a greater number of start/stop operations, so care should be taken to ensure that:

a) the machinery is mechanically robust enough to withstand the possible extra duty;
b) the drive motors do not overheat – it is 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 would have an adverse effect on existing equipment;
d) where reversal of motion is possible, the control operations needed are readily distinguishable; and
e) suitable maintenance procedures are in place to take account of a) to d).

A brake can be required to ensure effective limited movement control.

A limited movement device may be either a timed impulse device (see **8.6.2**), in which a predetermined timed impulse is given with the object of achieving a limited movement, or a controlled movement device (see **8.6.3**), 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 control settings.

8.6.2 Timed impulse device

A timed impulse device has a limitation because the resultant movement of the machinery could 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; and
c) frictional variations depending on temperature, etc.

8.6.3 Controlled movement device

Controlled movement devices initiate and stop machine movement within a predetermined limit. These devices are applicable only in conjunction with an efficient means of stopping the hazardous parts.

8.7 Mechanical restraint device (see Figure 69 and Figure 70)

8.7.1 General

A mechanical restraint device prevents or restricts the movement of a hazardous part of machinery which has been set in motion due to failure of the machinery controls or other parts of the machinery, so as to prevent a hazardous situation.

8.7.2 Down-stroking platens

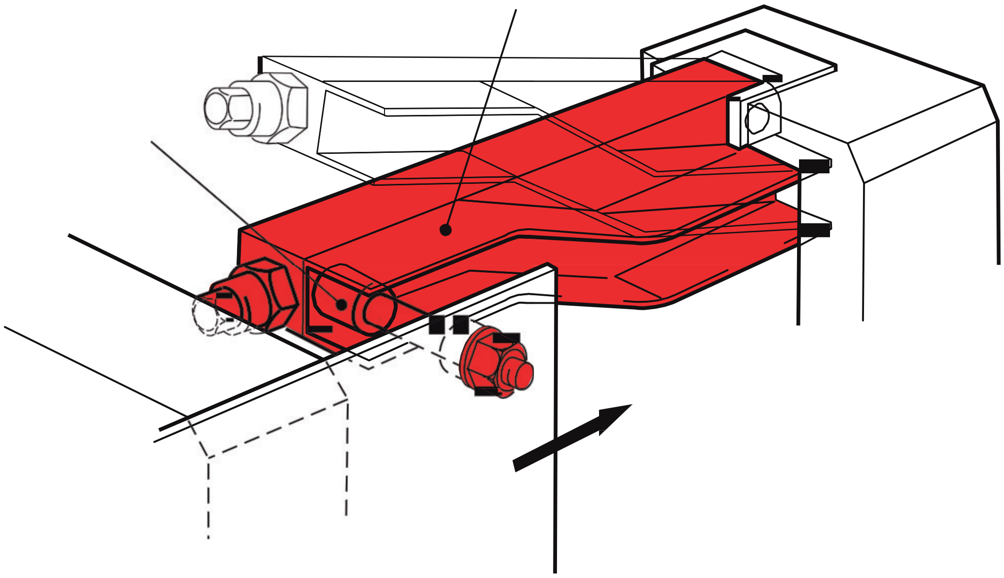
Loss of pressure at certain critical points in the hydraulic system of a down-stroking press can cause the platen to fall under gravity. On small machines, the weight of the platen and speed of descent could be insufficient to cause a hazardous situation, but protection against such a failure on large machines should be provided by means of either:

a) one or more scotches, capable of supporting the weight of the ram, platen and tool, inserted automatically when the platen has returned to the top of its stroke (see Figure 70); or

b) a pilot-operated check valve and counterbalance valve assembly connected to the lower end of the hydraulic cylinder (see **10.2.8.4**).

Where a scotch operates in conjunction with an interlocking guard, the scotch should remain in position until the guard is closed. The guard should then remain locked closed until the platen has returned to the top of its stroke and the scotch is in place.

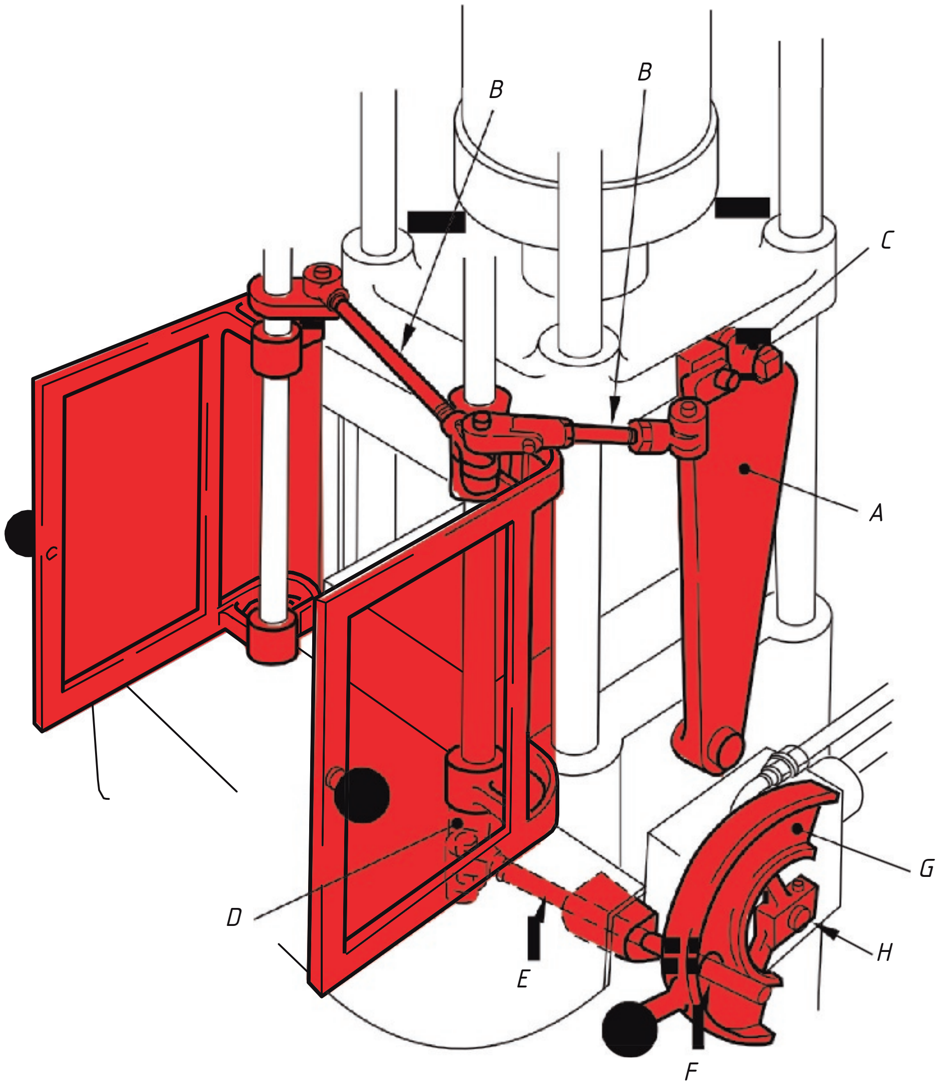
Figure 69 **Augmenting an interlocking guard with a mechanical restraint device**



As an additional precaution against unexpected closure of a hydraulically-powered platen with a double-acting cylinder, it might be possible to augment an interlocking guard with some form of mechanical restraint designed to prevent closure if the piston head and the connecting rod separate. The illustration shows a platen scotch consisting of a simple strut which is positively inserted between the platens by the guard when the platens are fully opened and there is access to the danger area between them.

As the guard is closed, the roller attached to it moves along the linear cam, lifting the scotch out of engagement. This form of scotch is suitable only where the guard remains locked closed until the platens are fully open. The profile of linear cam B ought to be designed so that the scotch remains in place until the guard is almost closed.

Figure 70 **Mechanical restraint**



The illustration shows a down-stroking hydraulic press with an interlocking guard which incorporates mechanical restraint (scotching) to protect against gravity fall of the platen in the event of failure of the hydraulic system. The scotching is effected by a hinged plate, A, connected by linkages, B, to the guard doors in such a manner that when the doors are opened the scotch, A, swings under projection C secured to the top platen. At the same time link D, attached to the guard pivot, forces spindle E through hole F in plate G, which is attached to the hydraulic valve spindle H. In this position the valve is open to exhaust and remains locked. When the guard doors are closed, bolt E is withdrawn from hole F and scotch A swings clear of projection C. The press is then free to operate, the doors being held closed by bolt E when the valve plate, G, is rotated. Fixed guarding at the sides and rear of the press are not shown in the illustration.

8.8 Emergency operation – emergency stop and emergency switching off

8.8.1 General

Emergency operation functions are described in BS EN 60204-1:2006+A1:2009, Annex D. Emergency stop and emergency switching off are described in **8.8.2** and **8.8.3**. They are complementary protective measures that are not primary means of risk reduction for hazards, such as trapping, entanglement, electric shock or burn at a machine.

Emergency stop and emergency switching off are initiated by a single human action when an existing or impeding hazard is recognized. When initiated, once active operation of the emergency switching off or emergency stop control device has ceased, the effect of the command should be maintained (i.e. the control device is latched, for example as specified in BS EN 60947-5-5 in the case of electrical control devices) until it has been reset (unlatched) at the place(s) it was initiated.

Resetting of the emergency stop or emergency switching off command should only take place only when all latched devices have been unlatched. Resetting should not initiate restarting or re-energization.

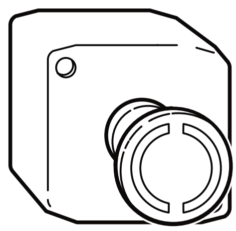
The types of emergency stop and emergency switching off device actuators include:

- push-buttons of the palm or mushroom head type (see Figure 71);
- wires, ropes, bars; and
- foot pedals without a protective cover (in specific applications for emergency stop only).

The actuators should be coloured red with a yellow background where one exists immediately behind the actuator (see also **5.4.2**).

Electrical emergency stop or emergency switching off devices should have direct opening action in accordance with BS EN 60947-5-1:2004+A1:2009, Annex K.

Figure 71 **Emergency stop button**



Emergency stop buttons should be of the mushroom head type and coloured red, with a yellow background (see also **5.4.2**, **8.8.1** and BS EN ISO 13850).

8.8.2 Emergency stop

The detailed requirements for emergency stops are specified in BS EN ISO 13850 and those for electrical equipment in BS EN 60204-1:2006+A1:2009, **9.2.5.4** and **10.7.4**. However, the scope of BS EN ISO 13850 indicates that some machines are exempted from the requirements. For such machines the machine supply disconnecting device when locally operated may serve this purpose (see BS EN 60204-1:2006+A1:2009, **10.7.4**).

The emergency stop should not be used for normal stopping, should be available at all times and should not be relied on as a means of isolation. An emergency stopping device, when operated, should stop operation of the machine as quickly as possible without generating additional hazards. Care should be taken so that the operation of the emergency stop does not, in itself, increase the risk of harm from another source.

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

They should be located so that they can be operated without placing the operator in a hazardous situation.

An emergency stopping device may, in certain circumstances, 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.

8.8.3 Emergency switching off

The detailed requirements for emergency switching off are specified in BS EN 60204-1:2006+A1:2009, **9.2.5.4** and **10.8**.

Emergency switching off should be provided:

a) where protection against electric shock (for example, by contact with live conductors) is achieved by using obstacles (see BS EN 60204-1:2006+A1:2009, **3.38**) or by placing out of reach; or

b) where there is a possibility of other hazards or damage (for example, fire) caused by electricity.

The emergency switching off function should be available at all times. Where dedicated devices are provided for emergency switching off, they should not be used for normal switching off of the power supply, and should not be relied on as a means of isolation. Means to prevent confusion between emergency switching off devices and emergency stop devices should be provided (for example, by placing an emergency switching off device in a break-glass enclosure) where appropriate.

8.8.4 Pull-cord actuators (see Figure 72 and BS EN 60947-5-5:1998+A11:2013, 6.4.2)

The pull-cord system should be designed and arranged so that it operates the associated switching device and generates the emergency stop (or emergency switching off) command when either:

- the pull-cord is pulled in any direction; and
- a perpendicular pulling force is applied to the pull-cord; and
- a perpendicular deflection of the pull-cord; or
- the pull-cord breaks; or
- the failure of a single spring occurs [see Figure 72b)].

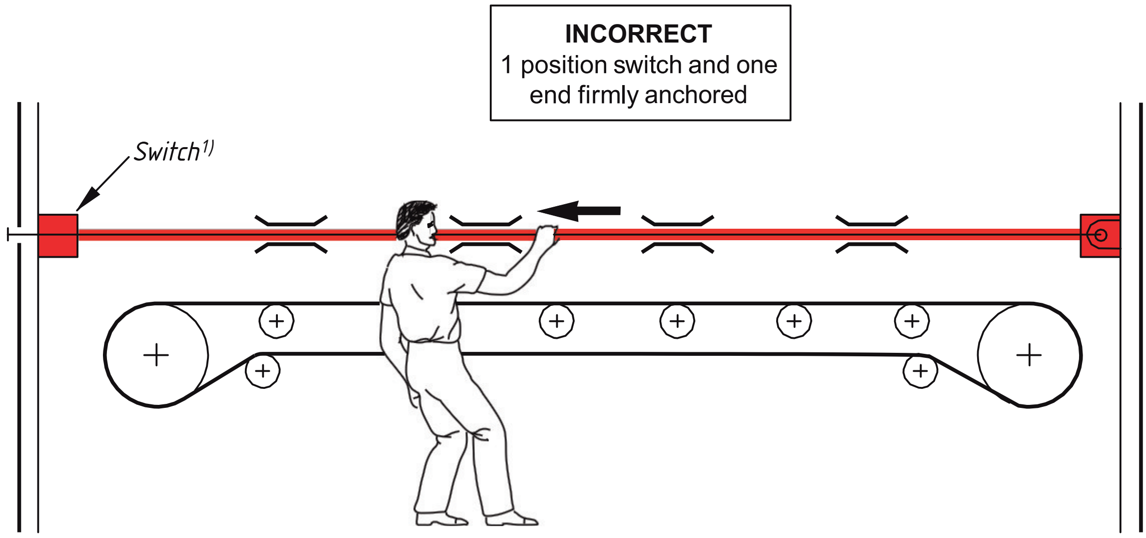
The perpendicular pulling force required to generate the emergency stop command should be not greater than 200 N. The perpendicular deflection required to generate the emergency stop command should be less than 400 mm.

In addition, the pull-cord should be able to withstand without breaking a tension force ten times greater than that necessary for generating the emergency stop signal.

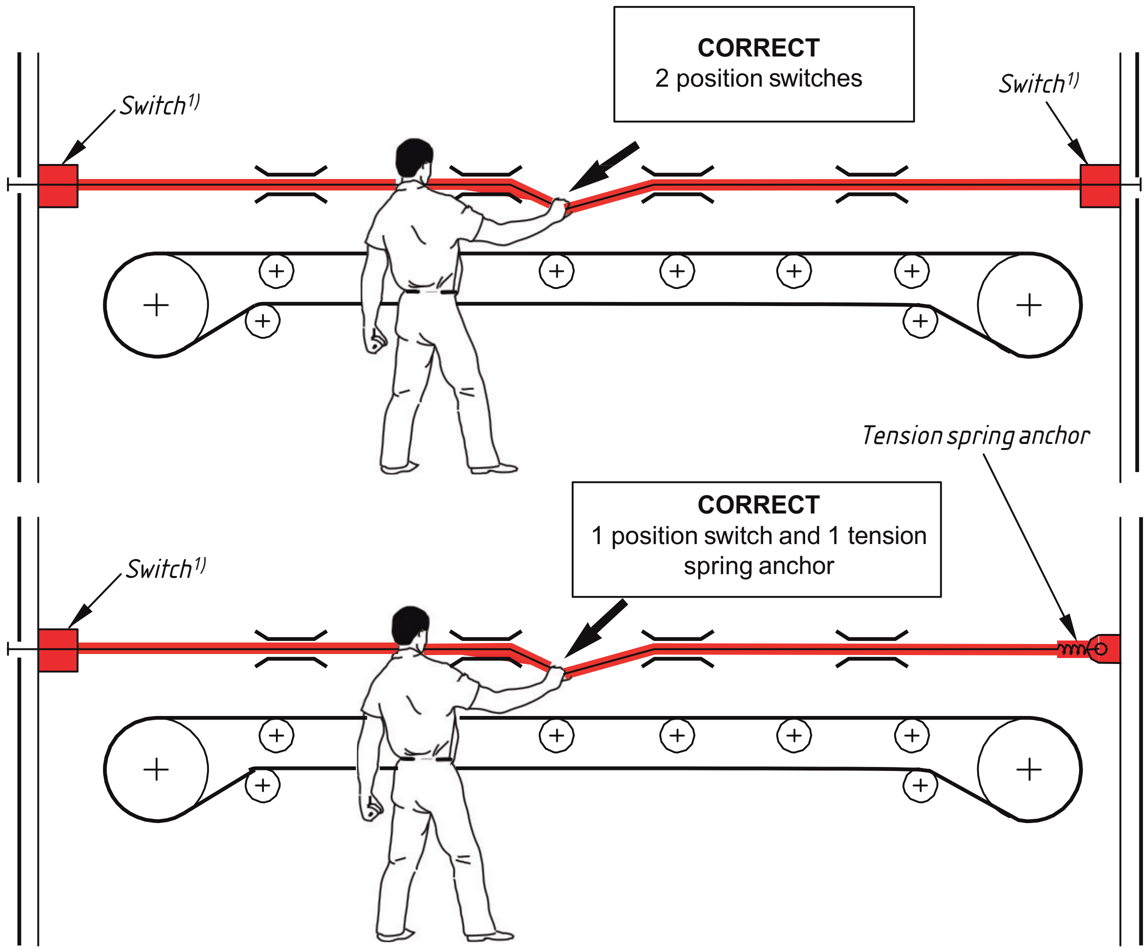
The movement of the pull-cord and the force to operate the system could be affected by the design of the pull-cord supports and the distance between them. Care should therefore be taken to ensure that the pull-cord is free to move through the supports at all times, particularly at changes of direction, without becoming disengaged from them. Where more than one switching device is necessary, means for a visual indicator should be provided to show which device has operated. The indicator may be at a central position or at an individual device.

An emergency stop pull-cord is not an alternative to guarding.

Figure 72 **Emergency stopping of conveyors** *(1 of 2)*



a) Emergency stop pull-cord installed incorrectly

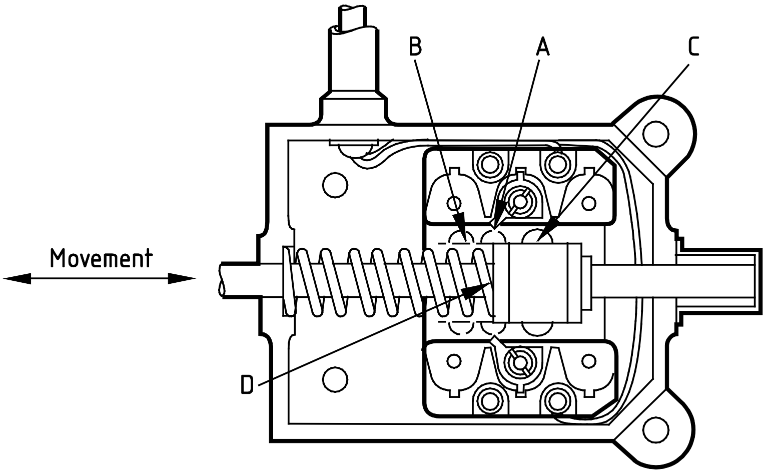


This shows two methods of installing an emergency stop pull-cord correctly. Either a switch is provided at each end or a single switch is used at one end and a tension spring anchors the other end so that a pull on the cord in any direction stops the conveyor. It should be noted that the use of a switch at each end of pull-cord ensures that positive opening operation will take place.

b) Two methods of installing an emergency stop pull-cord correctly

[1)] Internal detail of a typical switch is shown in Figure 72c).

Figure 72 **Emergency stopping of conveyors** *(2 of 2)*



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 72b).] The switch illustrated has a central spindle, D, to which a pull-cord is connected. 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 opens the contacts (position B) while breakage or slackness of the pull-cord causes them to open in the opposite direction (position C) under the action of the compression spring. Note that the latching mechanism is not shown in the drawing for clarity.

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, brings the conveyor to rest. The arrangement should be such that after manual operation resetting is necessary.

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Section 9: Interlocking

9.1 Functions of an interlock

An interlock is a type of protective device that provides the connection between a guard and the control or power system of the machinery to which the guard is fitted. The interlock and the guard with which it operates should be installed and adjusted so that:

a) until the guard is closed the interlock prevents the machinery from operating (for prevention of unexpected start-up, see **5.6** and BS EN 1037); and

a) either the guard remains locked closed until the risk of harm from the hazard has passed or opening the guard causes the hazard to be eliminated before access is possible.

Interruption of the power supply itself might be sufficient to eliminate the hazard before access is possible. Interlocking methods suitable under these circumstances are described in **9.3**. Where the hazard cannot be eliminated immediately by power interruption, the interlocking system should include a guard locking and/or a braking system (see **9.4**) or other suitable provisions, for example, a purging system in the case of a hazardous gas. Where whole-body access to a hazardous area can be gained through an interlocked door, the possibility of inadvertent entrapment should be considered (see **12.3.3.6**).

Care should be taken to ensure that actuation of an interlock installed to protect against one hazard, for example by stopping hazardous movement, does not create a different hazard, for example, the release of a hazardous substance into the area surrounding the machinery.

Principles for the design and selection of interlocking devices are also specified in BS EN ISO 14119.

9.2 Interlocking media

The media most commonly encountered in interlocking are electrical, mechanical, hydraulic and pneumatic. The principles of interlocking apply equally to all media. The choice of interlocking medium depends on the type of machinery, operational environment and the method of actuation of its hazardous parts.

Some applications require the use of more than one interlocking device or more than one interlocking channel. It is often advantageous to design or select these device(s) so that similar failures in both channels from the same cause (common cause failures) are unlikely (see Section 10).

9.3 Interlocking methods for power interruption

9.3.1 General

Methods of interlocking which ensure that the power supply is interrupted when a guard is open fall into two groups:

a) the interlocking device directly interrupts the power supply (power interlocking); and

b) the interlocking device indirectly interrupts the power supply via a control system (control interlocking: see Section 10 for interlocking control systems).

In addition, a guard can be arranged to interact with its interlocking device in different ways. Examples include:

1) a guard and its interlocking device arranged so that the interlocking device has to be moved to the unlocked position before the guard can be opened (interlocking guard with guard locking); and
2) the interlocking device is non-locking and is operated by movement of the guard (interlocking guard without guard locking).

These techniques can be used in power and control interlocking.

9.3.2 Common interlocking methods

Some of the more common interlocking methods are as follows:

a) interlocking guard without guard locking (see **9.3.3**);
b) interlocking guard with guard locking (see **9.3.4**); and
c) interlocking guard with mechanical trapped-key interlock (see **9.3.5**).

9.3.3 Interlocking guard without guard locking

NOTE See BS EN ISO 14119:2013, ***4.2****.*

A guard associated with an interlocking device permits the following functions to be performed:

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

9.3.4 Interlocking guard with guard locking

NOTE See BS EN ISO 14119:2013, ***4.3****.*

A guard associated with an interlocking device and a guard locking device permits the following functions to be performed:

a) the hazardous machine functions "covered" by the guard cannot operate until the guard is closed and locked;
b) the guard remains closed and locked until the risk due to the hazardous machine functions "covered" by the guard has disappeared; and
c) when the guard is closed and locked, the hazardous machine functions "covered" by the guard can operate (the closure and locking of the guard do not by themselves start the hazardous machine functions).

9.3.5 Mechanical trapped-key guard interlock (see Figure 86)

Typically, the guard lock can only be operated with a unique key that is obtained via another lock that directly controls the power supply to the hazard. When the guard is open, the key is trapped in the guard interlock and the machine is switched off. When the guard is closed, the key can only then be removed (locking the guard closed in the process). The key can then be inserted into the lock of the power disconnection device to switch the machine on. The key cannot be removed (i.e. it is trapped) from the power disconnecting device without switching it to the "off" position (see **9.6.5**).

9.4 Interlocking methods incorporating braking, purging, etc., and/or guard locking

9.4.1 General

A hazard could exist after interruption of the power medium, for example, due to the continuing release of stored energy or the presence of hazardous substances, if it is not isolated by using the systems detailed in **9.3**. Under these circumstances, systems should incorporate one or more devices to either:

a) cause the hazard to be eliminated as the guard is opened (for example, by braking); or

b) prevent the guard from being opened until the risk of harm has passed (for example, by guard locking).

The design principles of Section 10 are applicable to systems intended to prevent the guard being opened and for systems intended to remove the hazard. However, where the desired effect is not only to disconnect the power supply, but to provide guard locking, braking, etc., guidance is given in **9.4.2** and **9.4.3**. As the level of risk increases, the integrity of the interlocking device(s) and the associated control system should increase correspondingly (see Section 10). The use of power interlocking and the use of dual interlocking devices, monitoring systems, etc., should be considered (see Section 10). Similar considerations apply to systems incorporating trip devices (see **8.1**).

9.4.2 Braking system

A braking system could be brought into operation to bring a machine to rest before access to a hazardous area can be gained.

For further information on braking devices and systems see **5.9**.

9.4.3 Guard locking systems

9.4.3.1 General

Some machines require a guard locking function in addition to the interlocking methods described in **9.3** when either:

a) opening or removing the guard does not eliminate the hazard before access is possible; or

b) opening a guard other than at predetermined points in the machine cycle can cause a hazard and/or damage to the machine processes.

A guard locking system comprises a locking device (see **9.4.3.4**) and a means to control guard locking/unlocking. Conditions for guard unlocking typically depend on an appropriate input from the machine’s control circuit, a timing device (see **9.4.3.3**), a motion or position-sensing device (see **9.4.3.2**) or other appropriate sensing device. These can be individual units or combined in one assembly. Variable conditions of operation of machinery produce, for example, variable amounts of overrun, and in these circumstances a timing device could be inappropriate since it has to be set for the longest overrun or purge time that might be expected. The variable time element can, however, be eliminated by the use of a motion, position or a hazardous substance sensing device which allows the guard to be opened as soon as the hazard is no longer present.

9.4.3.2 Motion or position-sensing devices

There are different types of motion or position-sensing devices, some of which can be ineffective at low speed and are therefore acceptable only where residual motion after the guard has been opened cannot cause injury. However, where injury could result from residual motion the use of more sensitive devices (for example, a high-resolution shaft encoder) and/or timing devices might be necessary. Examples of typical motion or position-sensing devices are:

a) rotation-sensing device, which operates on various principles such as centrifugal force, eddy current generation, voltage generation, optical or electronic pulse generation;

b) photo-electric device;

c) proximity device; and

d) position switch or valve.

9.4.3.3 Timing devices

Examples of typical timing devices are:

a) mechanical, electric or electronic clocks;

b) delay relay;

c) sequence valve;

d) threaded bolt; and

e) dashpot.

9.4.3.4 Guard locking devices

Examples of typical guard locking devices are:

a) captive-key unit;

b) the guard lock of a trapped-key system;

c) mechanical bolt;

d) solenoid-operated latch; and

e) shot-bolts, which can be solenoid-operated (see BS 6753), hydraulic or pneumatic.

NOTE Further information on guard locking devices is given in BS EN ISO 14119:2013, ***5.7.2****.*

9.5 Security of interlocking

The security of interlocking can be improved by avoiding motives for its defeat and/or by making defeat more difficult.

The design of the safeguarding should take full account of the need for human intervention in the machine during any phase of its life. Where this aspect of the design is inadequate, motives to defeat the interlock commonly arise when unanticipated access inside the guards is needed, for example, during maintenance or when experiencing production problems.

These aspects should be considered before putting a machine into service. Where identified during use, any aspects that result in an unsafe condition should be addressed by either modification of the machine to eliminate the hazard or by the application of suitable safeguards.

Defeat can be made more difficult by:

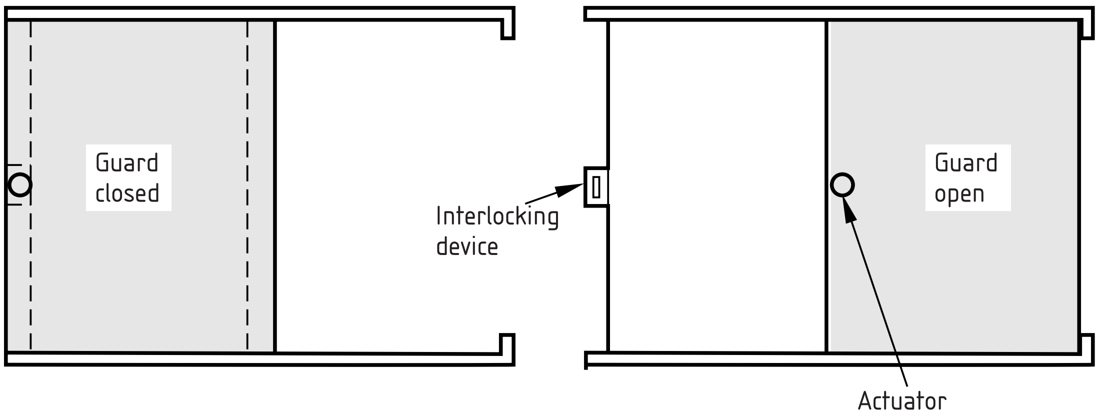
a) the use of interlocking devices or systems which are coded, e.g. mechanically, electrically, magnetically or optically; or

b) physical obstruction or shielding of the interlocking device while the guard is open (see Figure 73 and Figure 74).

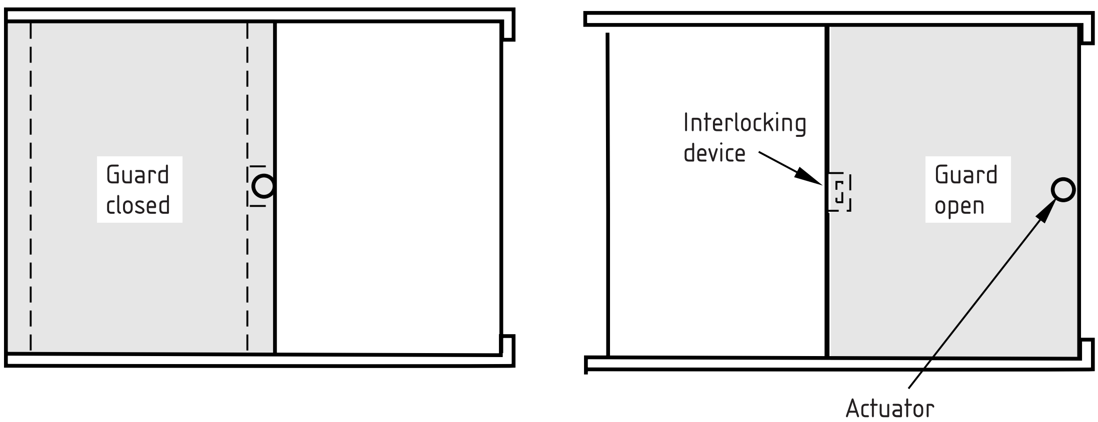
Where systems rely on special actuators or keys (coded or not) care should be taken over the availability of spare actuators or keys and master keys (see BS EN ISO 14119:2013, Clause **7**).

NOTE The use of uniquely coded actuators can avoid the problem of defeat by a spare actuator.

Figure 73 **Defeatability of sliding interlocking guards**



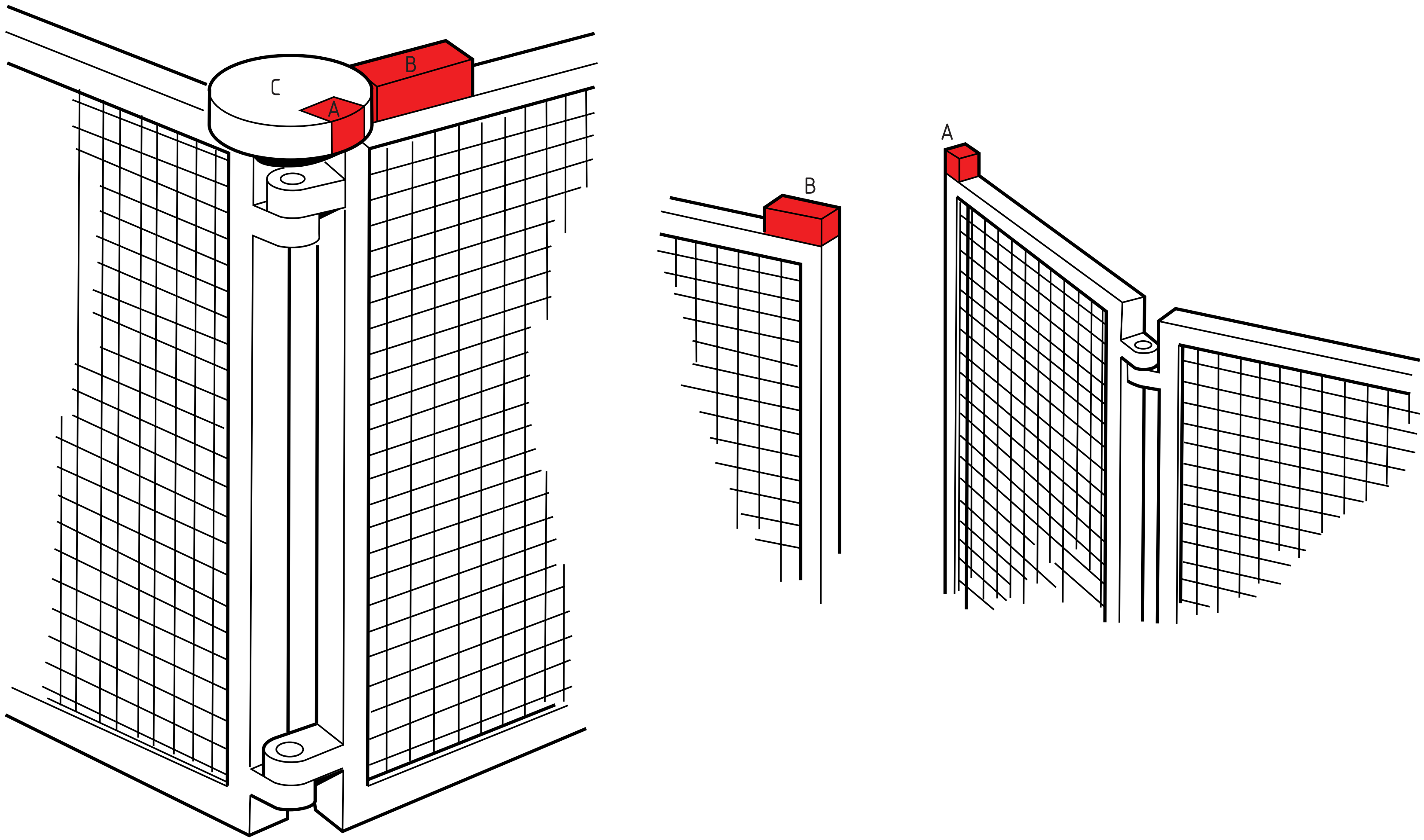
a) Simple to defeat with spare actuator



b) Difficult to defeat with spare actuator

By carefully positioning interlocking devices of the key, tongue, magnetic or inductive proximity type, defeating the device can be made more difficult. a) shows a sliding guard with the interlocking device positioned to the left of the access with the guard opening to the right. Defeat is simple using a spare actuator because the switch is exposed. b) uses identical components but the interlocking device is positioned to the right of the access. If the guard dimensions are correct and stops are provided to prevent complete removal of the sliding guard, defeat with a spare key is difficult because the guard provides a physical obstruction in front of the interlocking device at all times.

Figure 74 **Defeatability of hinged interlocking guards**



a)

b)

Proximity switches with their encapsulated design make ideal interlocking devices for the food and the pharmaceutical industries. They can be arranged as shown in b) where defeat is made difficult by coding the target, A, to operate only with the matching sensing head, B. However, a similarly coded target could be used to gain unauthorized access. On the other hand, if the arrangement shown in a) has been adopted, the disc, C, containing the target, A, physically prevents a duplicate target being offered up to the sensing head, B.

9.6 Electrical interlocking devices

9.6.1 General

Interlocking devices used for interfacing guard movement with a safety-related electrical control circuit include the following (see also BS EN ISO 14119:2013, **4.1**):

a) cam-operated position switches (see **9.6.2**);

b) tongue-operated switches (see **9.6.3**);

c) captive-key switches (see **9.6.4**);

d) trapped-key interlocking system (key exchange) (see **9.6.5**);

e) uncoded non-contact switches (see **9.6.6**);

f) coded non-contact switches (see **9.6.7**);

g) magnetic switches (see **9.6.8**);

h) plug and socket systems (see **9.6.9**);

i) manually-operated delay device (see **9.6.10**);

j) solenoid-operated shotbolts (see **9.6.11**); and

k) power interlocking (see **9.6.12**).

Devices should be selected only from those whose performance, as stated by the manufacturer, is suitable for the specific safety application. The following performance criteria should be considered:

1) resistance to environmental conditions, e.g. index of protection (IP) (see BS EN 60529), corrosion resistance, vibration resistance, electromagnetic disturbances;

2) useful lifetime;

3) duty rating;

4) reliability; and

5) functional safety characteristics.

9.6.2 Cam-operated position switch

A cam-operated position switch can be actuated in either of two modes, positive or non-positive (see Figure 76 and BS EN ISO 14119:2013, Annex A).

NOTE In BS EN ISO 14119:2013 the terms "positive" and "non-positive" are replaced by "direct action" and "non-direct action".

When operated in the positive mode, the switch actuator is depressed when the guard is in any position other than closed. This is normally achieved by a cam or track attached to the guard. The final closing movement of the guard releases the switch actuator, allowing the contacts to close by the action of the return spring, i.e. the contacts are normally closed and, when the guard is opened, the contacts are opened by the cam (see Figure 76, Figure 77, Figure 78 and Figure 79).

In addition, switches actuated in the positive mode should be position switches incorporating direct opening action (see BS EN 60947-5-1:2004+A1:2009, Annex K). Care should be taken when installing such switches to ensure that the contacts are fully open when operated. Additionally, an adequate degree of over-travel should be utilized to allow for the foreseeable loss of movement due to cam or track wear and to prevent damage to the switch or its mounting.

Certain types of unit incorporate early break, snap-action contacts. These units offset the disadvantages caused by a slow break of the electrical circuit on opening a guard. However, great care should be taken to ensure that the switch contacts are the positive opening type and, when installing such units, contacts are fully opened when the unit is operated.

When operated in the non-positive mode, the final closing movement of the guard depresses the actuator of the position switch, closing its contacts and allowing the machine to be set in operation. When the guard is opened, the switch contacts are opened by the action of their switch return spring [see Figure 75b)].

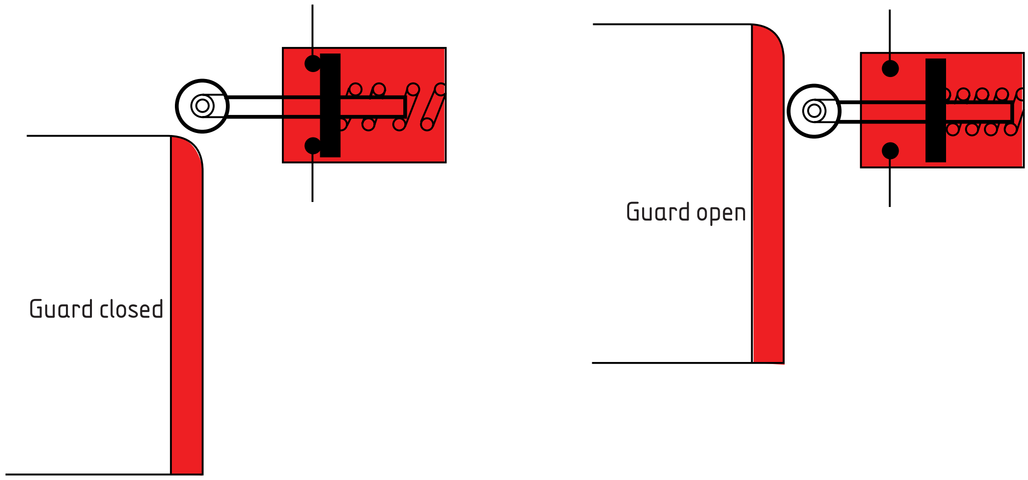
If a single electro-mechanical switch is used it should be cam-operated to enable it to be installed in the positive mode. This ensures that the switch contacts are directly opened by the operation of the cam, and prevents the switch from being easily defeated. Figure 80 shows an example of an incorrectly installed position switch. Because of the absence of a cam it can be easily defeated by depressing the actuator while the guard door is open. In the event of spring failure the contacts can remain closed.

If two switches are used to improve mechanical integrity, one in the positive and one in the non-positive mode, it can reduce the possibility of common cause failure, for example, due to guard displacement or wear (see Figure 76 and Figure 77).

When a guard can be completely removed from the machinery, i.e. it is not restrained by hinges or track, positive mode actuation is not possible by using a cam that is permanently attached to the guard. The use of tongue-operated switches is not recommended due to the scope for damage to the actuating tongue when the guard is handled.

One of the options in **9.6.1**, items c) to g), should therefore be used, provided the device is specifically designed for the safeguarding of machinery (see Figure 89).

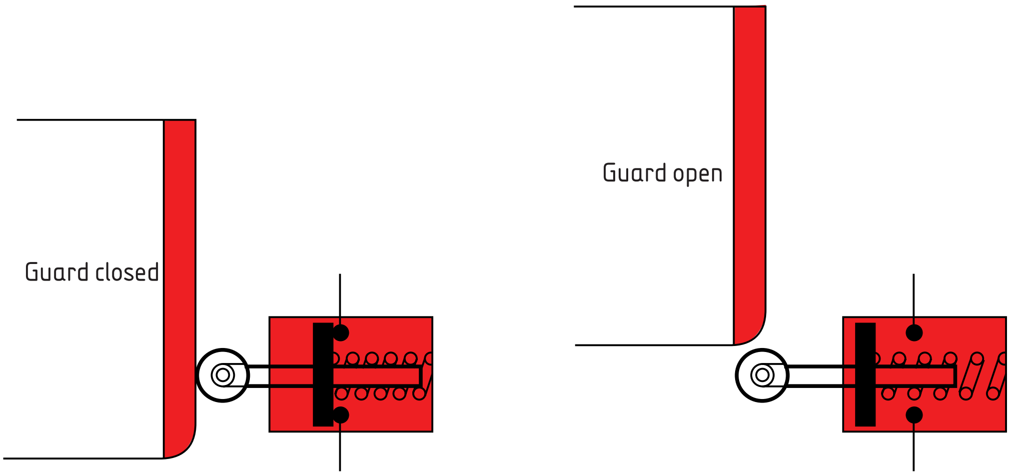
Figure 75 **Mounting of individual position switches**



In this mode of operation, the switch actuator is held depressed by a cam attached to the guard, when the guard is in any position other than fully closed. The final closing movement of the guard releases the switch actuator allowing the contacts to close by the action of the return spring, i.e. the contacts are normally closed, and when the guard is opened the contacts are positively (directly) opened by the cam. This arrangement is more reliable than that shown in b) because it does not rely on a spring to return it to the safe condition and it cannot be defeated by depressing the switch actuator. It can, however, ultimately fail to danger if the components of the guard are not properly maintained, e.g. excessive wear or misalignment of the cam with the switch can result in the switch actuator not being depressed far enough to open the contacts. The arrangement shown in Figure 81 is a method of reducing this possibility.

NOTE This type of switch element is specified in BS EN 60947-5-1.

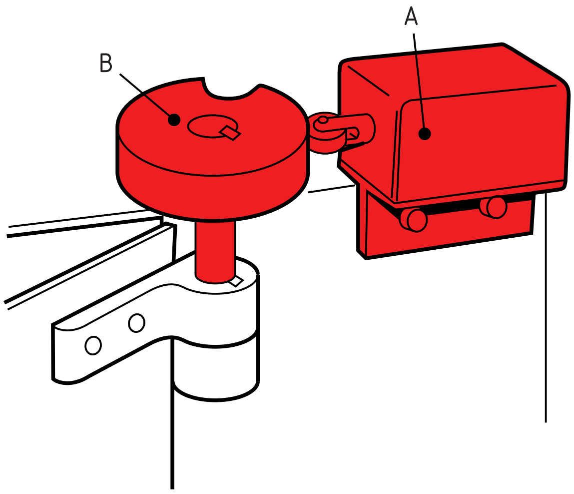
a) Position switch operating in the positive mode



In this mode of operation, a linear cam attached to a guard operates a position switch which has normally open contacts. The final closing movement of the guard depresses the actuator of the position switch, closing its contacts and allowing the machine to be set in motion. When the guard is opened, the switch contacts are opened by the action of the switch return spring. This mode of operation is unreliable because if the switch return spring weakens or breaks or the switch actuator jams, or the contacts become welded together, the circuit could remain closed after the guard has been opened. Moreover, by depressing the switch actuator manually, or by securing it permanently in that position, it is possible to operate the machine with the guard open. This arrangement, in which the switch is set to operate in the non-positive mode, would therefore fail to danger and can be readily defeated. However, it has the advantage that excessive wear in the guard or misalignment of the guard with the switch actuator can prevent the stem from being depressed far enough to allow the machine to be set in motion. This feature could be exploited by connecting the switch alongside one having normally closed contacts as illustrated in Figure 81. (Figure 79 shows an equivalent arrangement for a hinged guard.)

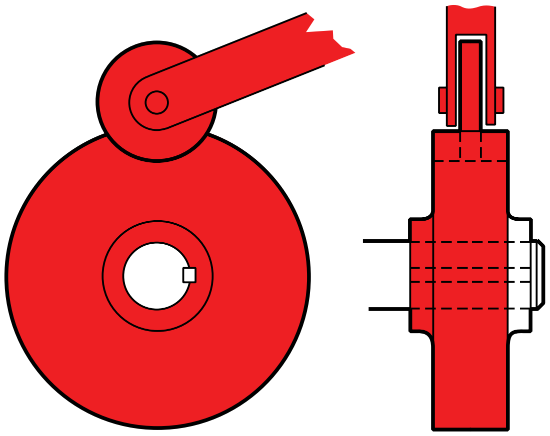
b) Position switch operating in the non-positive mode

Figure 76 **Position switches or valves actuated by rotary cams**



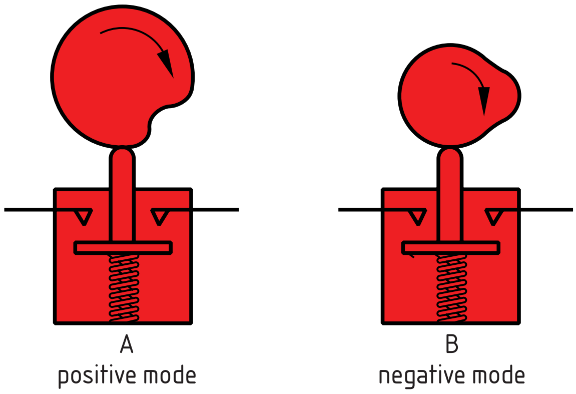
Position switch A operates in the positive mode, with a cam, B, mounted on the door hinge, profiled so as to operate swiftly as the door is opened. The switch contacts are opened positively (directly) by the action of the cam profile and closed by spring action when the door is closed.

Figure 77 **Actuation of roller-operated position switches or valves by a cam**



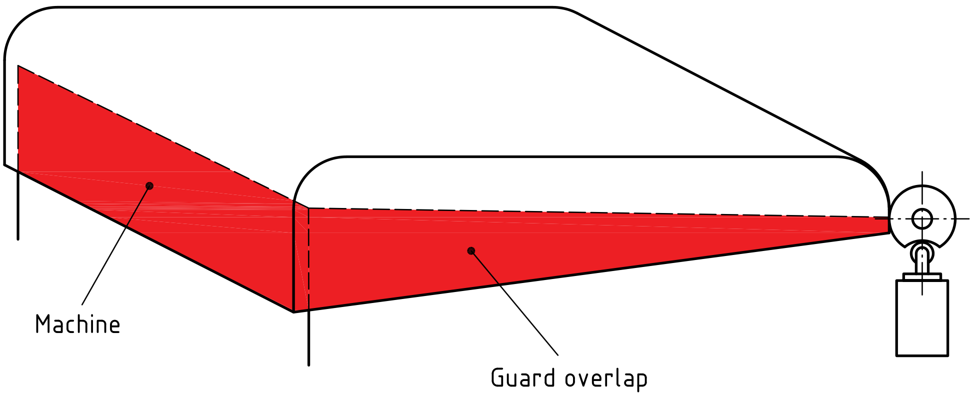
Accidents have been caused by displacement, usually due to lack of maintenance, between a cam or track and the operating member of a position switch or valve it was intended to control. The risk of failure due to lateral displacement can be reduced by increasing the width of the cam and roller. A wide roller as well as a wide cam is therefore helpful and has the additional advantage of reducing local wear. Cams should be keyed, pinned, welded or otherwise securely attached to their shafts (see BS EN ISO 14119:2013, **5.2** and **5.3)**.

Figure 78 **Position switches actuated by rotary cams (guard in open position)**



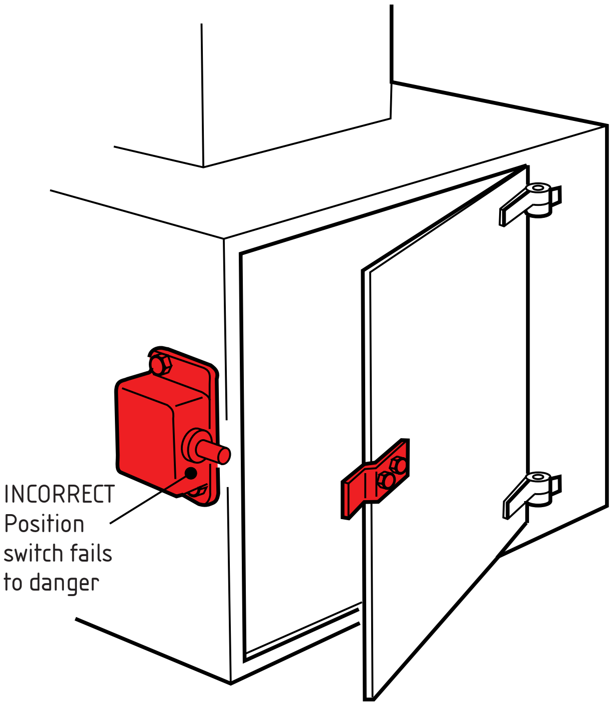
Switch A is installed in the positive mode, i.e. the contacts have been opened by a positive mechanical action of the cam. Switch B is installed in the non-positive mode, i.e. the contacts have opened by spring pressure alone. When switches are used singly, the positive mode should always be used.

Figure 79 **Large hinged guards**



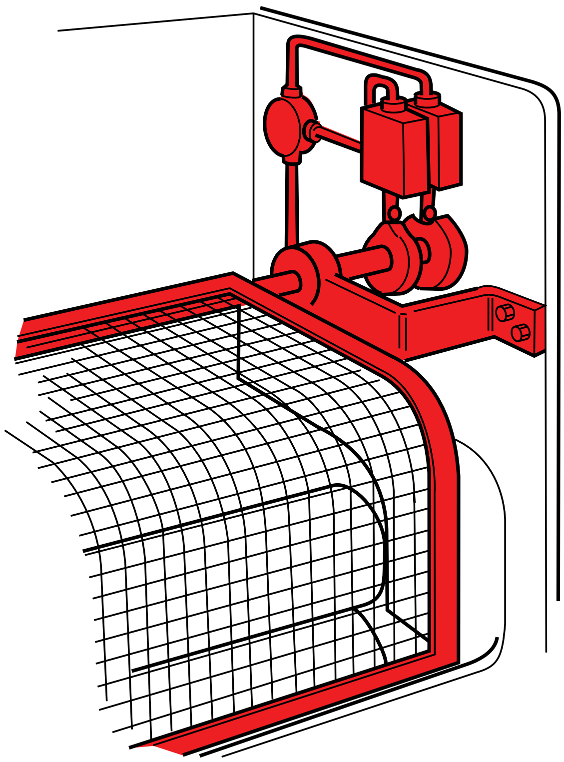
When the interlock on a large hinged guard or cover is a position switch installed in the positive mode and operated by a cam mounted on the hinge, a lack of sensitivity in the operation of the interlock can allow the cover to be opened, thus permitting access before the switch operates. One solution is to provide the cover with sufficient overlap to ensure that access to the hazardous parts cannot be gained before the cover has opened far enough for the switch to be operated. Alternative solutions involve the use of other types of interlocking switches, e.g. tongue-operated, captive key.

Figure 80 **Position switch operating in the non-positive mode (incorrect application)**



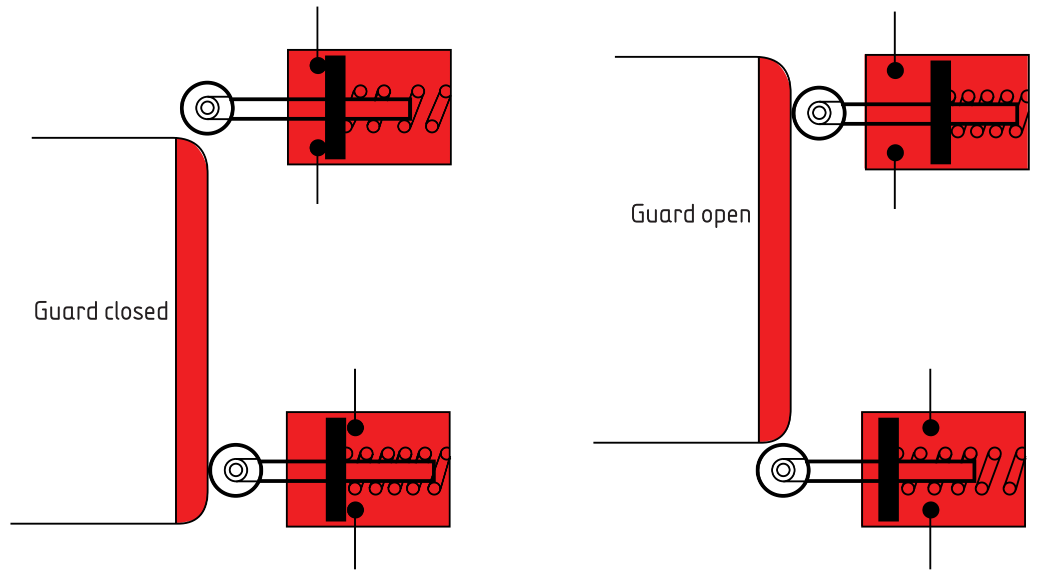
This is an example of incorrect application of a position switch as there is nothing to prevent wilful interference with its working. It would, moreover, fail to danger in the event of the switch actuator failing to extend under the action of its return spring.

Figure 81 **Two position switches operating in opposite modes, mounted side-by-side, each actuated by its own cam mounted on the guard hinge**



The non-positive mode switch [see Figure 75b)] provides safety in the event of displacement of the guard relative to the switches.

Figure 82 **Mounting of position switches in opposite modes**



By using two position switches, one with contacts normally closed and the other with contacts normally open, a higher standard of integrity is achieved. However, if one switch fails, the failure is not immediately apparent and the operator's safety depends on the correct functioning of the other. This can be overcome by monitoring the circuits in which the switches are used, as described in **10.2.1.2**.

9.6.3 Tongue-operated switch

9.6.3.1 General

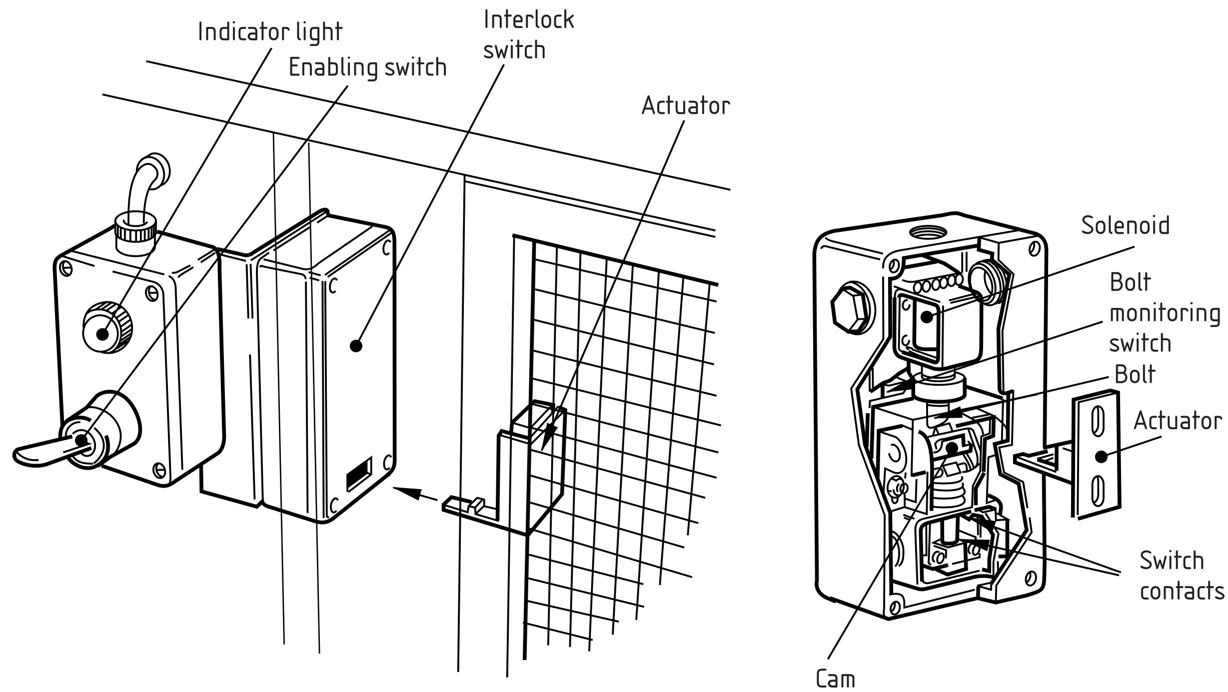
Generally, for a tongue-operated switch, a tongue is secured to the movable part of the guard that positively (directly) operates the cam of a combined cam and switch fitted to the fixed part of the machinery (see BS EN ISO 14119:2013, Annex B).

9.6.3.2 Interlocking switch with solenoid-operated guard locking (see Figure 83)

An interlocking switch with solenoid-operated guard locking contains an integral solenoid-operated lock which holds the guard in the closed position. The guard position is monitored and, where the locking function is safety related, the locking position should also be monitored so that the machine does not run unless the guard is closed and locked. Once closed, the guard cannot be opened without a release signal being applied to the solenoid which can be supplied via either a preset timing device or a remote source such as a rotation sensing device, temperature controller or end-of-cycle instruction. Once the lock release signal is available guard opening can take place (see BS EN ISO 14119:2013, **5.7.2** and Annex F).

The locking element should be "power to unlock" or "power to lock and power to unlock" unless the risk assessment shows that this is not appropriate. If in a specific application other methods, for example, "power to lock" are used, they should provide an equivalent level of protection.

Figure 83 **Solenoid locking interlock switch**



The switch is mounted on the fixed portion of the guard. The actuator is mounted on the moving guard. Closing the guard causes the actuator tongue to enter the switch, engage the bolt and operate the integral cam allowing the contacts to close. When the solenoid is energized the actuator tongue can be withdrawn, turning the cam and opening the contacts by direct opening action.

9.6.4 Captive-key switch (see Figure 84)

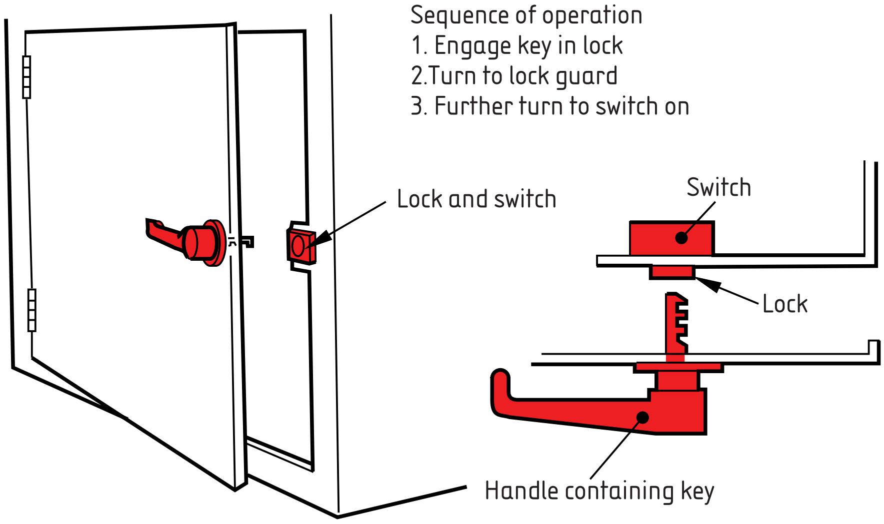
9.6.4.1 General

Generally in a captive-key switch, a key is secured to the movable part of the guard, and a combined lock and switch unit is fitted to the fixed part. To open the guard, the key is turned which puts the switch to the "off" position and releases the key from the lock so that the guard can be opened.

9.6.4.2 Time or remote delay captive-key unit (see Figure 85)

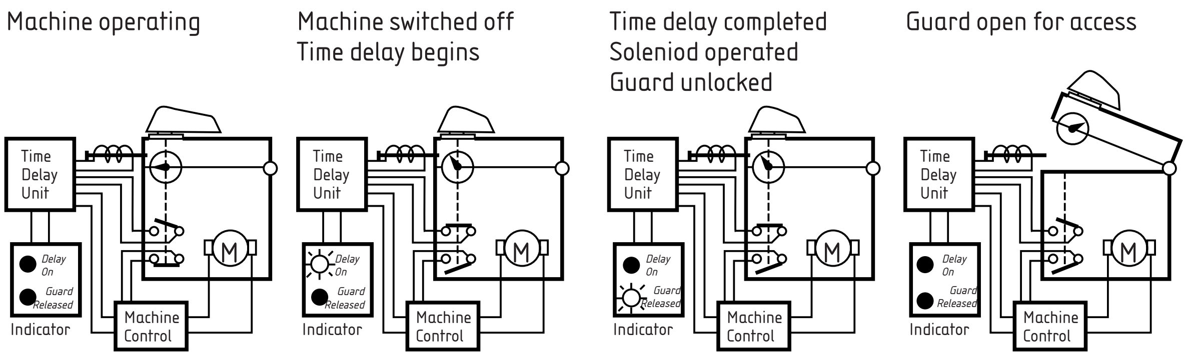
Captive-key interlock systems can be designed with an integral electromechanical locking element that ensures that the key cannot be turned to the "guard open" position until the machine has come to rest (or the hazard is no longer present). The signal for unlocking can be generated by an electrical timer or from a remote device such as a rotation sensing device or hazardous substance detector. A lamp to indicate when the guard has been released is an added advantage.

Figure 84 **Captive-key switch**



In this method of interlocking, a combined switch and lock is attached to the machine and a key is secured to the guard. In order to engage the key in the lock, the guard has to be fully closed. Alignment of the key and switch can be aided by providing a location pin or pins that engage in bushes prior to the key entering the switch.

Figure 85 **Time delay captive-key unit**



The time delay commences when the machine is switched off. When the time delay is completed, the locking element is released by energizing the solenoid and the guard can be opened for access.

9.6.5 Trapped-key interlocking system (key exchange)

9.6.5.1 General

A trapped-key interlocking device relies upon the transfer of keys between a control element and a lock fixed on the guard (guard lock). In a trapped-key interlocking device, the guard lock and the switching element, which also incorporates a lock, are separate as opposed to being combined into a single unit.

The essential feature of the system is that the key is trapped either in the guard lock, or in the switch lock. The lock on the guard is arranged so that the key can be released only when the guard has been closed and locked. This allows transfer of the key from the guard to the switch lock.

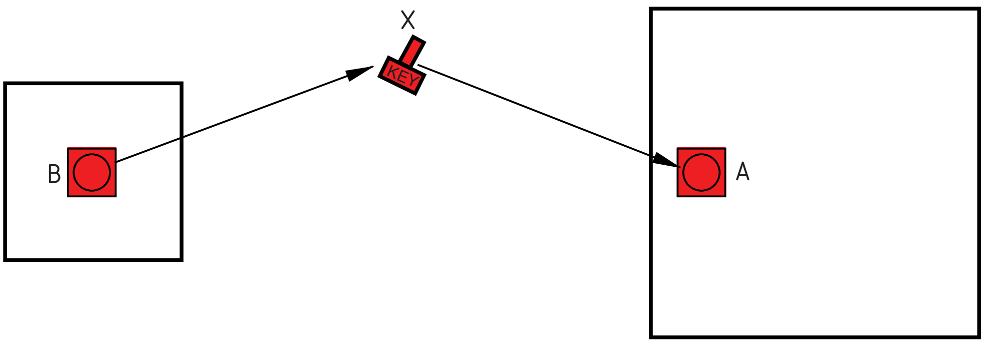
Closing the switch traps the key, so that it cannot be removed while the switch is in the "on" position.

If there is more than one source of power, and therefore more than one element in the output system to be actuated, then a key-exchange box (see Figure 86) is necessary, to which all keys have to be transferred and locked in before the access key, which is of a different key coding, can be released for transfer to the guard lock. Where there is more than one guard, the exchange box can accommodate an equivalent number of access keys.

Where, for the purpose of the process or of safety, a number of operations has to be carried out in a definite sequence, then the transferable key is locked in and exchanged for a different one at each stage. The exchange box can be integral with the lock.

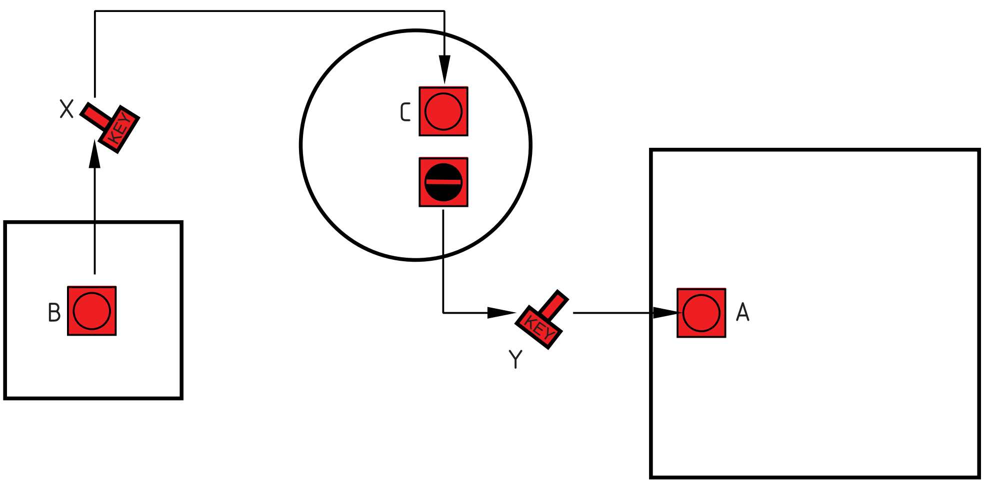
There is the possibility with any interlocking system employing separate keys that the keys could be used without authorization. The operation of such systems should therefore be restricted to responsible persons (see BS EN ISO 14119:2013, **G.2)**.

Figure 86 **Trapped-key interlocking systems** *(1 of 2)*



A represents a lock on a guard preventing access to hazardous parts and B is the switch or valve controlling the power supply to the machine. Key X, when engaged with lock A, cannot be freed until the guard is fully closed and locked. Only in these circumstances is key X available to switch on the power supply at B and this action automatically traps key X which cannot be freed until the power supply is switched off. An application of this arrangement is shown in Figure 87.

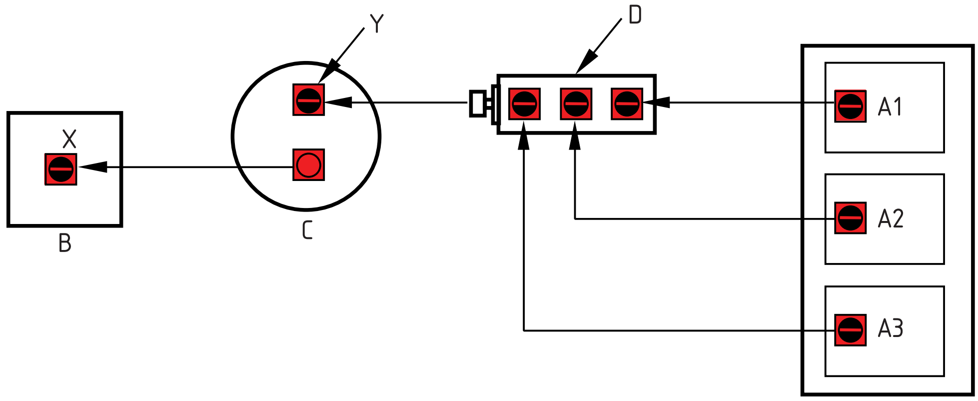
a)



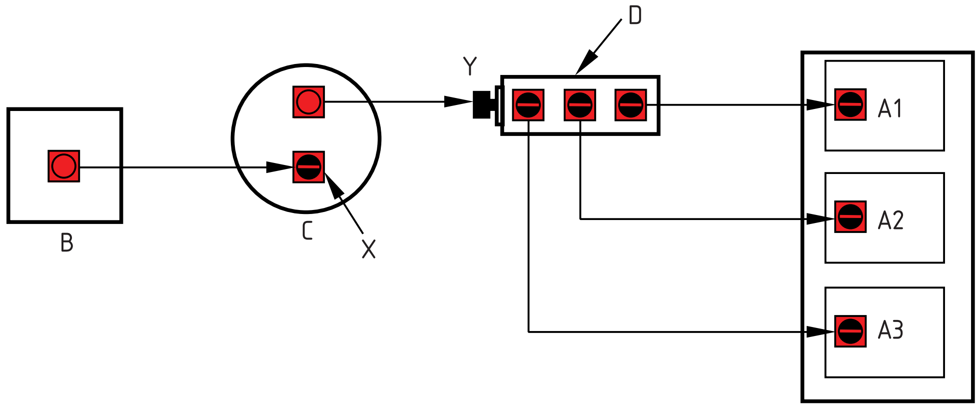
This shows the same arrangement as in a), except that C represents a time delay key exchange unit and X and Y are independent, different keys. The time delay unit ensures that there is a specific time interval before key Y is made available for unlocking guard A and this interval has to be greater than that required for hazardous operation to cease after the power is cut off. Power can be applied to the machine only when key X is captive in the switch at B (i.e switched on) and therefore guard A is closed and locked. When power is switched off at B, key X is freed and can be inserted in the upper lock in C. It is only after the specified time interval that key Y can be freed to unlock guard A. Key X remains captive in the time delay unit C.

b)

Figure 86 **Trapped-key interlocking systems** *(2 of 2)*



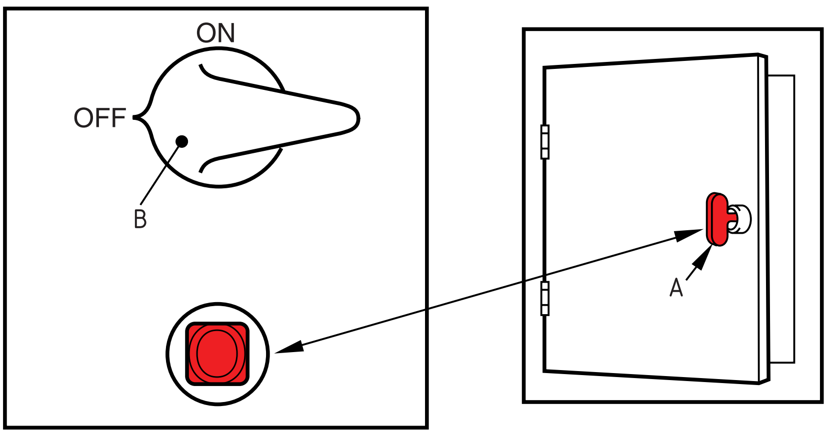
c)1) Key transfer from guard doors to switch



c)2) Key transfer from switch to guard doors

This shows the principles outlined in b), extended to cover three guards, A1, A2, and A3, each with a separate (but not necessarily different) key. The addition of a multiple key exchange box, D, complicates the arrangement only to the extent that the master key, Y, is kept captive until all the keys, A1, A2 and A3, are replaced within exchange box, D. When key Y is thereby freed it can be transferred to the time delay key exchange box, C, and then be made captive in it by the removal of key X to switch on the power supply at B. The subsequent unlocking procedure is as outlined in b). Keys A1, A2 and A3 can be replaced in D only when the guards to which they relate are closed and locked.

Figure 87 **Practical application of the trapped-key interlocking system shown diagrammatically in Figure 86a)**



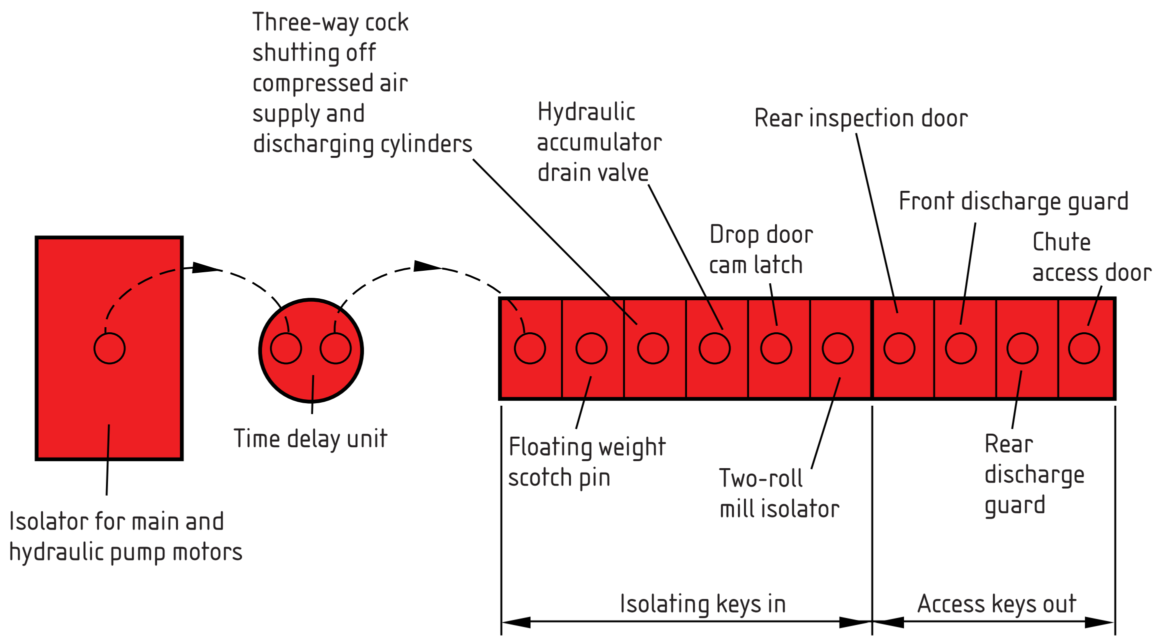
Key A is trapped in the guard door and can only be turned and removed when the guard door is closed thus locking the door. Switch B cannot be turned on until key A has been inserted, turned and thereby captive in lock C. Key A can only be removed from C when B is in the "off" position.

9.6.5.2 Time delay key exchange unit

Where a trapped-key interlocking system is employed (see Figure 88), a time delay key exchange unit containing a timing mechanism can be used to prevent the guard from being opened until the hazard is no longer present.

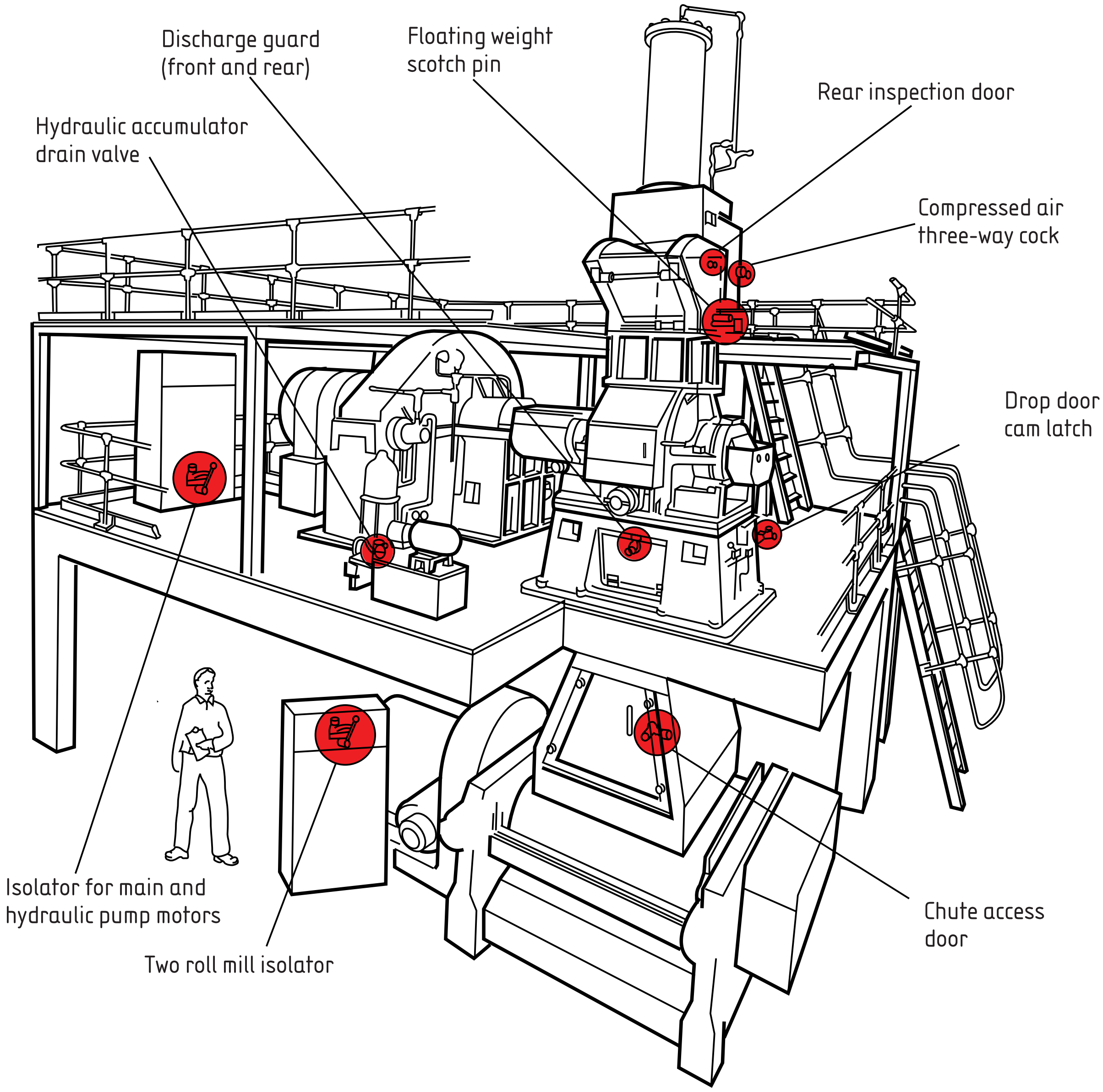
Until the power has been cut off and the preset time in the timing mechanism has elapsed, the key required for unlocking the guard cannot be removed from the exchange.

Figure 88 **Internal mixing machine: example of the use of a trapped-key interlocking system** *(1 of 2)*



a)

Figure 88 **Internal mixing machine: example of the use of a trapped-key interlocking system** *(2 of 2)*



b)

At an internal mixing machine, used in the processing of rubber, trapped-key exchange interlocking provides one means of preventing access to a number of widely separated danger areas. The principle employed is that all sources of power are isolated, and all stored energy is dissipated, before access is possible. For this and other methods of interlocking, see also BS EN 12013.

Interlocking is achieved by means of a main key exchange box, shown in a), into which all isolating keys have to be inserted before any access key can be released. When a guard is open, an access key is trapped in it. Similarly, when a part controlled by an isolating key is live, the key remains trapped in it. For example, before the rear inspection door shown in b) can be unlocked and opened, the compressed air supply has to be locked shut, with both ends of the floating weight cylinder vented to atmosphere and the floating weight supported on a scotch pin which is locked in position. In addition the isolator for the main and hydraulic pump motors has to be locked open and the rotors have to be at rest. This latter condition is achieved by a time delay unit which releases an isolating key for the main exchange box only after sufficient time has elapsed for the motor to come to rest.

Access to the other hazardous parts is obtained by a similar process.

9.6.6 Uncoded non-contact switches

These devices have various operating principles, including: inductive, magnetic, capacitive, ultrasonic and optical. Uncoded non-contact switches are not generally suitable for interlocking duties unless additional measures are taken to prevent their defeat (see BS EN ISO 14119:2013, **7.2**).

9.6.7 Coded non-contact switches (see Figure 89)

These devices have various operating principles, including: magnetic, radio frequency identification (RFID) and optical. Different levels of coding are provided varying from low level (1 to 9 codes) to high level (greater or equal to 1 000).

These devices can be used where the following attributes are required:

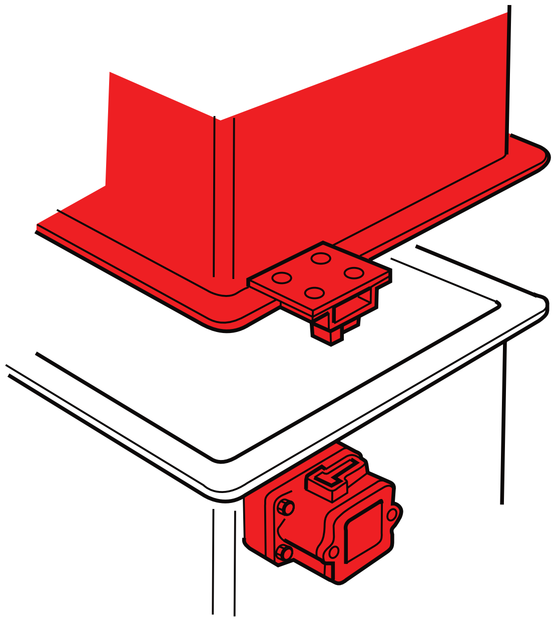
a) high integrity;

b) resistance to ingress of liquid and dusts, i.e. high IP rating (see BS EN 60529); and

c) tolerance to guard misalignment and movement.

NOTE See Type 4 interlocking devices in BS EN ISO 14119:2013, Table 1.

Figure 89 **Example use of a non-contact switch where an interlocking guard has to be removed**



Where a guard has to be removed from a machine, interlocking can be achieved by the use of a coded non-contact switch. The act of removing the guard separates the two parts of the switch, thus opening the control circuit. The use of tongue operated switches is not recommended where there is the possibility for damage to the actuating tongue when the guard is handled (see also **7.2.2**).

9.6.8 Magnetic switch

Magnetic switches should be selected only from those whose performance, as stated by the manufacturer, is suitable for the specific safety application.

Where the switching element is a reed, it should be specifically designed for machinery safeguarding. It should be designed to provide maximum immunity from vibration and contact welding. If overloaded, the switch should fail to an open circuit condition.

9.6.9 Plug and socket system

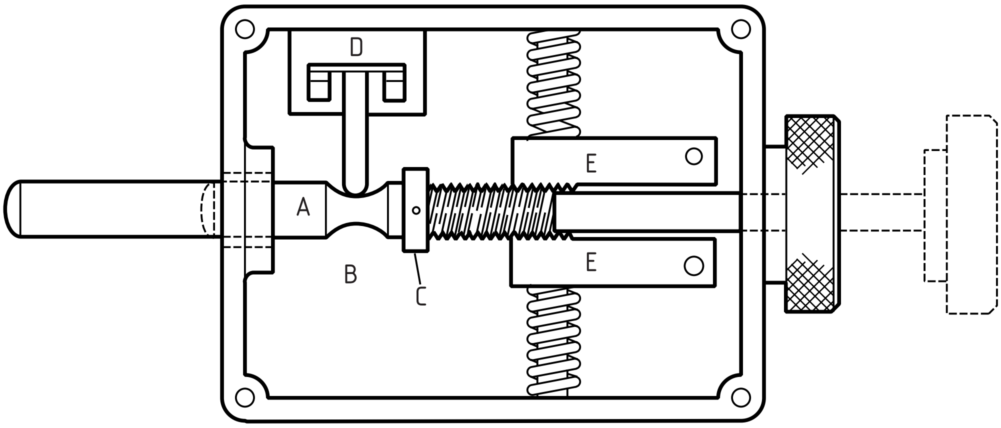
In some cases a plug with a diode link and a socket is used as a control switch, the socket being used in the control circuit and mounted on the machine, with the plug mounted on the guard. This diode linking method uses a slugged relay that responds only to direct current, and not to alternating current. The control relay cannot therefore close unless the alternating current is rectified by passing through the diode that links the terminals in the plug. This reduces the risk of the system being defeated by the insertion of a bridging wire into the socket. The risk of electric shock should be minimized by the use of an extra-low voltage system.

9.6.10 Manually-operated delay device (see Figure 90)

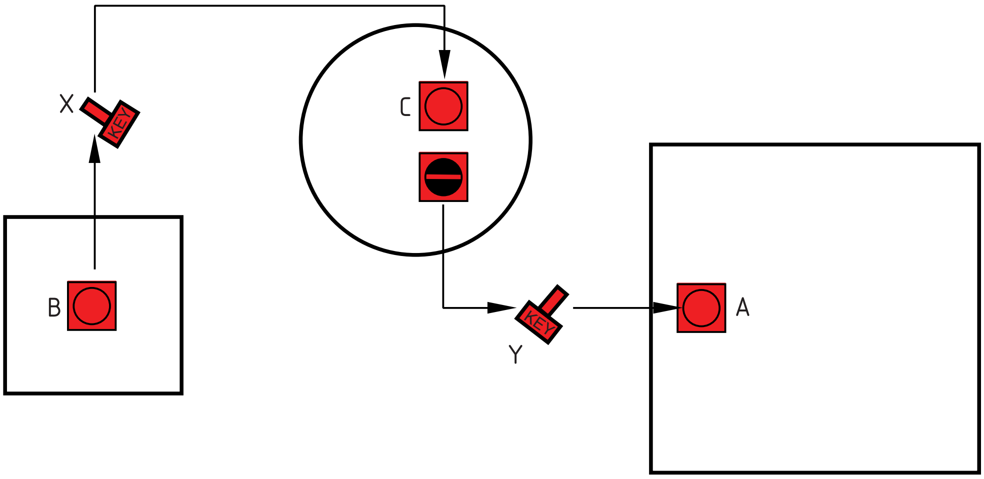
In place of a timing mechanism to provide the delay element, a bolt with a long threaded portion can be used, the length of the thread and the design of the mounting being such as to ensure that the time taken to manually unscrew the bolt exceeds the time required for the hazardous operation to cease after the power has been switched off. For example, the bolt can be arranged to operate a position switch so that as the bolt is unscrewed the first few turns cause the contacts to open and switch off the power supply.

The design of the guard and interlock arrangement should ensure that the bolt cannot be extended unless the guard is fully closed.

Figure 90 **Manually-operated delay device**



a)



b)

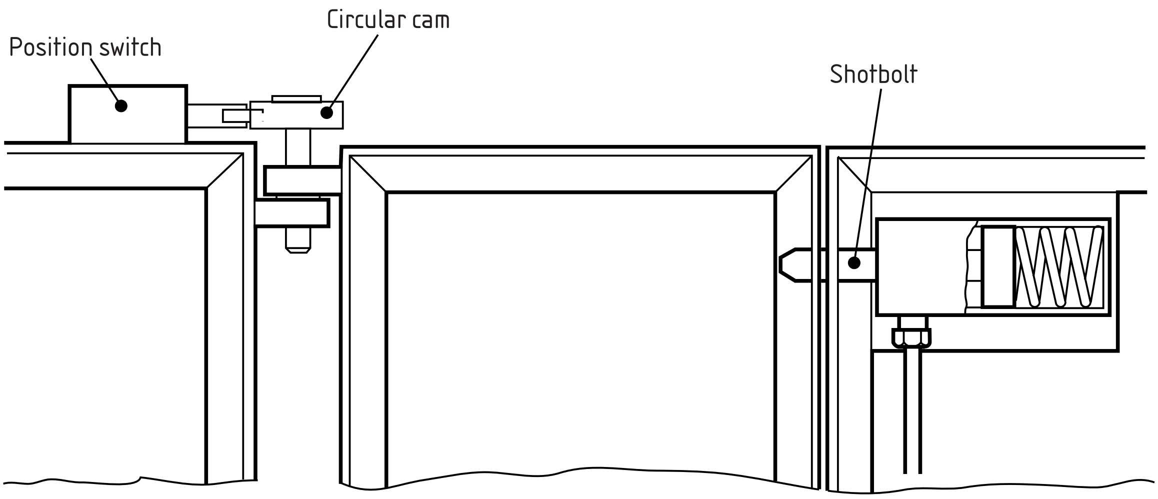
The method of operation of a manually-operated delay device, and its application to a hinged guard are shown respectively in a) and b). The device consists of a captive bolt, A, with a knurled head at one end and a long portion which carries a fine thread. Pinned to the bolt is a collar, C, which acts as a stop and machined into the bolt is an annular recess, B, into which the actuator of the switch, D, can locate allowing the switch contacts to close, when as shown bolt A is in its outermost position with the guard locked. The machinery is then operable. If bolt A is now unscrewed, the first few turns open switch D in the positive mode, i.e. not by the switch return spring, but the door cannot be opened until the end of the period of time required to unscrew the bolt to its limiting position as shown dotted. It is not possible to restart the machinery until the guard has been closed and the delay bolt fully returned, but this does not involve any loss of time because the bolt can be pushed in a straight line causing the split threads, E, to open against spring pressure. The construction prevents straight-line movement in the direction of withdrawal.

9.6.11 Shotbolt (see Figure 91)

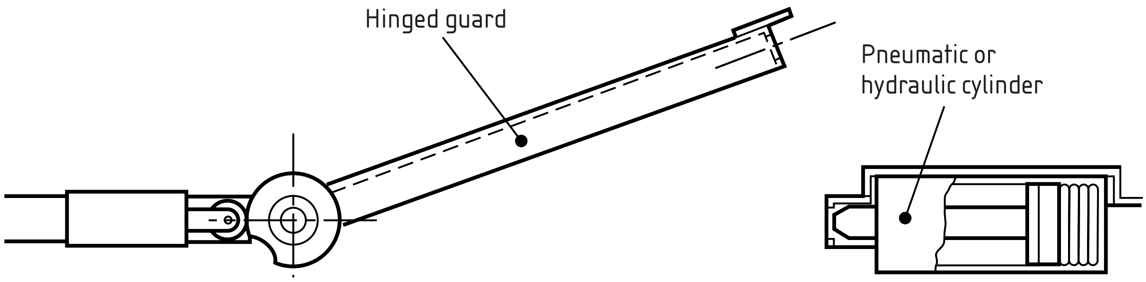
In addition to specially-designed safeguarding devices with integral bolts, solenoid-operated bolts can be used, in conjunction with conventional interlocking devices, to retain guards in position while a machine is operating and during run down, etc.

BS 6753 specifies requirements for power-retracted, spring-extended shotbolts for this purpose. Their integrity can be improved by monitoring the position of the bolt so that the machine can only operate when the bolt is extended and locking the guard in the closed position. The guard can be designed so that in all positions other than closed the bolt movement is blocked.

Figure 91 **Locking a guard closed with a shotbolt**



a) Closed



b) Open

The illustration shows a hinged guard with a position switch interlock and circular cam arranged to operate in the positive (or direct) mode. The addition of a shotbolt (shown in the diagram as a pneumatic or hydraulic cylinder, but which could equally well be a solenoid-operated bolt) can provide additional protection, particularly when time delayed access is required.

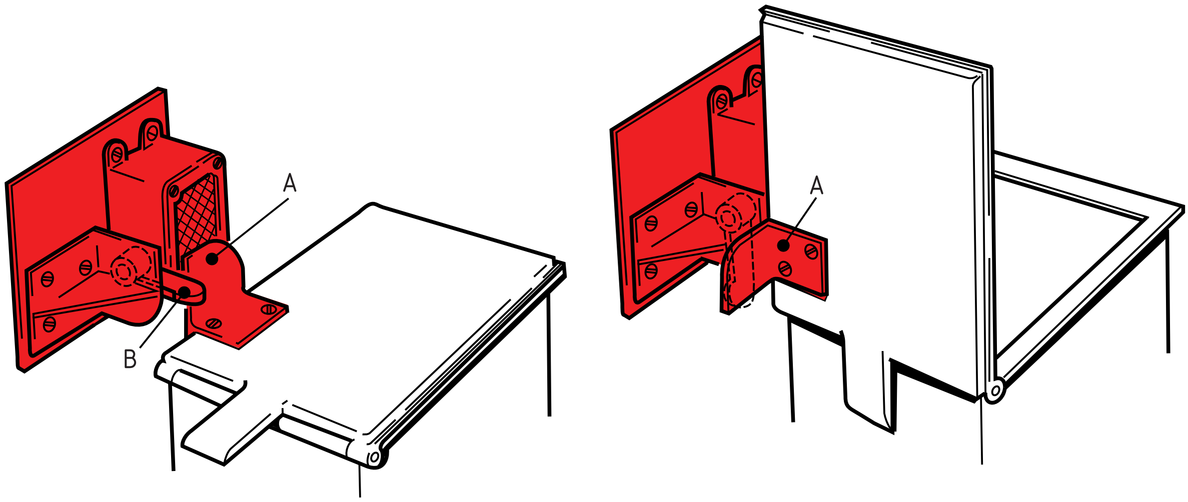
9.6.12 Power interlocking (see Figure 92)

Power interlocking directly interrupts the energy supply to the machine actuators or disconnects moving parts from the machine actuators. "Directly" means that, unlike control interlocking, the control system does not play any role in the interlocking function.

Resumption of the energy supply is only possible with the guard in the closed position.

Usually, power interlocking is applied when the requirement to open the guard is infrequent. High-power switching devices have a limited rating for the number of operations under load, and care should be taken not to exceed this rating.

Figure 92 **Guard locking power interlocking**



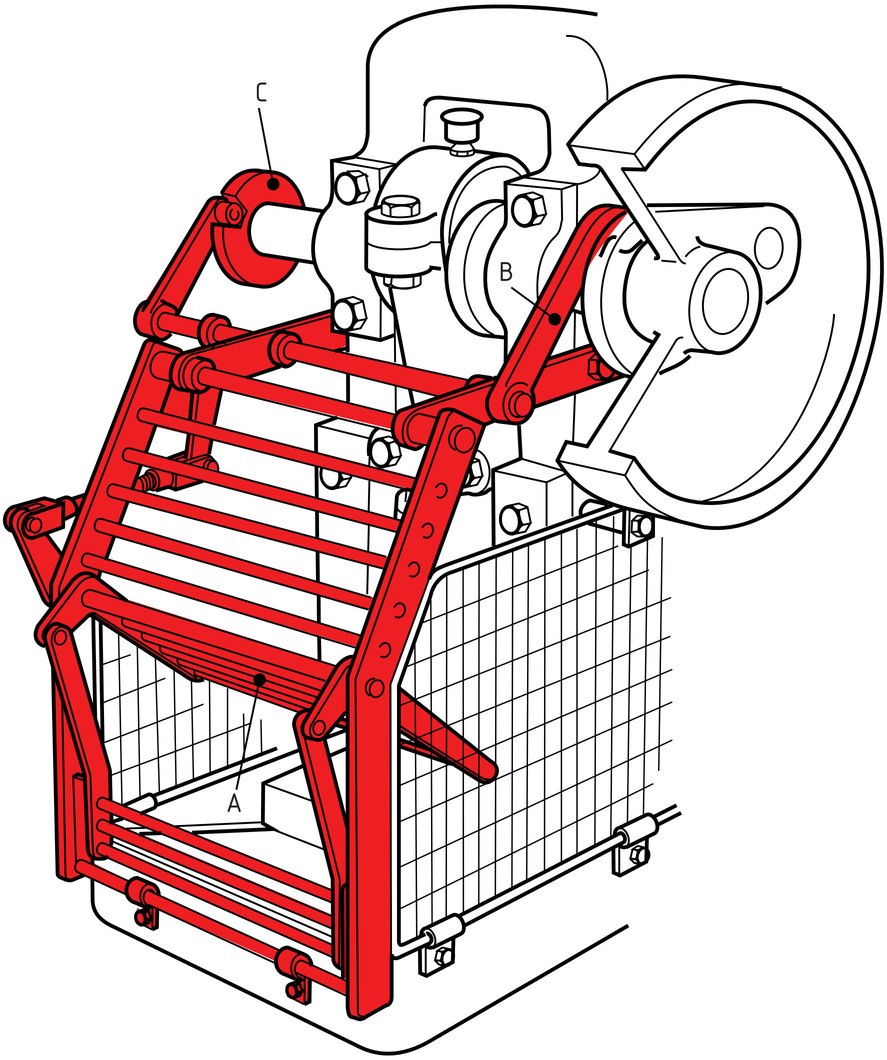
Direct mechanical control of an industrial ironclad switch in series with the mains power supply is achieved by interlocking projection A on a guard with the switch handle, B.

9.7 Mechanical interlocking devices

9.7.1 General

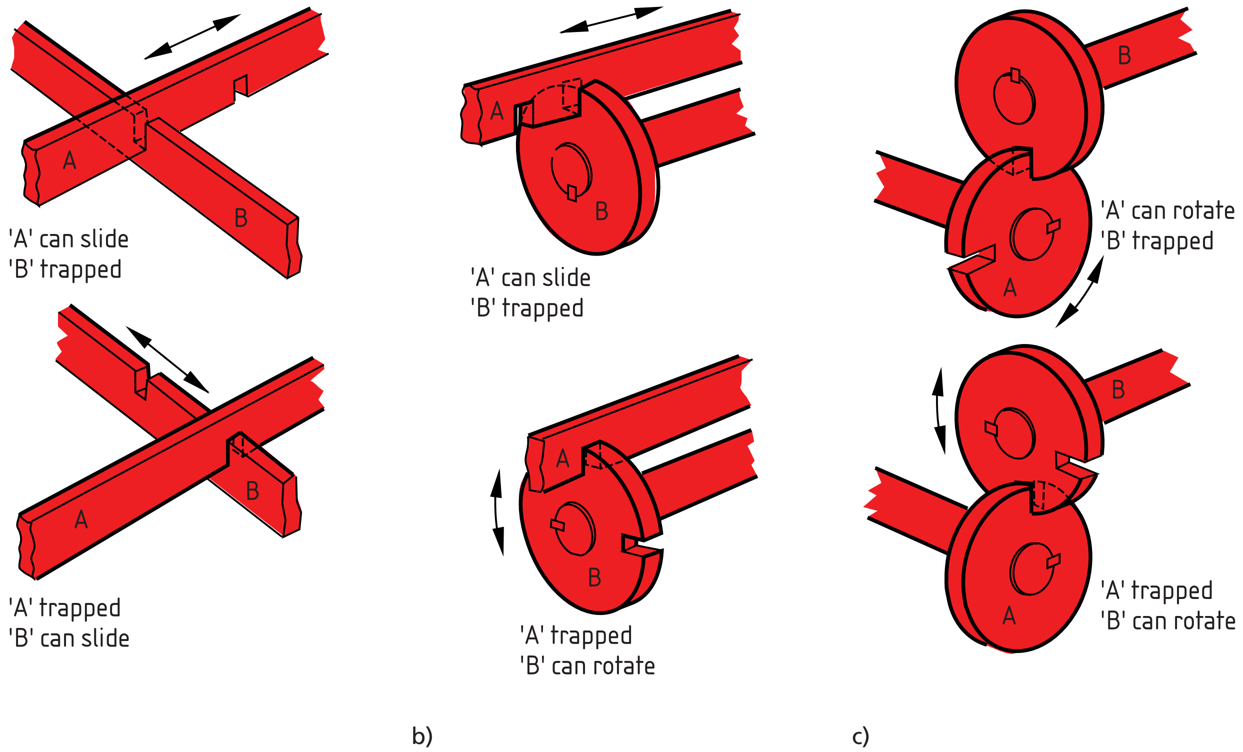
Mechanical devices for connecting guard movement with the machine power or control system can take various forms, but generally perform the same function. They are usually in the form of discs, bars or levers, arranged so that operation of the guard and the machine can only be carried out in a correct safe sequence. Figure 93 shows one such arrangement in which a cam, C, prevents the guard from being opened until the press stops at the end of its cycle and lever B prevents the clutch being engaged to start the press while the guard is open. A safe sequence of operation is thus ensured. Three different ways of mechanically interlocking two components are shown in Figure 94.

Figure 93 **Interlocking guard for positive clutch power press**



The guard consists of an enclosure with a movable gate, A. When the gate is closed the guard prevents access of any part of the body to the hazardous area from any direction. The gate is interlocked by lever B with the clutch mechanism in such a way that the press cannot operate until the gate is fully closed. While a stroke is being made the gate is held closed by cam C and cannot be opened until the clutch has disengaged and the crankshaft has come to rest at the correct stopping position, usually at top dead centre.

Figure 94 **Principles of mechanical interlocking**



In each of the three methods illustrated, there are two components, each of which is responsible for a particular function. One of these is usually the movement of a guard; the other could be, for example, the operation of a clutch, switch or the actuation of a hydraulic or pneumatic valve. The purpose of mechanical interlocking is to ensure that the two functions are performed in a correct safe sequence.

9.7.2 Design

Transmission of forces and movements in a mechanical interlocking system relies on the integrity of the individual components and their mechanical construction and assembly.

When assembling components on to shafts, these should be secured positively (e.g. welded, keyed or pinned), following good engineering practice to prevent loosening.

Certain components are provided with adjustment to enable them to be correctly installed. These adjustable components should then be fixed, e.g. by pinning, to prevent improper setting thereafter. Adequate provision should be made for regular maintenance and lubrication where necessary.

9.8 Pneumatic interlocking devices

9.8.1 General

Devices used for interlocking guard movement include:

a) cam-operated valves (see **9.8.2**);

b) captive-key valves (see **9.8.3**);

c) trapped-key interlocking system (key exchange) (see **9.8.4**);

d) pneumatically-operated shotbolts (see **9.8.5**); and

e) power interlocking (see **9.8.6**).

When valves are selected for machinery safeguarding applications, the valve operating parameters (pressure, temperature, etc.) and reliability should be suitable for the environment and the duty envisaged (see also Section 10).

9.8.2 Cam-operated valve

A cam-operated valve can be actuated in either the positive or non-positive mode [see Figure 95a) and b)].

In the positive mode, the valve is held in the shut-off position by a cam attached to the guard, when the guard is in any position other than fully closed. The final closing movement of the guard releases the valve, allowing the supply to connect to the output by the action of the return spring. When the guard is opened, the supply is cut off and the output exhausted by the action of the cam.

In the non-positive mode, the final closing movement of the guard positively operates the valve, connecting the supply to the output and allowing the machine to be set in motion. When the guard is opened, the valve is reversed by the action of a spring when the operating mechanism is released, the valve cutting off the supply.

In a system where a single cam-operated valve is used, the valve should always be installed in the positive mode except where two valves are used to improve the mechanical reliability [see **9.6.2** and Figure 95c)], to ensure that the valve flow paths are opened by the operation of the cam, and to prevent the valve from being deliberately defeated. Valves should have sufficient pre-travel and over-travel to avoid being damaged by the action of the cam. Care should be taken when installing such valves to ensure that the flow paths are fully open when operated. Additionally, an adequate degree of valve stem over-travel should be utilized to allow for the foreseeable loss of movement due to cam or track wear. Internal and external mounting arrangements should, as far as practicable, be proof against vibration or maladjustment.

When the guard or cover can be completely removed from the machinery, i.e. it is not restrained by hinges or a track, positive mode actuation by means of a guard operated cam is not possible. Either option captive-key valves (see **9.8.3**) or trapped-key control of pneumatic valves (see **9.8.4**) should therefore be used.

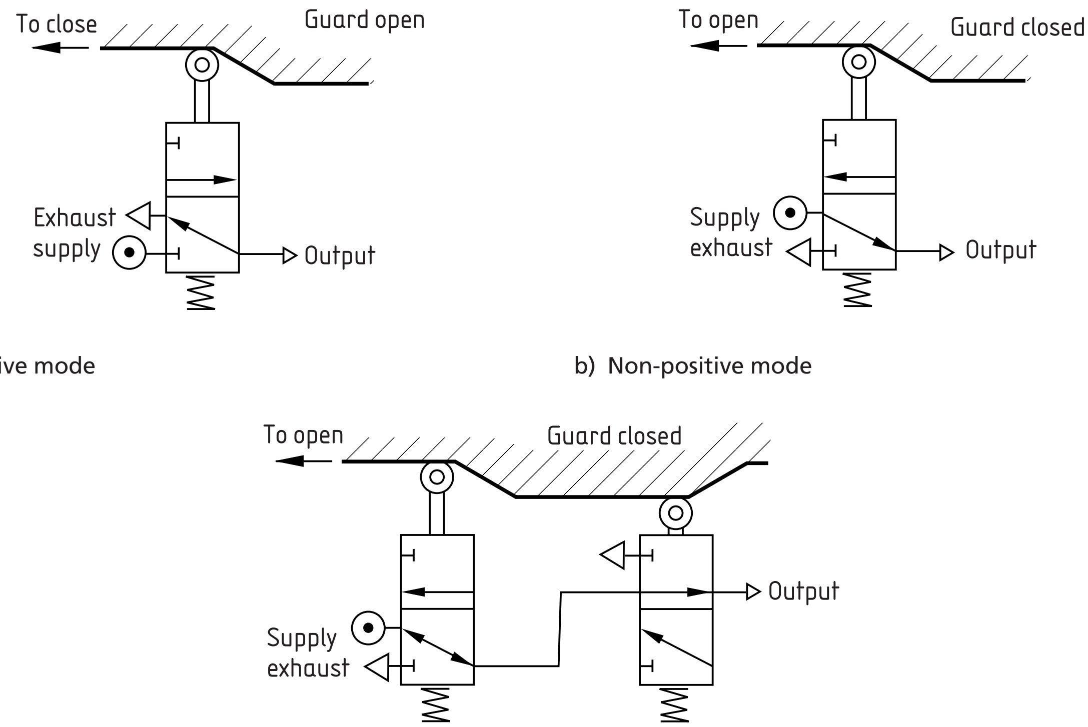
9.8.3 Captive-key valve

Generally, in the captive-key valve, a key is secured to the movable part of the guard and a combined lock and valve unit is fitted to the fixed part. To open the guard the first movement of the key puts the valve to “off”. Further rotation releases the key from the lock so that the guard can be opened. A delay can be incorporated as in the equivalent electrical device (see **9.6.4**).

9.8.4 Trapped-key interlocking system (key exchange)

In a trapped-key interlocking system, the guard lock and valve, which also incorporates a lock, are separate rather than combined into a single unit as in the captive-key valve. The essential feature of the system is that the removable key is trapped either in the guard lock or in the valve lock. The lock on the guard is arranged so that the key can be released only when the guard has been closed and locked. This allows transfer of the key from the guard to the valve lock. Closing the valve traps the key so that it cannot be removed while the valve is in the “on” position. Where a number of access points are to be interlocked, the use of a key exchange unit enables their interlocking with one or more valves. A delay can also be incorporated in the key exchange unit as in the equivalent electrical device (see **9.6.5**).

Figure 95 **Diagrams for a cam-operated pneumatic interlocking valve**



a) Positive mode

b) Non-positive mode

c) Combined positive and non-positive arrangement

This shows three arrangements for cam-operated valves.

a) shows the positive mode where the valve is opened positively by the action of the cam profile on the guard and closed by spring action. b) shows the non-positive mode where the valve is opened by spring action and positively closed by the action of the cam profile on the guard. c) shows an arrangement which combines both a non-positive mode and a positive mode valve to improve the integrity of the cam and valve assembly.

9.8.5 Pneumatically-operated shotbolt

As an alternative to safeguarding devices with integral bolts, pneumatically-operated bolts could be used to retain guards in the closed position while a machine is operated and during run down, etc. Where shotbolts of this nature are used, they should be designed to minimize failure to danger, i.e. power retracted/spring extended, or bistable.

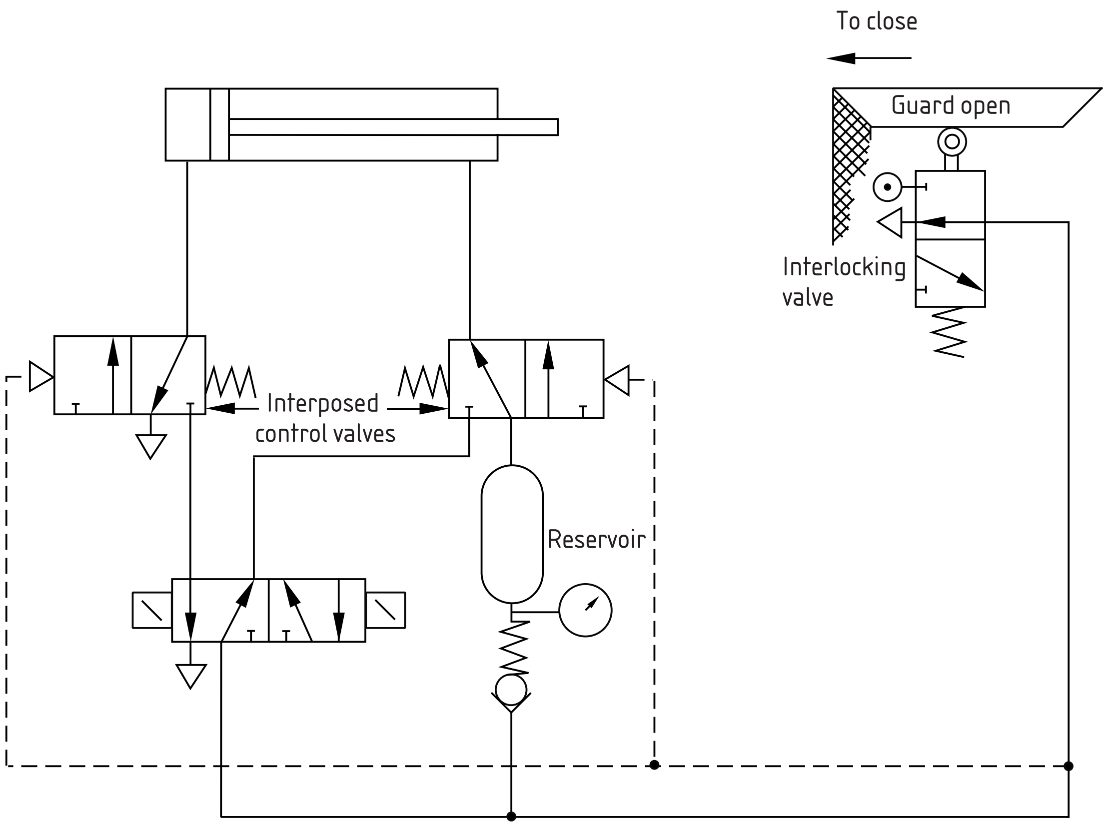
Where the guard is designed so that in all positions, other than closed, the bolt movement is scotched (see Figure 91), guard interlocking can be achieved by monitoring the position of the bolt so that the machine can only operate when the bolt is extended and locking the guard in the closed position. Guard interlocking could also be achieved by using the shotbolt in conjunction with conventional interlocking devices.

9.8.6 Power interlocking

Power interlocking is achieved by direct mechanical action of a valve in the main air supply, close to the actuator. The mechanical action may be direct from guard movement (see Figure 96), via a linkage or by a captive key or trapped key.

Interlocking by means of air isolation and exhaust could give rise to difficulties on machinery which relies on the air supply to keep heavy articles suspended or components clamped in position. Similarly, where machinery is designed to perform automatically a series of functions in sequence (see Figure 105), air isolation and exhaust interlocking could lead to the need for extensive manual resetting of actuators and sequencing valves before the automatic cycle can be restored. For these reasons, power interlocking methods are not normally practicable for complex air-operated machinery so that control system interlocking of the pilot signals has to be used.

Figure 96 **Interlocking guard with and without guard locking** *(1 of 2)*

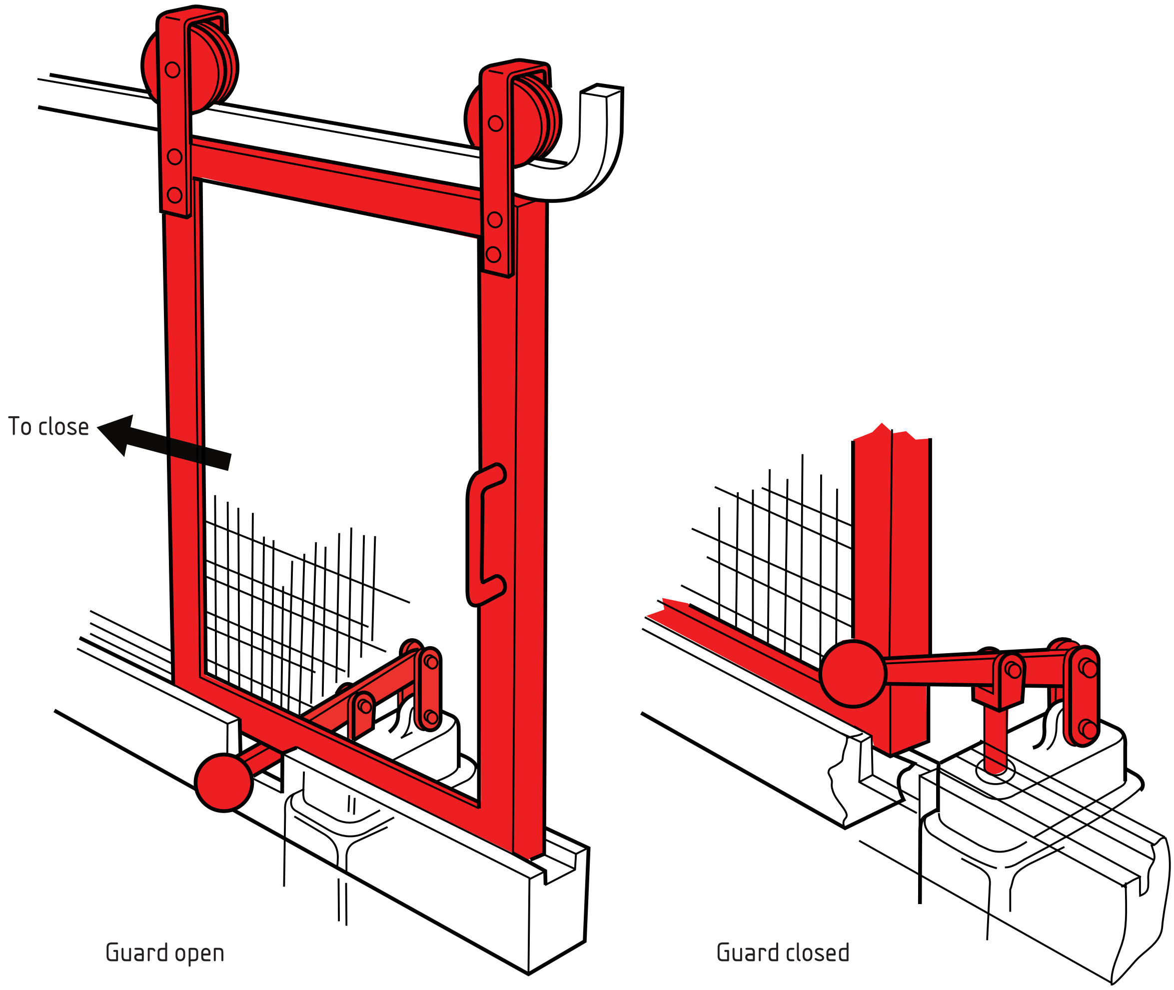


a) Interlocking without guard locking

NOTE 1 Cylinder returned to instroke position whenever guard is open.

NOTE 2 Where it is practicable to use a single acting cylinder, the interposed control valve and reservoir may be dispensed with.

Figure 96 **Interlocking guard and interlocking guard with guard locking interlocking** *(2 of 2)*



b) Interlocking guard with guard locking

NOTE Circuit is as shown in a) but with manual interlocking valve arranged as shown.

The difference between power interlocking without guard locking (see **9.3.3**) and power interlocking with locking (see **9.3.4**) is illustrated. In a) the compressed air supply is interrupted directly by the interlocking valve which is automatically operated by movement of the guard. Nothing prevents the guard from being open or closed.

In b) the principle of guard interlocking with guard locking interlocking is exemplified in this illustration of a horizontally sliding guard. While the guard is open the lower edge of the guard retains the lever of the control valve in the safe position. When the guard has been closed the lever can be moved to set the press in motion thus locking the guard closed.

Where machinery parts could fall under gravity, a suitable anti-fall device should be incorporated (see **5.10** and **8.7**).

9.9 Hydraulic interlocking devices

9.9.1 General

Devices used for interlocking guard movement include:

a) cam-operated valves (see **9.9.2**);

b) hydraulically-operated shotbolts (see **9.9.3**); and

c) power interlocking (see **9.9.4**).

9.9.2 Cam-operated valves

A cam-operated valve can be actuated in either the positive or non-positive mode. When actuated in the positive mode, the valve is held in the shut-off position by a cam attached to the guard, when the guard is in any position other than fully closed. The final closing movement of the guard releases the valve, allowing the supply to connect to the output by the action of the return spring. When the guard is opened, the supply is cut off and the output returned to tank by action of the cam. When actuated in the non-positive mode, the final closing movement of the guard positively operates the valve, connecting the supply to the output and allowing the machine to be set in motion. When the guard is opened, the valve is reversed by the action of a spring when the operating mechanism is released, the valve cutting off the supply.

If a single valve is used it should be installed in the positive mode such that the valve is directly opened by the operation of the cam. If a cam is not used, the valve cannot be operated in the positive mode and can therefore be easily defeated by depressing the actuator while the guard door is open. In the event of spring failure the valve can remain open. See Figure 95 for general principles.

If two valves are used to improve mechanical integrity, one in the positive and one in the non-positive mode, it can reduce the possibility of common cause failure, for example, due to guard displacement or wear (see Figure 77 and Figure 78).

In addition, valves actuated in the positive mode should have sufficient pre-travel and over-travel to avoid being damaged by the action of the cam. Care should be taken when installing such valves to ensure that the flow paths are fully open when operated. Additionally, an adequate degree of over-travel should be utilized to allow for the foreseeable loss of movement due to cam or track wear. Internal and external mounting arrangements should, as far as practicable, be proof against vibration or maladjustment.

When a guard or cover can be completely removed from the machinery, i.e. it is not restrained by hinges or a track, positive mode actuation by means of a guard operated cam is not possible. Therefore, the interlocking system should include other devices which are not hydraulic, e.g. captive-key control or trapped-key control.

9.9.3 Hydraulically-operated shotbolt

As an alternative to safeguarding devices with integral bolts, hydraulically-operated bolts could be used to retain guards in the closed position while a machine is operated and during run down, etc. Where shotbolts of this nature are used, they should be designed to minimize failure to danger, i.e. power retracted/spring extended, or bistable.

Where the guard is designed so that in all positions, other than closed, the bolt movement is scotched (see Figure 91), guard interlocking can be achieved by monitoring the position of the bolt so that the machine can only operate when the bolt is extended, locking the guard in the closed position. Guard interlocking could also be achieved by using the shotbolt in conjunction with conventional interlocking devices.

9.9.4 Power interlocking

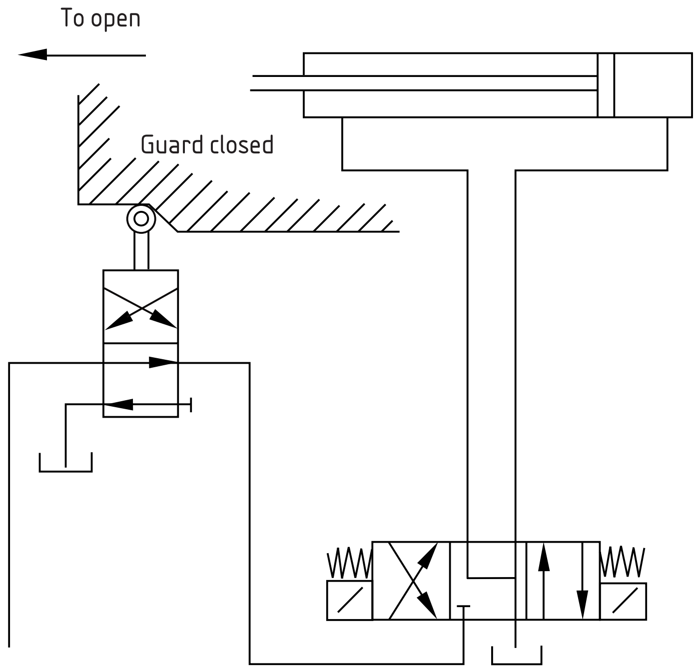
In hydraulic systems used on machinery which is designed with its own integral electric motor driven pump, power interlocking can be achieved in two different ways. Either:

a) the pump is left running and the guard interlocking device directly interrupts the flow of hydraulic fluid to the actuator and releases system pressure back to tank (see Figure 97); or

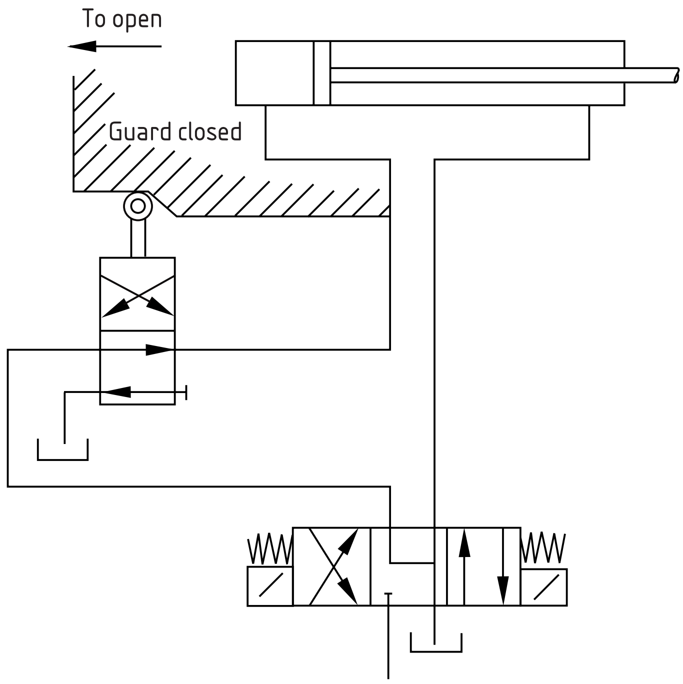
b) the guard interlocking device is an electrical position switch which directly interrupts the electrical supply to the electric motor driving the pump.

On large machines the effort required to operate the interlocking device could be too high for option a). Where option b) is chosen, any accumulators forming part of the machine system should be dumped automatically by the interlock.

Figure 97 **Power interlocking in hydraulic systems**



a) The cylinder is prevented from being extended or retracted under power while the guard is open.



b) The cylinder is allowed to be retracted under power (permissible only where there are no hazards during retraction) while the guard is open.

Section 10: Safety-related control systems associated with protective devices

10.1 General

Safety-related control systems associated with protective devices, such as interlocks, light curtains and speed monitoring devices, can be electrical, mechanical, hydraulic and pneumatic. Each has advantages and disadvantages, and the choice depends on the type of protective device, machinery and the method of actuation of hazardous parts. Electrical control systems are the most common, and electrical components are often incorporated in hydraulic and pneumatic circuitry, e.g. solenoid-operated valves.

The characteristics of the protective device should be appropriate for the application, including environment, frequency of use and resistance to impact damage.

Safety-related control systems used to implement protective measures should be appropriate for the required risk reduction (see **2.1**).

NOTE Further information on safety-related parts of control systems is given in BS EN ISO 13849-1, BS EN 62061 (electrical systems only) and BS EN 954-1 (withdrawn).

10.2 Architectural considerations

10.2.1 Types of control systems

10.2.1.1 General

Types of control systems associated with protective devices include:

a) fault-tolerant with automatic monitoring, e.g. dual-channel with cross-monitoring (see **10.2.1.2**);

b) fault-tolerant without automatic monitoring, e.g. dual-channel, without cross-monitoring (see **10.2.1.3**); and

c) zero fault-tolerant, e.g. single-channel (see **10.2.1.4**).

These types of control systems exhibit different features of design architecture, and with components and interconnections of a similar quality achieve different levels of integrity (see **10.2.2**, **10.2.3** and **10.2.4**).

Other features are possible, including dual systems, e.g. those incorporating both a power interlock and a control interlock. Voting logic systems requiring, typically, two out of three or three out of five votes to activate a function are less common in the field of machinery safeguarding and are therefore not described in this Published Document.

Routine inspection and testing should be carried out at a frequency appropriate to ensuring the continued integrity of the safety-related control system (see **10.2.2**).

10.2.1.2 Fault-tolerant with automatic monitoring

In fault-tolerant systems with automatic monitoring, fault tolerance is typically achieved by the use of:

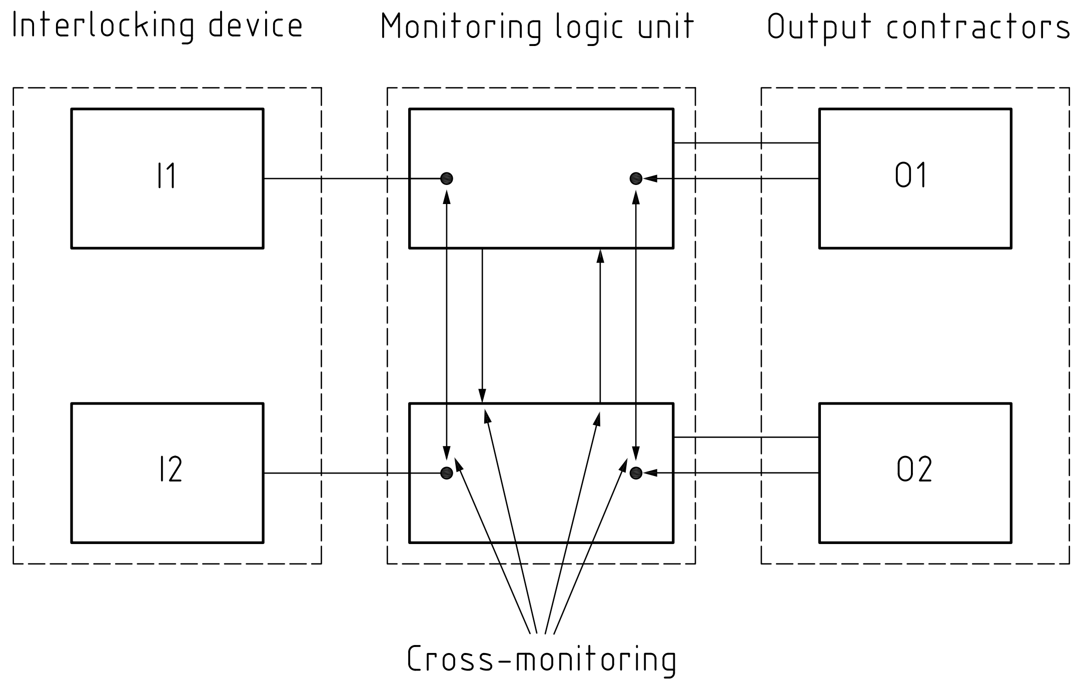
a) two input signals, e.g. from two separate interlocking switches on a guard;

b) dual-channel logic solver, e.g. a monitoring relay unit; or

c) two separate output devices arranged in series so that the operation of either interrupts the power.

Any single fault in either channel will be detected and will result in a safe state of the system, e.g. shutdown or prevention of start-up (see Figure 98).

Figure 98 **Designated architecture**



Here, the logic monitoring relay unit automatically monitors signals from the interlocking devices and output contractors, as well as within itself, so that any failure is detected and a further operating cycle of the machinery prevented. The circuitry of each channel is kept physically separated as far as is practicable, to reduce the probability of the interlocking system failing to danger as a result of common cause failure.

Where one channel is in one medium (e.g. electrical) and the other in another medium (e.g. pneumatic) the reduced probability of common cause failures could improve overall integrity. Another way of reducing common cause failure is to avoid using identical components, e.g. normally closed/normally open switches that are actuated at the same time (see Figure 82).

10.2.1.3 Fault-tolerant without automatic monitoring

Fault-tolerant without automatic monitoring systems follow the same principles as those described in **10.2.1.2,** but without the facility to automatically monitor the correct functioning of the devices. Channels in different media can provide an improvement in integrity due to the reduced probability of common cause failures.

In the absence of automatic monitoring, it is possible for either interlocking channel to fail to danger and for the fault to remain undetected, which then reduces the integrity of the system to that of a single-channel system (see **10.2.1.4**). For dual-channel systems without automatic monitoring to function effectively, it is important that sufficient checking is carried out to ensure that both channels are working correctly. The frequency of checking depends on the reliability of the components used, and the conditions under which the control system is operating.

The integrity of such systems is highly dependent on the quality of the checking, including defined test procedures, suitably trained operators, defined test procedures, and suitable test equipment. Such systems can therefore be unsuitable for certain applications where high quality checking cannot be guaranteed.

10.2.1.4 Zero fault-tolerant

A zero fault-tolerant system typically employs a single input signal, e.g. from an interlocking switch on a guard that operates a single output device that interrupts the power. Because the failure of a single component can cause the whole system to fail to danger, the integrity of this system relies entirely on the resistance to failure of its components. Enhanced resistance to failure is typically achieved by, for example, the use of robust components and the simplicity of the design.

In some instances, an improvement in the overall integrity of the system can be achieved by duplicating some parts. The particular parts to be duplicated should be those which have been assessed as giving rise to the greatest risk of failure. For example, Figure 81 illustrates a situation where two cam-operated switches working in opposite modes are used because the risk of accidental displacement of the guard relative to a single positive mode switch is seen as significant.

The system should be checked and tested regularly, and any worn, damaged or time expired components replaced or repaired.

10.2.2 Failures in safety-related control systems (see BS EN 60204-1:2006+A1:2009, Clause 9)

The most common failures from which an interlocking control system might suffer are listed in Annex B.

The overriding aim of designers ought to have been to minimize the possibility of the safety-related control system failing to danger.

Power supplies, individual components and interconnections are liable to failure, and it is important to identify all potential failures and to select equipment to minimize system failure.

Components relying on the power supply for their functioning should be installed so that power loss minimizes failure to danger of the system as a whole. Examples of such components include:

a) relays and contactors;

b) pilot-operated, spring-return valves;

c) spring-engaged solenoid, pneumatic or hydraulic bolts; and

d) spring-applied, power-released brakes.

Components and interconnections usually adopt one of two conditions on failure, e.g. open or closed circuit, on or off, engaged or disengaged. In order to achieve the aim their mode of installation should be carefully considered.

For example, when stem- or lever-operated valves, or position switches, are used for interlocking, they can be installed in either of two different modes, positive or non-positive. Failure to danger is more common in the non-positive mode as a result of seizure, return spring failure, or, in the case of electrical position switches, contact welding. The interlock can also be defeated by holding down the stem or lever while the guard is open (see BS EN ISO 14119:2013, **5.4**).

Devices of this type operated in the positive mode can still fail to danger in the event of excessive wear, or displacement of cam, track, follower or internal and external mounting, resulting in insufficient movement to change the state of the interlock. Without frequent checking, this situation can remain undetected.

Mechanical arrangements for actuating position switches should be such that the roller and cam or other device is adequately proportioned and made of appropriate material to withstand wear which might lead to ineffective actuation of the position switch (see Figure 77). Steps should be taken to ensure that the means of actuation and the switch itself are maintained in their correct relationship and adequate stops should be fitted to prevent over-travel of guards. Position switches should withstand a degree of over-travel to prevent damage and subsequent failure of the switch (see also **9.6.2**). If a position switch is actuated by a cam, the cam should be such that reverse movement does not damage the switch (see BS EN ISO 14119:2013, **5.2** and **5.3**).

Measures can be taken to minimize the consequences of single failures in interlocking systems, such as the use of additional control or monitoring channels (see **10.2.3**).

10.2.3 Integrity of interlocking control systems

*NOTE Security of interlocks is covered in **9.5**.*

The integrity of an interlocking control system depends not only on the direct effects of failures, but also whether those failures lead to damage to other components or interconnections within the system. Therefore, an important consideration should be circuit protection, e.g. by a fuse, circuit breaker or relief valve, to prevent this type of damage (for example, see BS EN 60204-1:2006+A1:2009, **7.2.10**).

Other basic criteria for improving the integrity of an interlocking control system include:

a) correct installation;

b) good quality, high-integrity components, protected to withstand the environment and rated for the duty they have to perform;

c) minimizing by design, manufacture and correct installation, the probability of an earth fault occurring;

d) minimizing failure to danger (see **10.2.2**); and

e) minimizing misuse, for example deliberate defeat (see **9.5**).

Power interlocking systems achieve integrity by reducing the number of intermediate components and avoiding the failure modes associated with control systems.

Control interlocking systems achieve integrity by incorporating additional interlocking and/or monitoring channels.

10.2.4 Choice of interlocking control system

Appropriate interlocks and systems of interlocking should be selected for each specific application (see BS EN ISO 14119:2013, Clause **6**), taking account of such factors as:

a) the frequency with which approach to the hazardous area is required;

b) the probability and severity of harm if the interlocking system fails; and

c) the resources required to reduce the risk.

However, when selecting a system, the merits of a system that requires frequent, ongoing maintenance should be compared with those of a more reliable system that can have a higher initial outlay.

10.2.5 Electrical considerations

10.2.5.1 General

All electrical control systems can fail in ways that could result in hazardous situations. Particular attention should be paid to minimizing the probability of this occurring (see BS EN 60204-1:2006+A1:2009, **9.4**).

The main items for consideration are:

a) interlocking devices used for interfacing with guard movement (see **9.6**);

b) signal-operated devices, e.g. relays or contactors (see **10.2.5.2**);

c) logic-solving devices, e.g. programmable controllers;

d) interconnections within the system, e.g. wiring (see **10.2.5.3**); and

e) overall system design (see **10.2.5.4**).

10.2.5.2 Signal-operated devices (relays and contactors)

Electromechanical relays and contactors can cause the control system to fail to danger in the event of the contacts welding together, spring failure, or excessive mechanical stiction or seizure. For this basic reason, applications that require a particularly high integrity are provided with more than one interlocking channel.

Adequately rated relays and contactors used in control interlocking systems should be selected to ensure a high degree of reliability of operation. They should conform to BS EN 61810 and BS EN 60947-4-1. Care should be taken in the selection and mounting of contactors and relays to ensure that mechanical vibration or shock does not cause inadvertent closing of contacts.

Contactors having mirror contacts in accordance with BS EN 60947-4-1:2010+A1:2012, Annex F, can be used to give a reliable indication of the state of their main contacts. A similar principle can be applied to relay contacts. Requirements for relays with forcibly-guided (mechanically linked) contacts are specified in BS EN 50205.

10.2.5.3 Interconnections

All wiring between control switches, relays and contactors should be insulated and, where necessary, adequately protected and securely mounted.

Secure terminations, adequate clearances and creepage distances, suitable barriers between terminals, and identification of circuits should be provided. See **10.2.5.7** for information on systems incorporating solid-state components. Further information on these subjects is given in BS EN 60204-1.

10.2.5.4 Overall system design

To reduce the probability that a control system circuit incorporating electromechanical/electromagnetic components fails (see **10.2.2**), the following points should be observed.

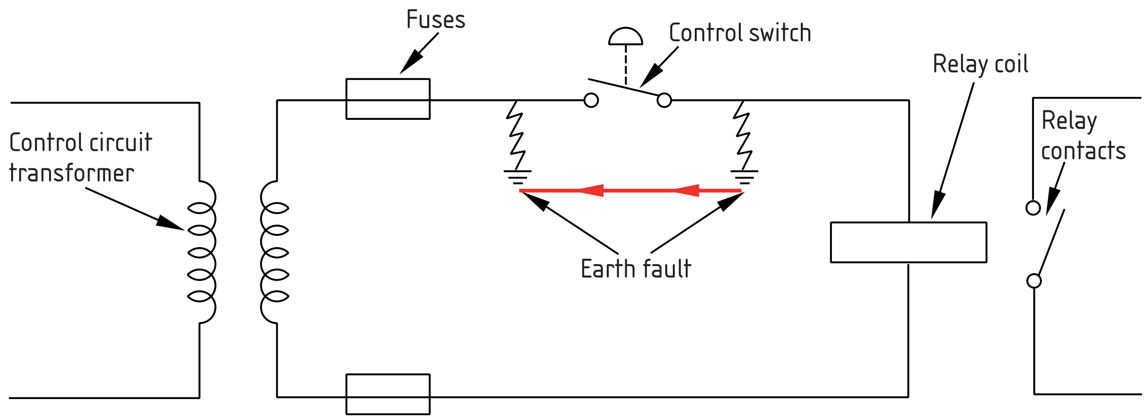
a) Relay and contactor contacts in the safety-related circuit should open on de-energization of their coils.

b) Where the supply to the safety-related circuit is taken from the secondary winding of an isolating transformer, to protect against failure arising from earth faults, one side of the circuit should be connected to the protective circuit of the machine electrical installation at the transformer. All other coils in the circuit should be directly connected to this earthed side of the circuit and the other side of the circuit should be suitably fused (see Figure 99 and BS EN 60204-1:2006+A1:2009, **9.4.3.1**).

Alternatively, equally effective means should be adopted to prevent maloperation due to circuit faults [see Annex B, item e)].

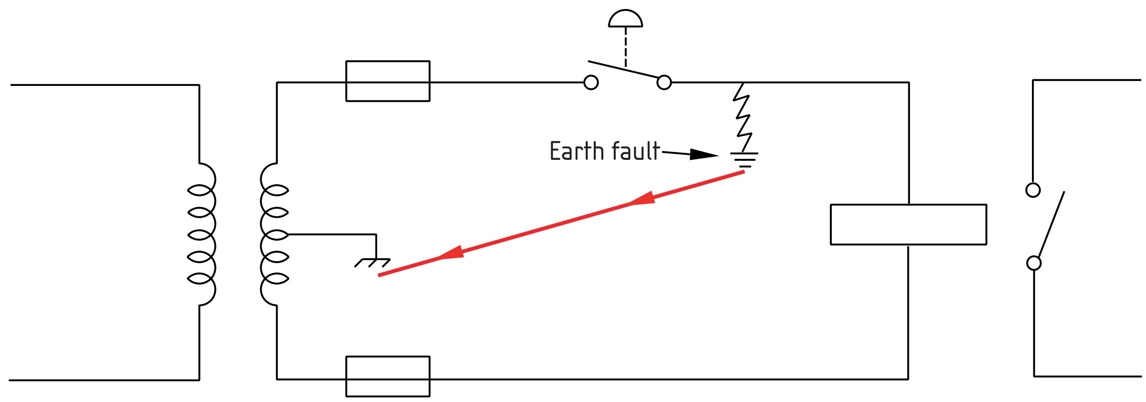
See **10.2.5.7** for information on systems incorporating solid state components.

Figure 99 **Prevention of earth fault sneak circuits**



On an unearthed control circuit, two earth faults can bypass the control switch. This could lead to unintended start-up and inability to stop the machine.

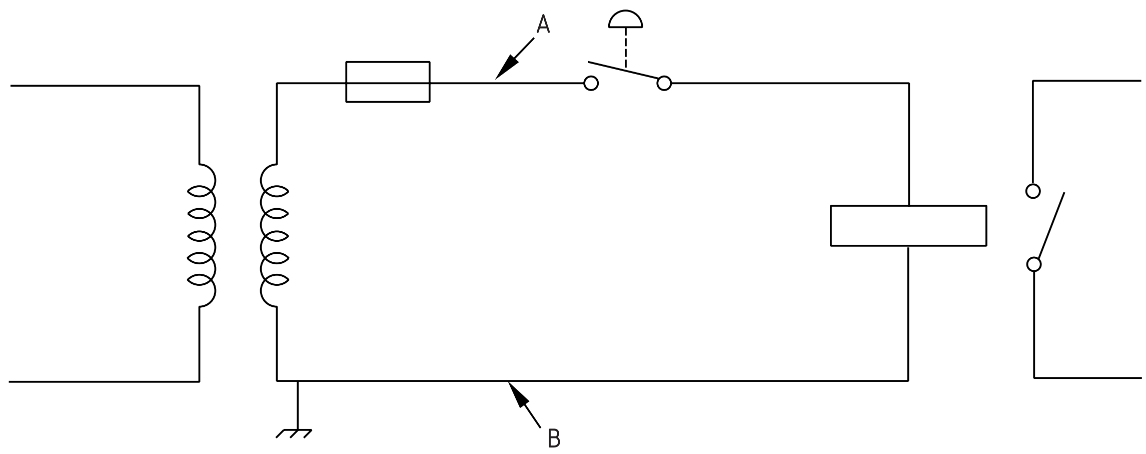
a) Fails to danger



On a mid-point earthed control circuit, one earth fault can leave 50% voltage on the relay coil. The relay might hold on resulting in inability to stop the machine.

NOTE Replacing the fuses by a two-pole over-current switching device set to detect earth faults can prevent a failure to danger.

b) Fails to danger



Earth faults on the switch line, A, cause the fuse to blow and the relay becomes de-energized in these circumstances. As coil line B is deliberately earthed, earth faults in that line are immaterial.

c) No failure to danger

10.2.5.5 Electrical interlocking control systems

10.2.5.5.1 General

NOTE Types of interlocking control systems are described in ***10.2.1****.*

Methods of electrical interlocking control systems include:

a) single-control system interlocking (see **10.2.5.5.2**); and

b) dual-control system interlocking with or without cross-monitoring (see **10.2.5.5.3**).

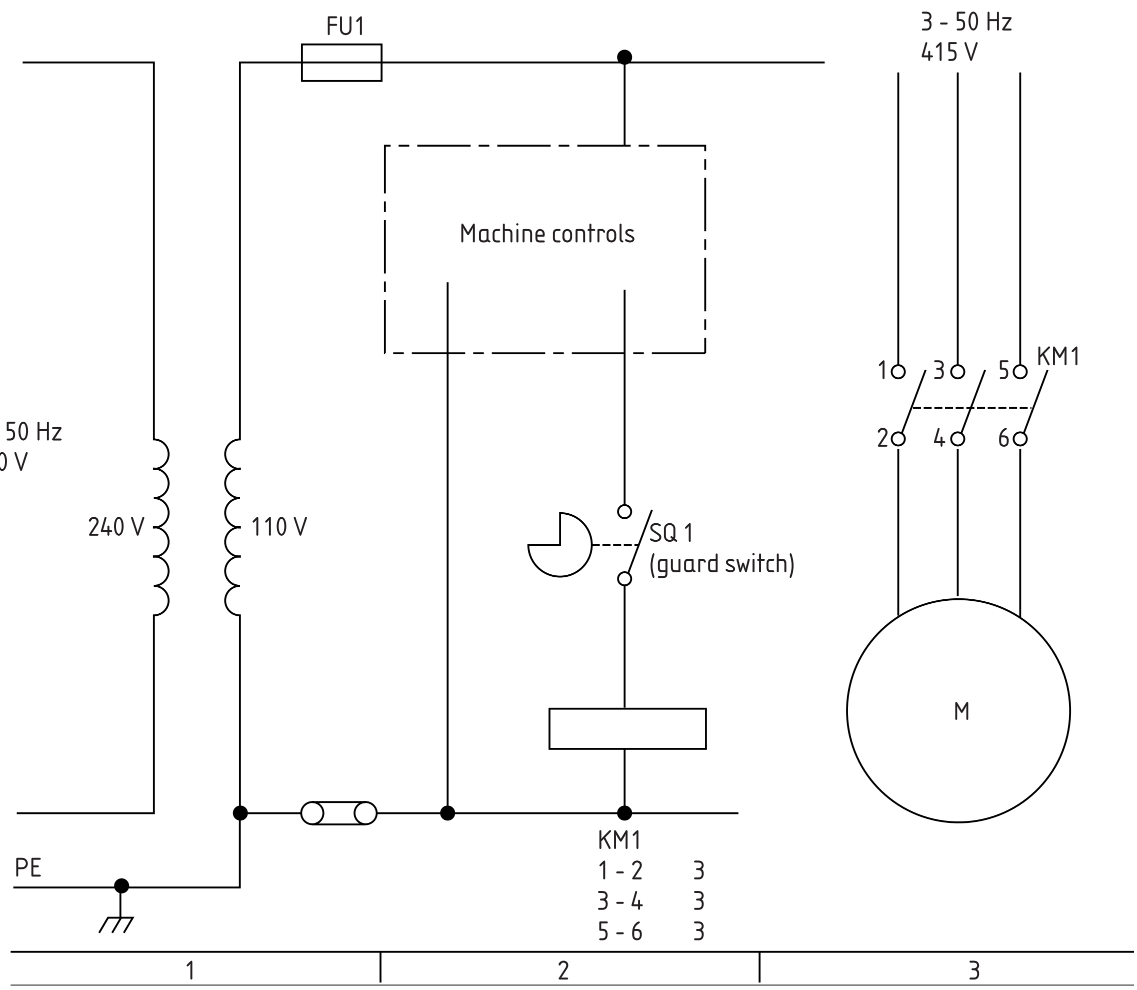
10.2.5.5.2 Single-control system interlocking (see Figure 100)

The basic elements of single-control system interlocking are:

a) the interlocking switch operated by the guard; and

b) the electromechanical contactor or solid-state equivalent, e.g. semiconductor motor controller or starter conforming to BS EN 60947-4-2 and/or a pneumatic or hydraulic solenoid valve controlling power to the drive.

Figure 100 **Example of single-control system interlocking**



This circuit shows the machine controls controlling the operation of the motor contactor, KM1, via the guard switch, SQ1. Opening the guard forces the contact of SQ1 to the open condition. This de-energizes the coil of KM1 and its contacts in the 415 V circuit to the motor go to the open condition. This interrupts the electrical power supply to the motor, M, driving the hazardous parts. Re-closing the guard enables the motor, M, to be restarted by operating the machine controls.

10.2.5.5.3 Dual-control system interlocking

To minimize the possibility of failure to danger, a dual-channel system utilizes two channels with the necessary interconnections for cross-monitoring (where provided) and connection to the supply.

Such systems can be hybrid, e.g. one channel electrical and one channel hydraulic (see **9.2**), one channel electrical and one channel pneumatic (see **10.2.7.3** and Figure 103), or entirely electrical. This diversity reduces the risk of common cause failures. In both channels, the output of the power controlling devices should be connected so that either can stop hazardous operation of the machinery irrespective of the condition of the other. Since failure of a single channel can remain undetected, the integrity of dual-control system interlocking should be improved by monitoring (see BS EN 13849-1 and BS EN 62061).

10.2.5.6 Power interlocking

The safety performance of power interlocking (see also **9.6.12**) is considered to be superior to that of single-control system interlocking, provided the switch and the mechanical interface arrangement between the guard and the switch are of high integrity. It should not be possible for the guard to be opened if, for any reason, the switch contacts stay in the "on" position.

10.2.5.7 Systems incorporating solid-state devices or components

10.2.5.7.1 General

Individual solid-state devices and components are usually extremely reliable, although it is possible for the overall reliability of a system to be reduced due to the potentially high number of components used.

Solid-state devices have high switching speeds and low signal voltage and current requirements, and can therefore respond to electromagnetic disturbances that would not affect electromagnetic and electromechanical devices. It is therefore essential that any control system selected for machinery safeguarding incorporating solid-state devices is designed to not be adversely affected by any mains-borne or radiated disturbances which can occur in the environment for which it was intended.

When any change occurs in the operating environment, e.g. installation of high-power electro-welding equipment, users should assess the likely level of disturbances and ensure that the system is either not adversely affected by or protected against such disturbances.

10.2.5.7.2 Electronic control systems

In electronic control systems it is not usually possible to predict whether the failure mode is to an on state or an off state. It is therefore necessary to incorporate dynamic fault-detection techniques and/or dual-channel systems in order to achieve adequate safety performance. Further information is given BS EN 60204-1. The overall integrity required should take into account **10.2.3**.

10.2.5.7.3 Programmable logic stages

Programmable logic stages involve solid-state devices which are capable of processing input signals in accordance with a pre-arranged instruction (or program) normally to produce electrical outputs. In addition to the same integrity considerations as for electronic control systems, it is necessary to avoid software errors and alteration of the stored program that can cause incorrect operation.

Considerations for programmable systems generally are given in **5.4.7** and **5.24** (see also **10.3**).

10.2.5.7.4 Interlocking of programmable machinery

Where the machinery is controlled by a programmable system, the options for interlocking control systems include:

a) conventional hard-wired systems of interlocking not affected by or routed through the programmable system;

b) systems of interlocking dependent upon a programmable system or systems;

c) a combination of a hard-wired and a programmable system where the programmable system has been used to provide an alternative safety channel; and

d) use of a programmable system to monitor the conventional system of interlocking to enhance its integrity.

Information on programmable systems and guidance on assurance of programmable systems integrity are given in **5.4.7** and **5.24** (see BS EN 62061 and **10.3**).

10.2.6 Mechanical considerations

10.2.6.1 General

The main considerations for mechanical control systems are:

a) interlocking devices used for interfacing with guard movement (see **9.7.1**);

b) clutches and brakes (see **5.8** and **5.9**);

c) interconnections, e.g. shafts, links; and

d) overall system design (see **10.2.5.4**).

10.2.6.2 Mechanical control system interlocking methods

Unlike electrical, hydraulic or pneumatic systems, it is unusual for mechanical systems to be anything other than single-control systems. However, consideration should be given to other system design possibilities, e.g. additional clutches, brakes or linkages. An approximation to power interlocking methods might be achieved when the link between the guard and the power interruption device is direct.

The basic elements of single-control system interlocking are:

a) the actuating device operated by the guard;

b) interposed mechanical linkages, if any; and

c) the clutch or brake controlling the drive (see **5.8** and **5.9**).

Reducing the number of interposed linkages reduces the probability of the system failing to danger. For overall system design see **10.2.5.4**.

An example of single-control system interlocking is shown in Figure 93.

10.2.7 Pneumatic considerations

10.2.7.1 General

Control system interlocking methods in general are described in **10.2.1**. BS EN ISO 4414 specifies safety requirements for pneumatic power systems and their components.

Methods of pneumatic interlocking include:

a) single-control system interlocking (see **10.2.7.2**);

b) dual-control system interlocking with or without cross-monitoring (see **10.2.7.3**); and

c) power interlocking (see **10.2.7.4**).

10.2.7.2 Single-control system interlocking (see Figure 101)

The basic elements of single-control system interlocking are:

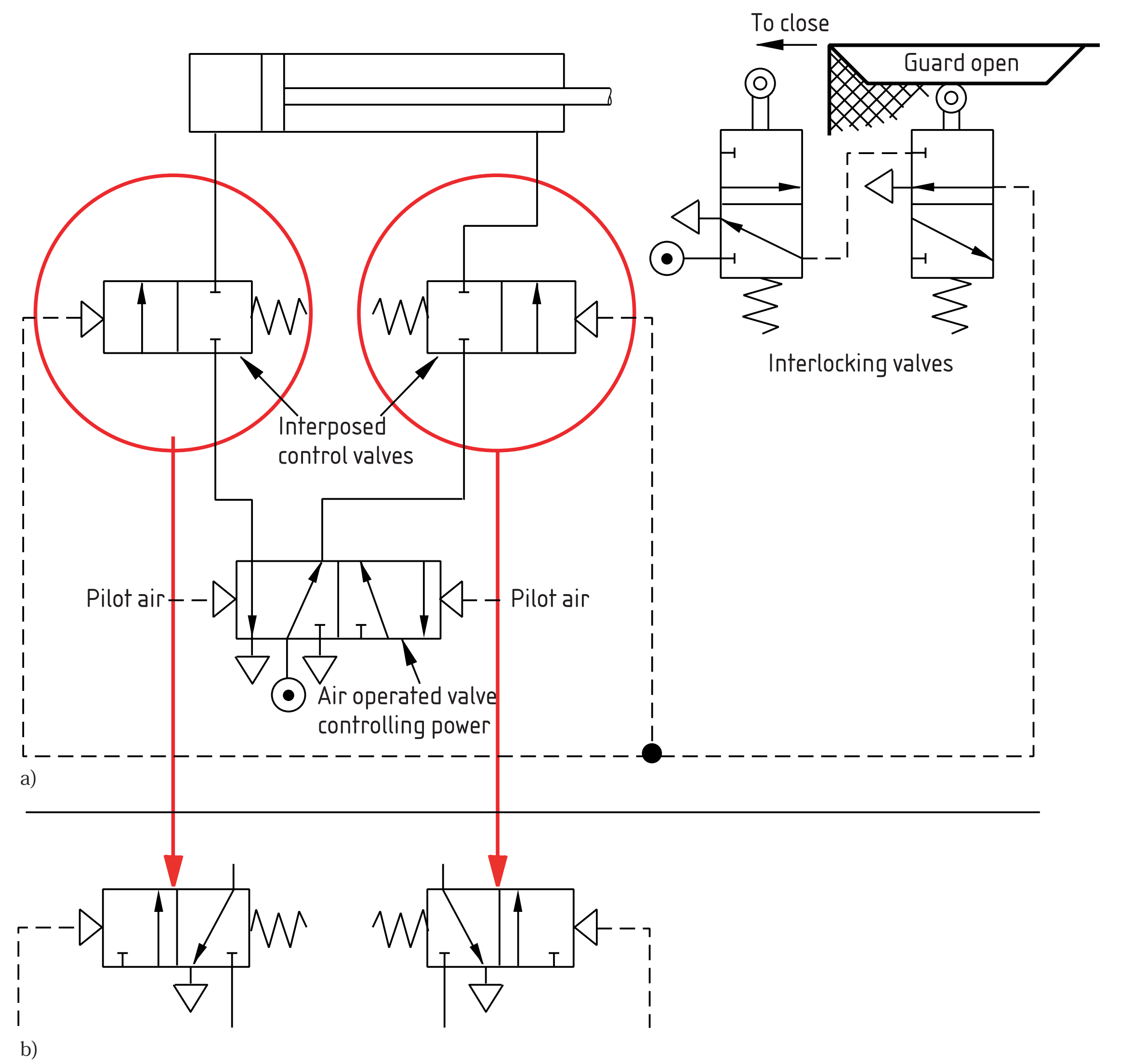
a) the interlocking valve or position switch operated by the guard;

b) interposed control valves, electromechanical relays and/or solid-state switching devices, if any; and

c) an air-operated, solenoid-operated, or solenoid-actuated, air-operated valve controlling power to the drive.

Any of these elements, or the piping or wiring interconnecting them, can fail to danger. Therefore, they should be selected to provide the maximum degree of reliability. The greater the number of devices incorporated in the system, the lower its inherent reliability. Interposing devices should therefore be avoided, if possible.

Figure 101 **Single-control system interlocking for arresting the motion of a cylinder**



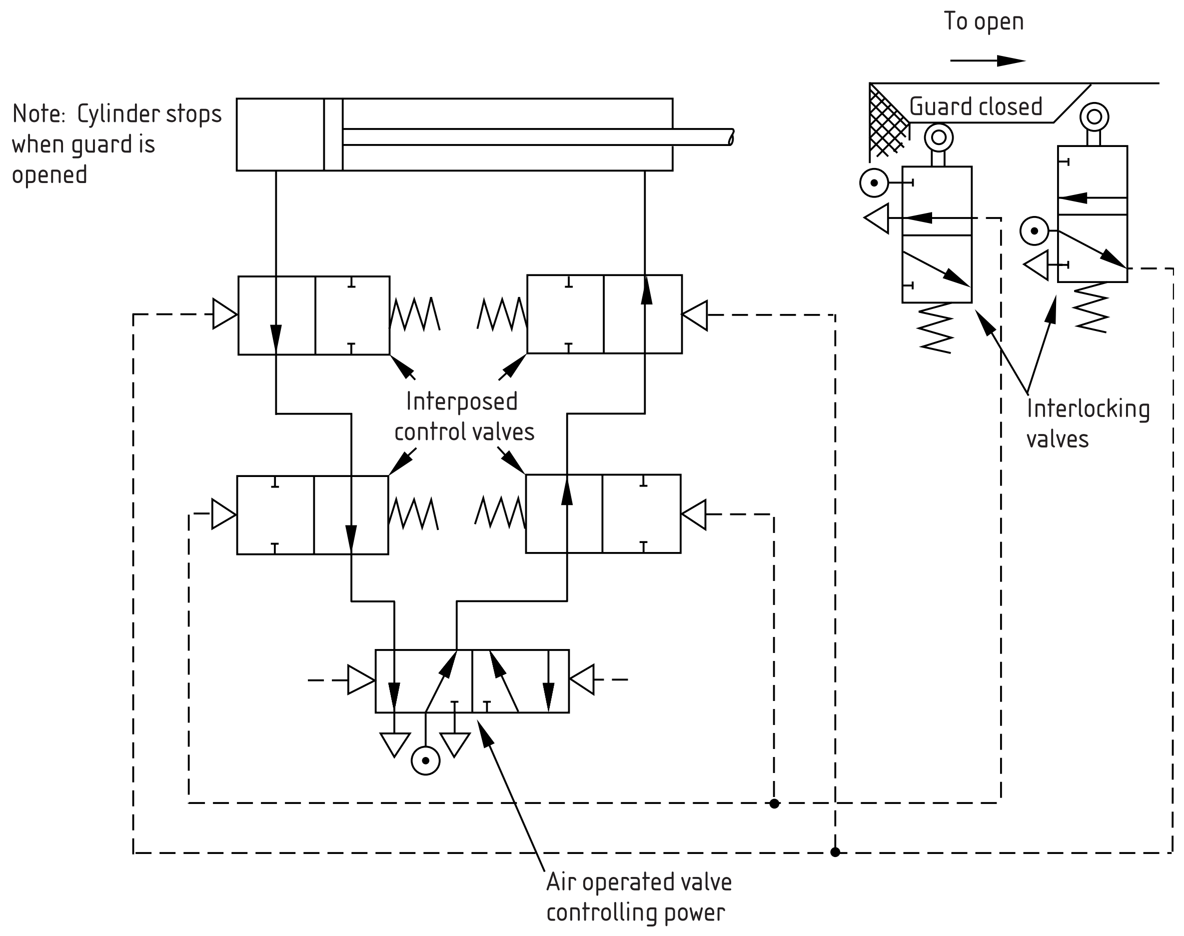
Motion of a cylinder is stopped, but it remains pressurized, if two poppet valves are used as shown in a). The cylinder can also be stopped and exhausted to atmosphere if two three-port, two-position valves are used as shown in b). In both cases two interlocking valves, one in each mode, are used to signal the interposed control valves.

10.2.7.3 Dual-control system interlocking

To minimize the possibility of failure to danger, a dual-channel system utilizes two channels with the necessary interconnections for cross-monitoring (where provided) and connection to the supply.

Such systems can be entirely pneumatic (see Figure 102) or hybrid, e.g. one channel pneumatic and one channel electrical (see Figure 103). In both channels the output of the power controlling devices should be connected so that either can stop hazardous operation of the machinery, irrespective of the condition of the other. Where the circuit is such that a single failure is not self-revealing, e.g. by failure of the actuator to operate, the integrity of dual-control system interlocking can be improved by cross-monitoring, shown also in Figure 103.

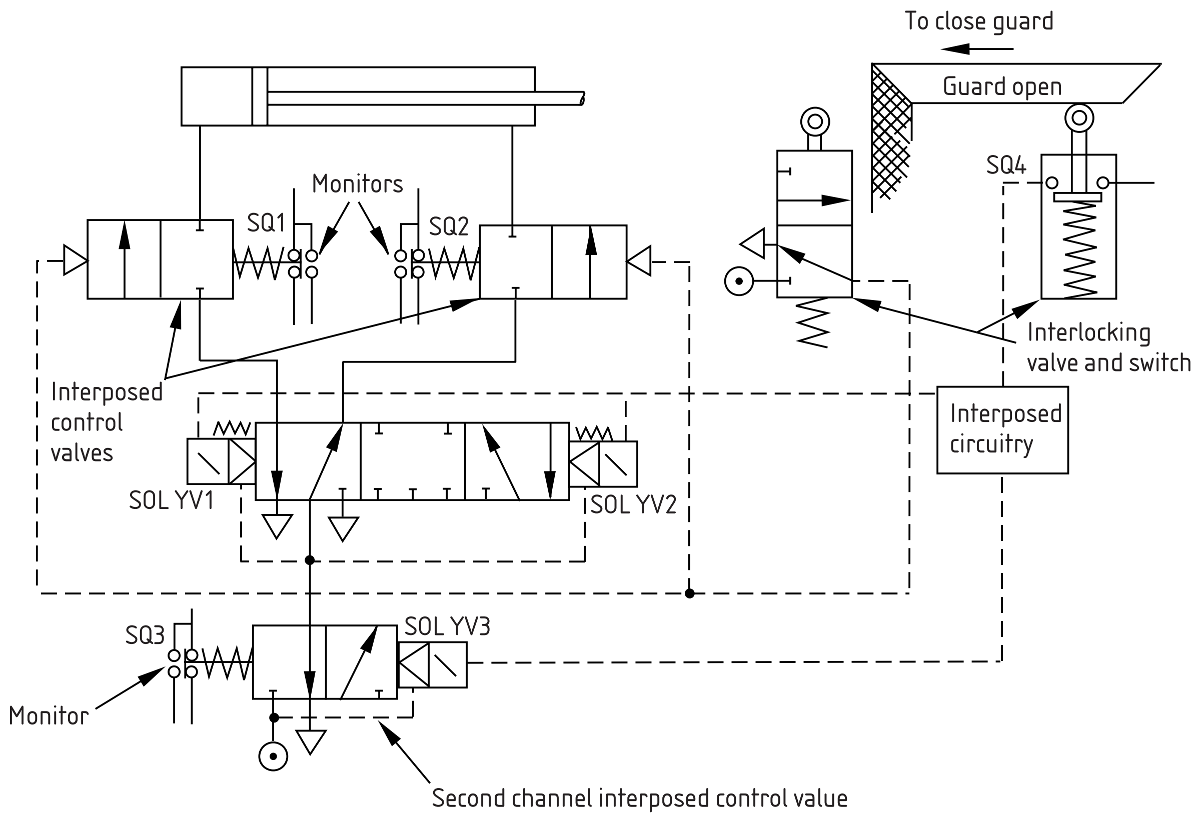
Figure 102 **Dual-control system interlocking without cross-monitoring: both channels pneumatic**



The illustration shows one method of achieving dual-control system interlocking using two pneumatic channels. The interlocking valves are fitted in opposite modes and each one pilots a pair of interposed control valves. These control valves are also arranged so that each pair is operated in opposite modes. The opposite modes and the separation of the two channels minimizes the possibility of common cause failure.

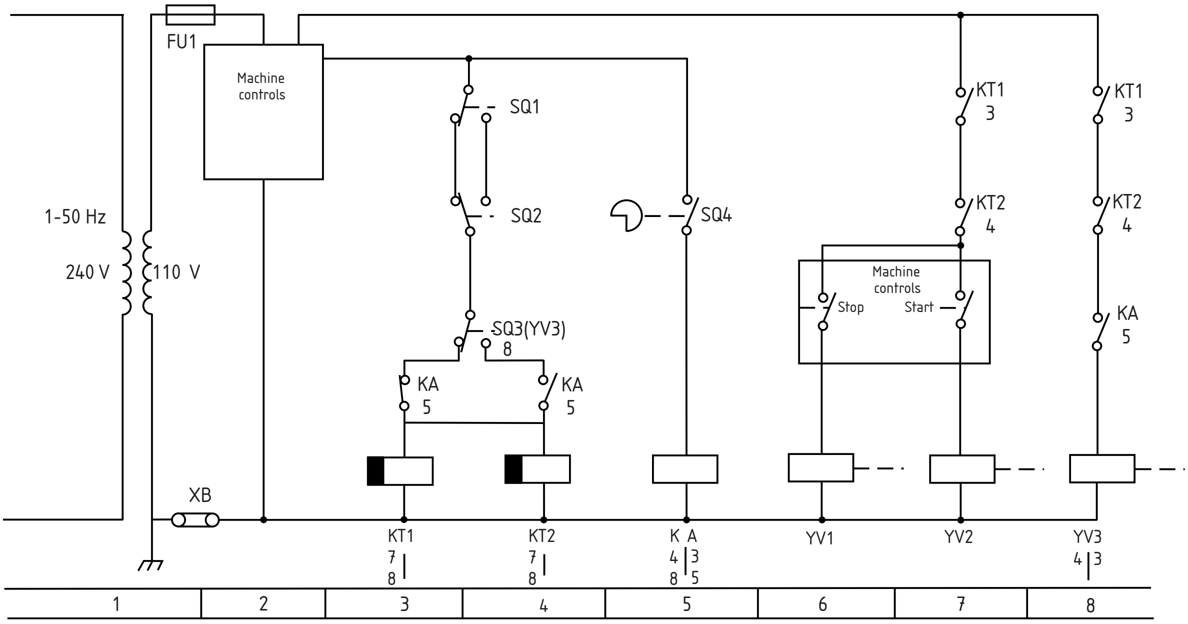
NOTE This diagram illustrates the principles only and does not provide all the information needed to construct a working system.

Figure 103 **Principles of pneumatic and electrical circuits: dual-control system interlocking with cross-monitoring, one control channel pneumatic, one electric (monitoring channel electric)** *(1 of 2)*



a) The illustration shows the principle of dual-control system interlocking using different control media for each channel. One interlocking device is a valve which pneumatically controls two separate power interrupting valves. The other interlocking device is a switch which, via interposed circuitry, controls the solenoid-operated power interrupting valve, YV3, in the second channel. All power interrupting devices are monitored electrically to improve integrity. The principle of the monitoring circuit is shown in b) where failure of any of the monitored devices causes solenoids YV1 and YV2 to de-energize allowing the directional control valve to centralize, causing the actuator to stop.

Figure 103 **Principles of pneumatic and electrical circuits: dual-control system interlocking with cross-monitoring, one control channel pneumatic, one electric (monitoring channel electric)** *(2 of 2)*



b) If the guard switch, SQ4, and guard interlock valve are open at switch-on and the safety valves, SQ1 and SQ2, are open and the main control valve, YV3, is open and the normally closed contacts on relay KA are made, the monitoring relays, KT1 and KT2, close. Contacts on these relays (line 7) prepare direction solenoid YV2. When the guard is closed, the guard switch, SQ4, and the guard interlock valve close. The safety valves, SQ1 and SQ2, close by pneumatic action. The monitoring contacts on these valves (lines 3/4) should both change over to retain the monitoring relays, KT1 and KT2. At the same time the guard switch, SQ4, energizes relay KA.

A contact on KA (line 8) together with contacts on KT1 and KT2 energize the main control valve, YV3, to prepare the machine motion. The monitoring contact, SQ3, on valve YV3 (lines 3/4) and the normally open contact on relay KA both have to change over to retain the monitoring relays, KT1 and KT2. The normal start and stop devices can now be used to initiate machine movement. If the guard is opened during normal operation, the relay, KA, and safety valves SQ1 and SQ2 open and prevent further motion.

NOTE The diagram illustrates the principles only and does not provide all the information needed to construct a working system.

10.2.7.4 Power interlocking

Where power interlocking is practicable, it is preferable to single-control system interlocking, provided the valve and the arrangement between the guard and the valve are of high integrity. The arrangement should ensure, as far as practicable, that the guard cannot be opened until the valve connections interrupt the air supply.

10.2.7.5 Signal-operated valves

Signal-operated valves could fail to danger in the event of spring failure, excessive mechanical stiction, or seizure. This is why single control system interlocking is unacceptable in situations requiring a very high integrity.

Signal-operated valves used in control interlocking systems should be selected to ensure a high degree of reliability of operation. They should be suitable for the function required, be able to withstand the minimum and maximum operating parameters of pressure and temperature specified, and be securely mounted. Care should be taken in the selection and mounting of all valves to ensure that mechanical vibration or shock does not cause inadvertent operation, e.g. main control valves should be mounted horizontally to avoid the possibility of the spool moving under gravity and/or vibration.

10.2.7.6 Interconnections

All piping between control valves and interlocks should be rated for maximum pressure and, where necessary, sufficiently protected and securely mounted, particularly where flexible plastics tubing is employed.

10.2.7.7 Overall system design

Because the power medium is compressible and normally exhausted to atmosphere, the control system interlocking circuit design is not as straightforward as for other power media. However, the basic aims for interlocking remain the same and, where possible, the power supply should be interrupted by the guard-operated interlocking device and any residual system pressure exhausted to atmosphere. In this condition any cylinders are pre-exhausted and alternative arrangements in the system design are necessary where any cylinders are required to be under constant load. In addition, particular precautions might be necessary when reinstating the supply to pre-exhausted cylinders if rapid acceleration is undesirable. This latter condition can be safeguarded against by introducing a "safe start" arrangement in the supply line to the machine that initially restricts the flow rate until a certain predetermined pressure has been attained.

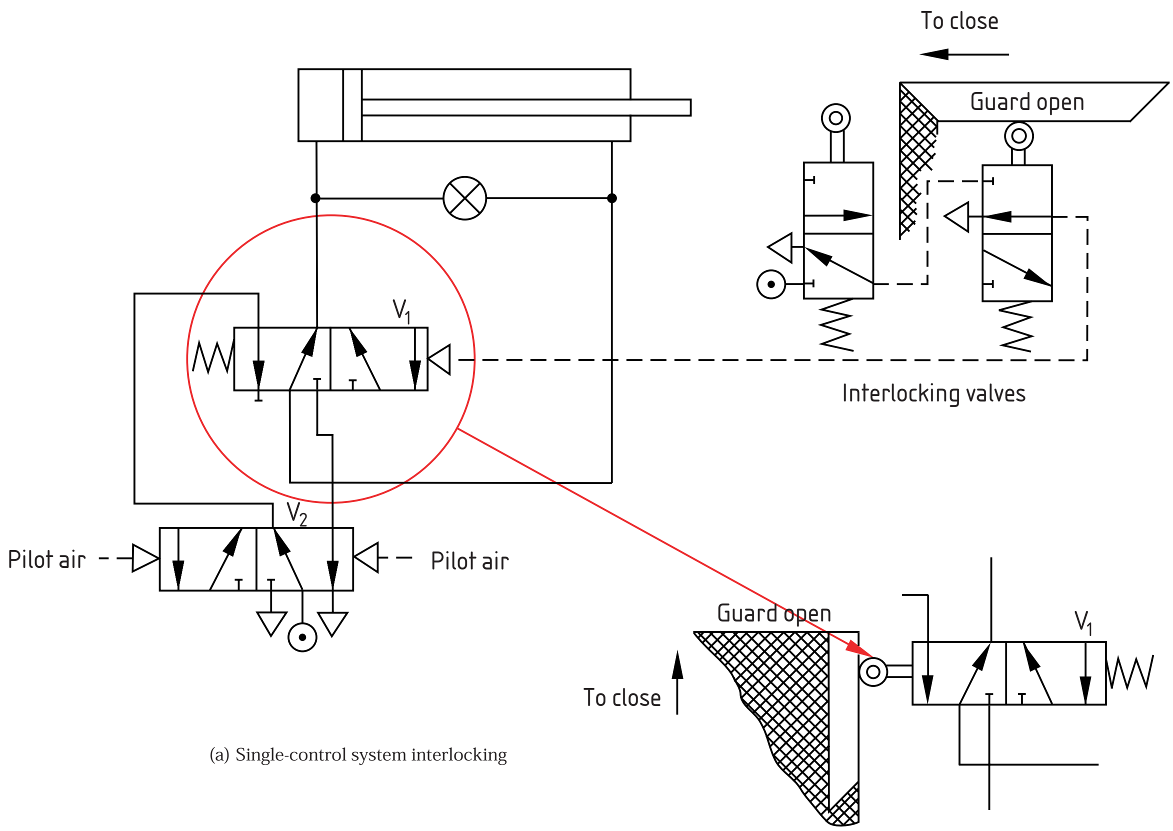
Cylinders under constant load could include clamps, elevators or supports. To avoid the need to maintain supply pressure, alternative features should be considered such as single-acting cylinders or spring-applied mechanical scotches. Where, for safety reasons, it is necessary to arrest and hold the piston in the position occupied when the guard is opened, two poppet valves can be used as shown in Figure 101. However, a hazard could arise if connections to the cylinder are broken, so overriding the locked position. Air exhausting through the broken connection could allow air under pressure on the opposite side of the piston to expand, causing movement that could lead to injury. Where it is found necessary to override the locked condition while the guard is open, a stop valve can be added to the circuit as shown in Figure 101. This would normally be closed, but by opening the stop valve during the locked condition the two ends of the cylinder are connected, balancing out the pressures and enabling the piston to be moved manually.

Where it is necessary just to arrest the movement of a piston when a guard is open, this can be achieved by using either two three-port two-position valves as shown in Figure 101 or an equalizing valve as shown in Figure 104. Both these techniques allow manual repositioning of the cylinder with the guard open without disconnecting pipes but are unsuitable for clamping or supporting applications.

It might be necessary to ensure that cylinders adopt a predetermined safe position in the event of the power supply failing. Again, the use of single-acting cylinders might be possible, but an alternative is to employ a reservoir and non-return valve arrangement (see Figure 96). It is important to ensure that where reservoirs are used they are of sufficient capacity to ensure that the cylinder does not stall in an unsafe position.

Where a machine is controlled by means of a manually-operated lever, the lever can be used to lock the guard closed while the dangerous parts are in operation [see Figure 96b)].

Figure 104 **Use of an equalizing valve**



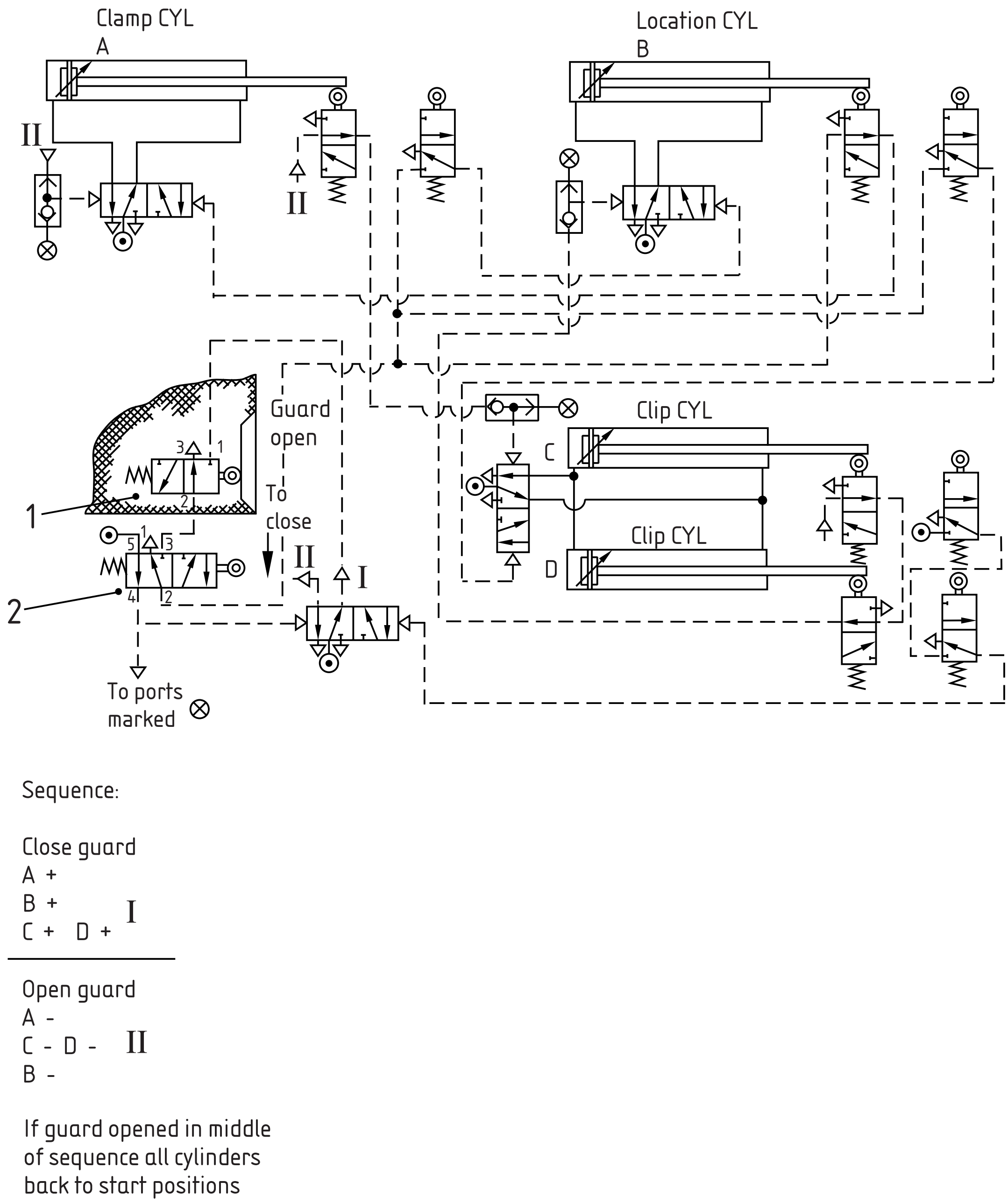
(a) Single-control system interlocking

(b) Interlocking guard power interlocking

A single five-port, two-position valve can be used, both for (a) single-control system interlocking and (b) interlocking guard power interlocking, to arrest the motion of a cylinder. The Figure shows the guard open and both sides of the cylinder connected via the valve thus equalizing the pressures and enabling the piston to be moved manually. Closing the guard causes the equalizing valve, V1, to change state so allowing the cylinder to be operated normally by the directional control valve, V2.

The interlocking arrangements should be effective against the issues highlighted. Users should consider these issues when carrying out modifications or maintenance. Although in many cases interlocking the pilot signals rather than the power supply might be the only practical solution (see Figure 105), this should be as a last resort unless monitoring of the main power control devices is incorporated.

Figure 105 **Control interlocking for machinery performing functions in sequence**



Interrupting the compressed air supply and exhausting system pressure to atmosphere could present problems if applied to machinery which either keeps articles suspended or performs functions in a set sequence as is the case here. One solution is illustrated where control system interlocking of the pilot signals has been used to return the machine to its start position when the guard is opened. This eliminates the need to carry out the potentially hazardous exercise of manually resetting the actuators and sequencing valves before the automatic cycle can be restored. However, this method should be used only where it can be shown that there would be a greater risk of injury if methods of interlocking were used which interrupt the compressed air supply.

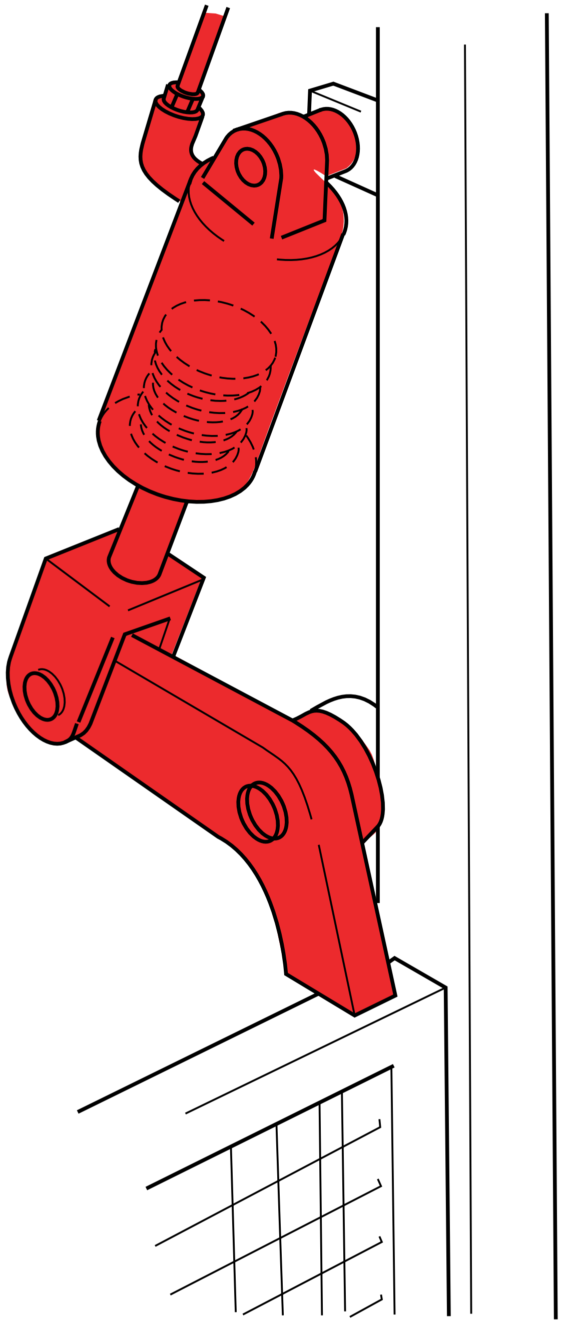
In order that a system incorporating pneumatic valve components is of the integrity set out in **10.2.3**, the following points should also be observed.

a) When the circuit incorporates devices that could be adversely affected by excessive pressure, e.g. diaphragm valves, suitable protection should be provided by fitting pressure relief valves.

b) Where practicable, signal lines should be kept to a minimum length to facilitate rapid decay of pressure. Where this is not practicable and pilot signals exhausting to atmosphere retain sufficient pressure levels to operate main control valves, even after a guard has been opened, additional interlocking devices should be provided which prevent opening of the guard until it is safe to do so (see Figure 106).

c) When three-position valves are used in safety-related circuits, the centre position should provide a supply-sealed-only condition (outlets vented) because an all-ports-sealed centre position can result in stored energy in the actuator, resulting in unintended movement when piping is disconnected.

Figure 106 **Locking a guard closed (see also 9.4.3)**



The illustration shows a rise and fall guard which is locked closed by a lever actuated by a single-acting pneumatic cylinder with spring return. It is inadvisable to use the cylinder piston direct because of the likelihood of damage to the surface of the piston rod. Overrun protection can be provided, when necessary, by means of a restrictor valve which delays the retraction of the lever.

10.2.8 Hydraulic considerations

10.2.8.1 General

Control system interlocking methods in general are described in **10.2.1**.

BS EN ISO 4413 specifies safety requirements for hydraulic power systems and their components.

Methods of hydraulic interlocking include:

a) single-control system interlocking (see **10.2.8.2**);

b) dual-control system interlocking with or without cross-monitoring (see **10.2.8.3**); and

c) power interlocking (see **9.9.4**).

10.2.8.2 Single-control system interlocking (see Figure 107)

The basic elements of single-control system interlocking are:

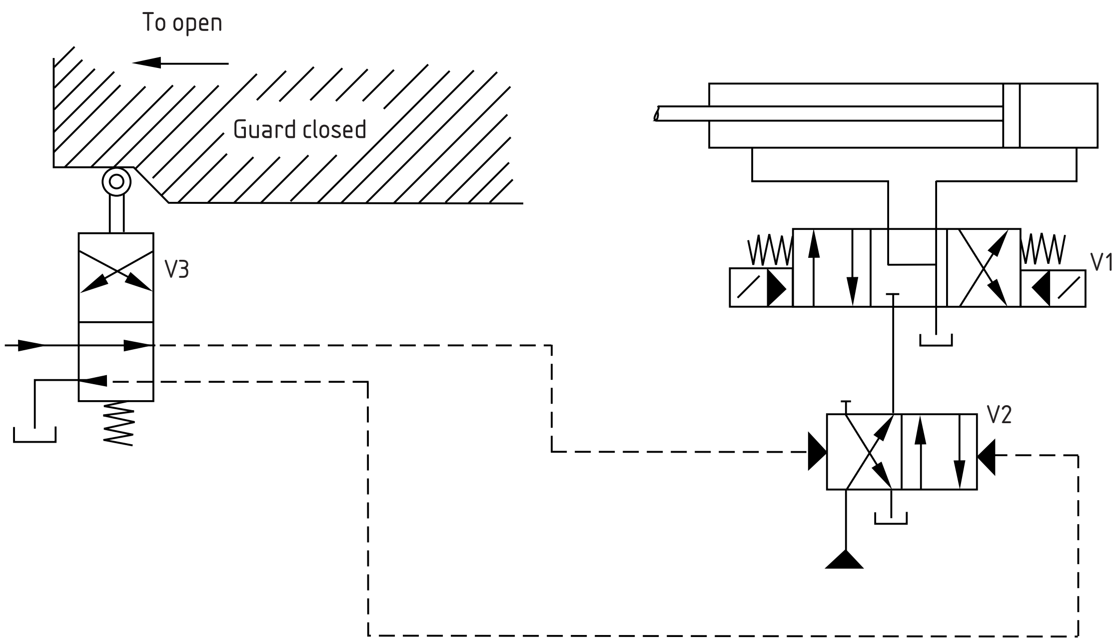
a) the interlocking valve or position switch operated by the guard;

b) interposed control valves, electromechanical relays and/or solid-state switching devices, if any; and

c) an hydraulic, air or solenoid-operated valve, or a solenoid-controlled, hydraulically-operated valve controlling power to the drive.

Any of these elements, or the piping or wiring interconnecting them, can fail to danger, so they should be selected to provide the maximum degree of reliability. The greater the number of devices incorporated in the system, the lower its inherent reliability. Interposing devices should therefore be avoided, where possible.

Figure 107 **Single-control system interlocking used to interrupt the main hydraulic supply to the actuator**



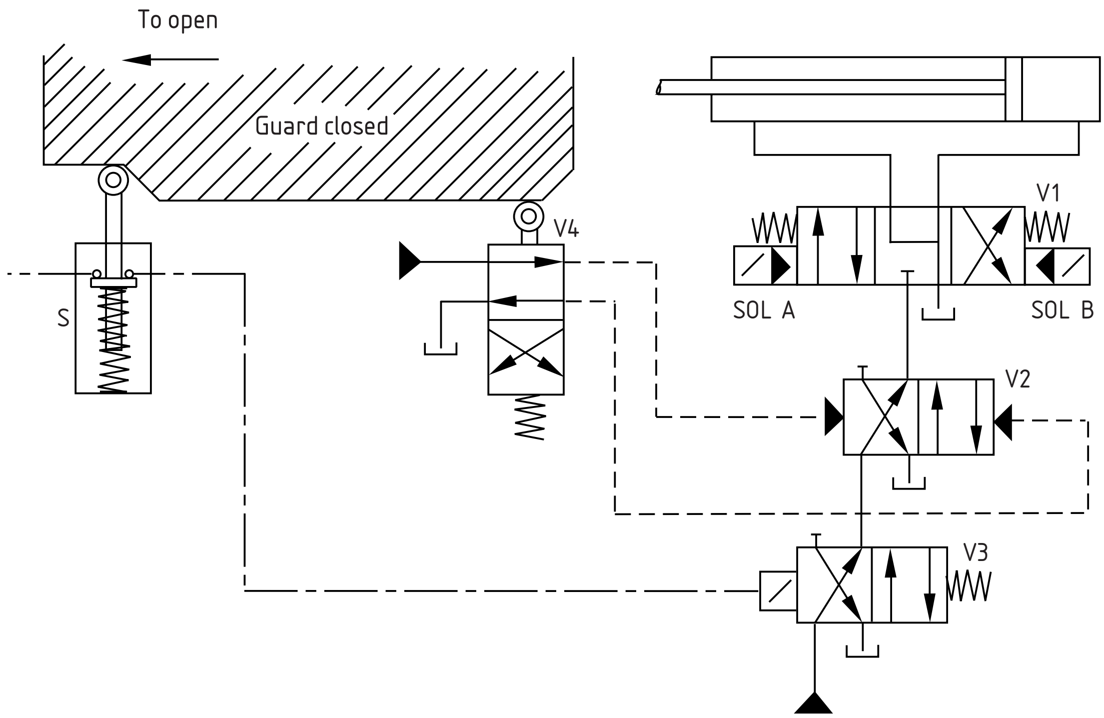
With the guard closed, hydraulic valve V3 pilots interlock valve V2 so that pump pressure is available at machine control valve V1. Valve V1 is not part of the interlocking system.

10.2.8.3 Dual-control system interlocking

To minimize the possibility of failure to danger, a dual-channel system utilizes two channels with the necessary interconnections for cross-monitoring (where provided) and connection to the pump.

Such systems can be hybrid, e.g. one channel hydraulic, one electro-hydraulic (see Figure 108), or both electro-hydraulic or entirely hydraulic. In both channels, the output of the power controlling devices should be connected so that either can stop hazardous movement of the machinery, irrespective of the condition of the other. Where the circuit is such that a single failure is not self-revealing, e.g. by failure of the actuator to operate, the integrity of dual-control system interlocking can be improved by cross-monitoring (see Figure 109).

Figure 108 **Dual-control system interlocking without cross-monitoring**



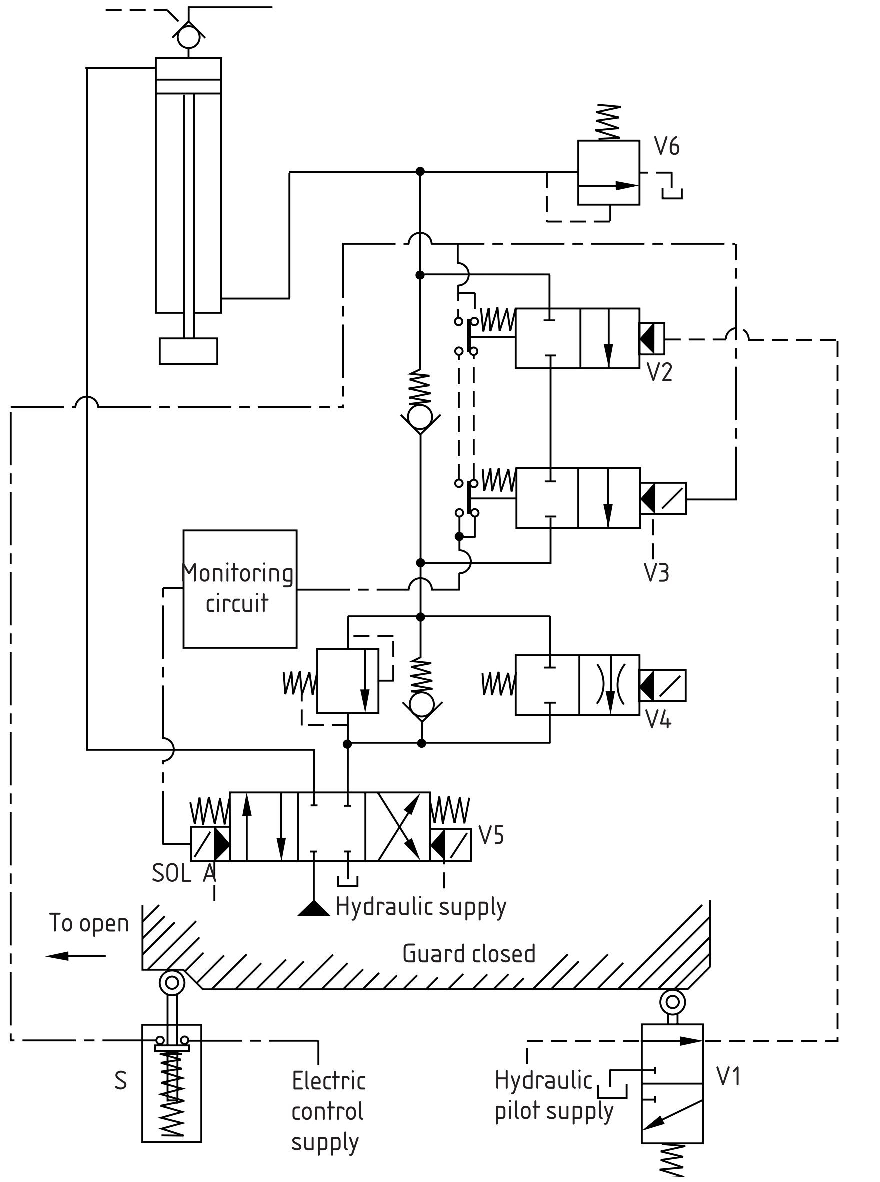
Two control system interlocking channels in different media are used to interrupt the main hydraulic supply to the actuator. With the guard closed, the switch, S, enables the solenoid of interlock valve, V3, to be energized and hydraulic valve V4 pilots interlock valve V2 so that pump pressure is available at the machine control valve, V1.

In most cases the hydraulic interlock is the most reliable because the solenoid provides a comparatively weak link in the electrical interlocking channel. However, there might be circumstances where it is preferable to reverse the modes of the electrical interlocking switch and valve.

Valve V1 is not part of the interlocking system as drawn. However, switch S could be arranged so that, with the guard open, the electrical signals to solenoids A and B of valve V1 are de-energized. Valve V1 then self-centres, interrupting the hydraulic supply and thus carrying out the same function as valve V3.

NOTE This diagram illustrates the principles only and does not provide all the information needed to construct a working system

Figure 109 **Dual-control system interlocking with cross-monitoring**



A typical interlocking system for a single-ram hydraulic downstroking press with pre-fill characteristic fitted with an interlocking guard is shown.

Guard-operated valve V1 interrupts the pilot supply to interlocking valve V2. In addition, guard-operated switch S interrupts the electrical supply to the solenoid on valve V3.

Valves V2 and V3 are monitored. If either of these valves fails to operate, the monitoring circuit interrupts the electrical supply to solenoid A of valve V5 thus preventing a further downstroke.

Valve V6 is a relief valve to protect against intensification and as such should be set at a pressure at least 10% above the maximum system pressure.

NOTE This diagram illustrates the principles only and does not provide all the information needed to construct a working system

10.2.8.4 Component and system design considerations

10.2.8.4.1 General

BS EN ISO 4413 specifies safety requirements for hydraulic power systems and their components.

The following are the main items for consideration:

a) interlocking valves used for interfacing with guard movement (see **9.9**);

b) signal-operated devices, e.g. pilot or solenoid-operated valves (see **10.2.8.4.2**);

c) interconnections within the system, e.g. piping, hose, tubing (see **10.2.8.4.3**); and

d) overall system design, in particular, problems of intensification and stored energy (see **10.2.8.4.4**).

10.2.8.4.2 Signal-operated valves

Signal-operated valves, actuated by a hydraulic or pneumatic pilot signal or an electrical signal, can fail in the event of spring failure, excessive mechanical stiction or seizure. This is why single-control system interlocking is unacceptable in situations requiring very high integrity.

Signal-operated valves used in control systems should be selected to ensure a high degree of reliability of operation. They should be suitable for the function required, be able to withstand the minimum and maximum operating parameters of pressure and temperature specified, be made of materials compatible with the system fluid, and be securely mounted. Care should be taken in the selection and mounting of all valves to ensure that mechanical vibration, shock or gravity does not cause unintended operation.

10.2.8.4.3 Interconnections

All piping, hoses, etc., between control valves and interlocks should be suitable for the fluid and operating environment, correctly sized and rated for maximum flow and pressure and, where necessary, sufficiently protected and securely mounted.

Pipework fittings should be selected to ensure their integrity does not compromise the overall integrity of the interlocking system. This might involve the use of welded or flanged connections.

10.2.8.4.4 Overall system design

Intensification and stored energy require particular attention. Protection against intensification in any part of the system should be provided.

Sources of stored energy include:

a) energy transmitted from a supported mass;

b) energy stored in an accumulator;

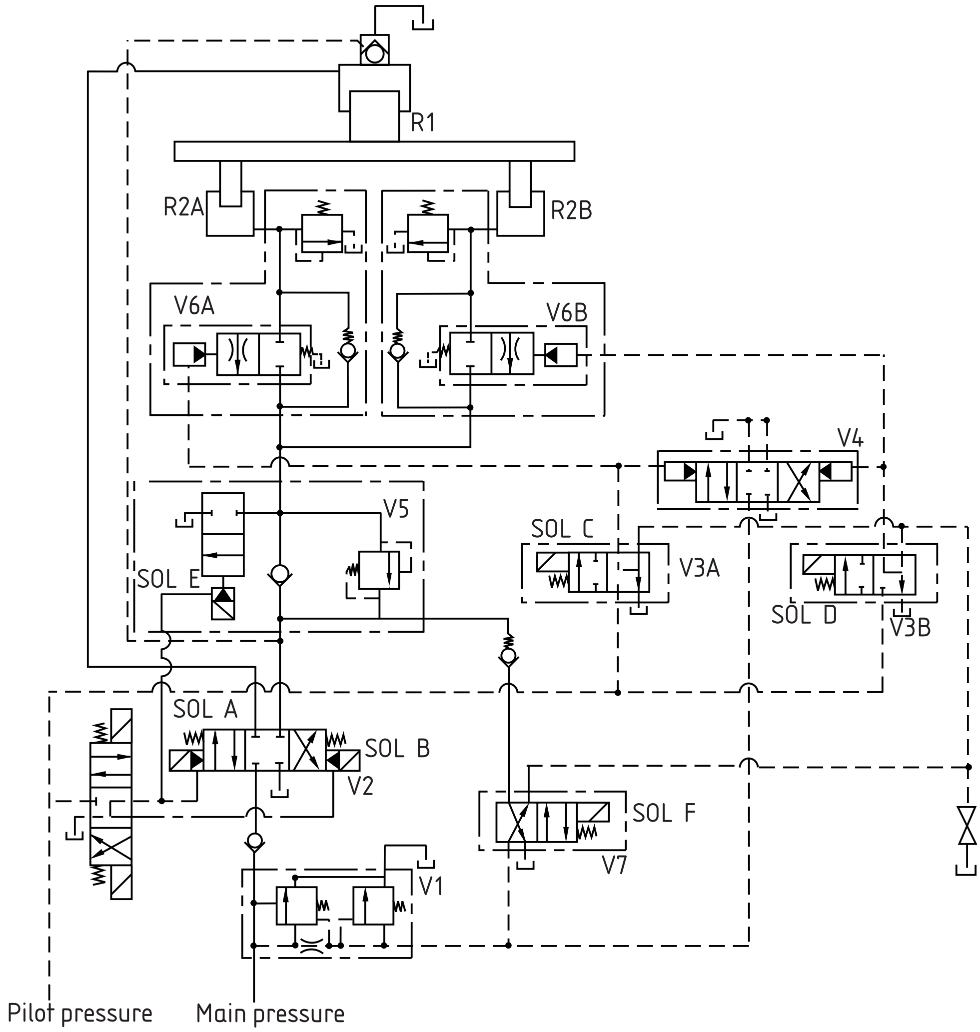
c) energy contained in a hydraulic cylinder under pressure; and

d) energy stored in large volume pipework.

Any interlocking control system should be designed to protect against the risk of injury from such stored energy sources. For example, where, on a down-stroking hydraulic press, scotches are used to support the platen at the top of its stroke and the scotches operate in conjunction with an interlocking guard, the scotches should remain in position until the guard is closed. The guard should then remain locked closed until the platen has returned to the top of its stroke and the scotches are in place.

Further information on protection against unintended fall under gravity is given in **8.7.2,** but, particularly on downstroking hydraulic presses, controlled gravity descent is frequently a deliberate design feature to facilitate rapid closing of the platen to the workpiece. In these circumstances, all the oil in the cylinder(s) supporting the platen should be passed through the main control valve or, if this is not possible, through an auxiliary valve, the operation of which is entirely dependent upon the supply of pilot oil from the main control valve (see Figure 110).

Figure 110 **Hydraulic press: control of stroke**



The sequence of operations is as follows.

a) To stroke the press, solenoids C and D are energized. These then feed pilot oil to valves V6A and B and also to V4. When V6A and B are both fully open, the position switches on these valves operate and allow solenoid A of valve V2 and E of valve V5 to be energized. Solenoid A directs oil to the main ram, R1. Solenoid E allows a controlled descent of the platen at a speed which has been preset: the oil from the return cylinders, R2A and B, is exhausted from V5 via V2.

b) At a predetermined position, solenoid E is de-energized by a position switch and the valve closes: the speed of the platen is then reduced by creating a back pressure in the return cylinders, R2A and B, as a result of passing the flow over the relief section of V5 (which is preset to a pressure greater than that caused by the weight of the platen acting upon R2A and B).

c) The press then carries on at the designed pressing speed to the predetermined reversal point, be it by position switch, pressure switch or timer, at which point all solenoids are then de-energized and all valves should return to the neutral condition thus the vent-operated relief valve, V1, is vented via V7 and V3.

d) To return the press, solenoids B and F are energized and the press returns to the top position switch where B and F are de-energized.

The safety features built in are position switches on valves V6A and B to prove these are open or closed. Movement of the press is inhibited if the correct electrical signals are not present.

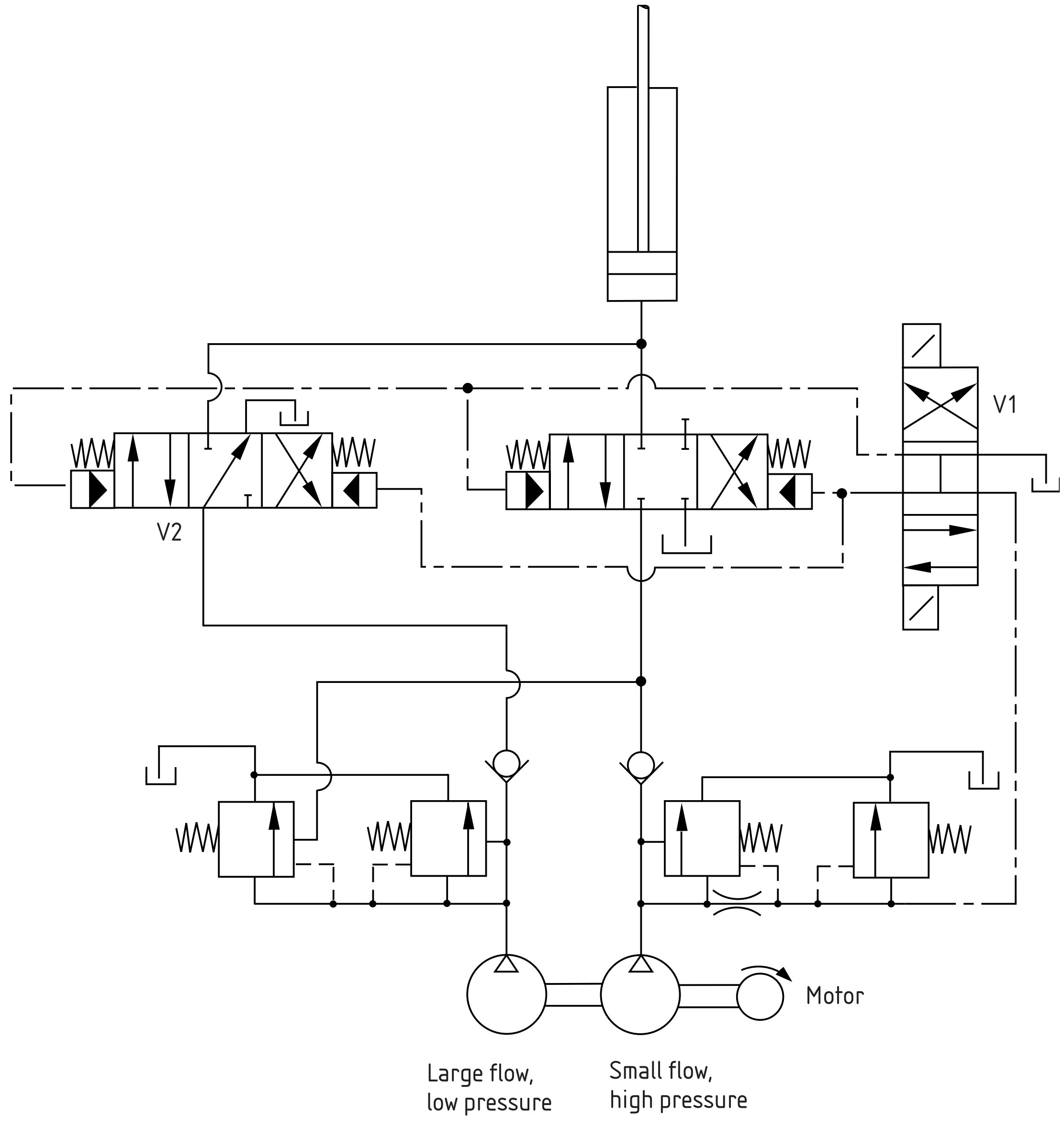
Valve V4 hydraulically monitors the solenoid valves, V3A and B: if either valve fails during the downstroke the press cannot be returned because V4 then vents V1 and relieves the main pressure.

NOTE This diagram illustrates the principles only and does not provide all the information needed to construct a working system.

On up-stroking presses, the platen has to be raised against the action of gravity and various methods can be used to obtain rapid closing of the platen to the workpiece. On large presses, all methods require large volumes of oil to be supplied to the press cylinder(s). If these are fed directly into the cylinder(s), e.g. by non-return valves, there is a danger that, due to back pressures in the system, the platen might make an unintended stroke. It is therefore essential that, whichever method is used for rapid approach, all the oil capable of causing the platen to make an unintended stroke should be passed through the main control valve or through an auxiliary valve, the operation of which is totally dependent upon the supply of pilot oil from the main control valve (see Figure 111).

When considering interlocking systems for presses with arrangements for fast approach, care should be taken to ensure that the valves interrupting the fluid flow are effective in bringing the platen to a halt whether the platen is closing under power or gravity.

Figure 111 **Rapid closing of an upstroking press**



This shows one method of achieving rapid closing of an up-stroking press. Note that the large flow, low-pressure oil is passed through an auxiliary valve V2, the pilot signals for which are dependent on the supply of pilot oil from the main control valve V1. This gives protection against an unintended stroke which could be caused by back pressure if large oil flow was fed directly to the cylinder.

10.3 Safety-related control systems

Machinery electrical control systems, particularly those that are programmable, are often associated with safety functions that need to be effective during many modes of operation of the machine. Hence, the application of protective measures performed by the machinery control system extends beyond interlocking requirements.

This applies to safety-related systems where the logic is entirely determined by permanent connections, e.g. a hard-wired electrical relay logic system, and to programmable safety-related systems, e.g. software-based systems. The complexity of modern electronic systems increase the difficulties faced by the designer who needs to assure system integrity.

BS EN 62061 and BS EN ISO 13849 specify requirements for the specification, design, implementation, validation, etc., of safety-related electrical control systems and are taken into account by designers and suppliers of new machinery (see also **10.2.3**). The approach adopted to the design of safety-related electrical control systems of machinery in previous editions of BS 5304 and PD 5304 differs from that in BS EN 62061 and BS EN ISO 13849.

Therefore, when upgrading safety-related electrical control systems at existing machinery, e.g. to incorporate complex electronic logic solvers rather than hard-wired relays, it is necessary to utilize appropriate expertise to provide confidence that the safety integrity is adequate to reduce the risks identified by the risk assessment at the machine. This could require demonstration that relevant essential safety requirements of the Machinery Directive (2006/42/EC) [14] and/or the technical requirements of BS EN 62061 and/or BS EN ISO 13849 have been properly satisfied.

Section 11: Installation considerations

11.1 Layout of machinery and plant

A machine should be installed with due regard to its interaction with other machines and the requirements of the process. Gangways should be kept free of obstruction and be wide enough to provide access for the transport of tools and materials, as well as personnel. Wherever possible, pedestrians should be separated from vehicles, in particular automated guided vehicles. Gangways should be clearly defined by, for example, floor markings. When they cannot be guarded, hazardous areas should be separately identified using a contrasting system.

Space should be provided around each machine to allow clear separation from passing traffic and for the storage of tools and work in progress. All phases of machine life should be considered, including cleaning and maintenance, as well as normal operation. Where workpieces, such as stock bars, overhang the machine, they should be included when determining the floor space occupied. Particular consideration should be given to the provision of working space for access to electrical equipment and additional space for work that might need to be carried out on live electrical equipment (for example, testing).

NOTE Attention is drawn to the HSR25 Memorandum of guidance on the Electricity at Work Regulations [15], Regulation 15 and Annex 3, regarding the width of passageways, means for unobstructed access etc. Other advice is given in BS EN 60204-1 and BS 7671.

11.2 Moving parts of machinery

A traversing part, or material carried by it, should not approach within 500 mm of any fixed structure, whether or not it is part of the machine, if anyone is liable to pass through the space between the moving and fixed parts. In particular, extra space might be required for large tools and components and/or for any handling equipment needed. The risk assessment might indicate a need for additional protective measures.

11.3 Services

11.3.1 Lighting

When considering the lighting for machinery the following aspects, which could affect the safety of the people involved, should be considered:

a) the direction and intensity of lighting;

b) the contrast between background and local illumination;

c) the colour of the light source;

d) reflection, glare and shadows; and

e) the stroboscopic effect from moving machinery.

The intensity and levels of lighting can have an injurious effect on eyesight.

NOTE Legal requirements on lighting in the workplace are contained in Regulation 21 of PUWER [2].

Guidance on local lighting is given in **5.20**.

11.3.2 Cables and pipes

Service pipes and cables should be protected against mechanical damage and situated to reduce tripping hazards by, for example, being:

a) placed below ground, clear of the machinery foundations;

b) provided with covers of adequate strength and access for maintenance as required (see **11.3.3**); or

c) placed at such a height as to have clear headroom.

The traversing of gangways by cables and pipes should be avoided, if possible.

11.3.3 Access to machinery for maintenance (see 5.23.3)

All machinery should be installed to enable all routine tasks, including operation, setting, cleaning and maintenance to be carried out by a person at ground level. Where this is not possible, and to facilitate cleaning and maintenance without causing interference to adjacent machinery, platforms, safe means of access and lifting appliance suspension points should be built-in, where practicable (see BS EN ISO 14122). Care should be taken to ensure that such means of access do not allow entry into hazardous areas. In such circumstances, it could be necessary to provide safeguards for hazardous areas which would otherwise be out of reach.

Section 12: Maintenance and safe working practices

12.1 General

Safety of machinery depends on a combination of risk assessment, hazard reduction by inherently safe design, safeguards and provision of information to enable the user to develop and apply safe working practices.

It is not always possible for designers and suppliers to eliminate all hazards or to design safeguards to protect people against all risks, particularly during such phases of machine life as commissioning, setting, process changeover, programming, adjustment, cleaning, maintenance and operation, where access to hazardous areas of the machine might be necessary. In these cases, safe working practices are required, which can involve the use of jigs, fixtures, fittings, controls and isolation arrangements.

12.2 Maintenance

12.2.1 Safeguards

Inspection and maintenance of safeguards is essential to their continued effectiveness. Reference should be made to supplier's specifications concerning the useful life and maintenance regimes of components used for safeguarding, e.g. switches, relays and valves.

Routine inspection of all safeguards should be part of the planned maintenance programme. In addition, some safeguards, in particular certain types of protective devices (for example, those described in **8.1.3**), should be functionally checked as part of the production procedure, the frequency of checking depending on the type of safeguard and its operational characteristics.

A maintenance log should be provided and kept up to date. A detailed maintenance log can provide information for future planning of maintenance activities and inform maintenance personnel and others of previous action taken.

The maintenance programme should be carried out by trained and experienced personnel. The degree and extent of training depends on the complexity of the machinery and the risks arising from its use.

In some applications, when tool-setting or repair and maintenance of machinery and process plant are carried out, the safeguarding arrangements effective during the normal operation of the process need to be suspended (see BS EN 60204-1:2006+A1:2009, **9.2.4**). When the work has been completed an appropriate check should be made to ensure that all the safeguarding arrangements are correctly reinstated. Safe systems of work should be implemented where access is required to a hazardous area (see **12.3**).

It is important to maintain the normal machinery control and operational functions which can have an effect on safety, for example, work-holding devices (see **5.16**).

12.2.2 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, waste or spilled materials.

12.3 Safe working practices

12.3.1 General

Safe working practices are an essential part of the management of safety and should be effectively communicated to all personnel. They may involve, for example, correct use of equipment, information, training and supervision. Subclauses **12.3.2** to **12.3.4** give examples of safe working practices.

12.3.2 Machinery operation

All personnel should be properly trained and supervised. The following general precautions should be observed (see **12.4** and **12.5**).

a) Safe access, with firm footholds (and handholds where necessary), should be provided. This should be free of obstruction and any material likely to cause tripping and slipping.

b) Where the hazards include entanglement and drawing-in, material likely to be caught up should be avoided, e.g. loose clothing, neckties, scarves, gloves, rings and other jewellery, long hair (unless tied back and/or covered), fabric first aid dressings and bandages, close-fitting overalls with close-fitting cuffs and no external pockets should be worn. Material being processed or by-products such as swarf might also present an entanglement hazard.

c) Personal protective equipment should be worn where residual risks remain, for example, eye protection during grinding.

NOTE Attention is drawn to the Personal Protective Equipment Regulations [16].

d) Precautions against impact injuries due to kickback are necessary on certain types of cutting and abrasive machinery, particularly where workpieces are manipulated by hand. These include:

   1) selection of tooling designed to minimize the risk of kickback;

   2) provision of backstops on vertical spindle moulding work;

   3) ensuring circular saw blades are adjusted to protrude through the material being cut, and that riving knives are of the correct thickness;

   4) ensuring work rests are adjusted close to abrasive wheels or tool rests are correctly adjusted; and

   5) ensuring that cutter speeds, or wheel speeds, are correct for the task in question: this includes ensuring that circular saw blades are of large enough diameter to have the correct tooth speed (machines ought to have been labelled with the minimum blade diameter).

e) Precautions against impact injuries due to bursting generally involve ensuring that relevant rotating equipment, and the abrasive wheels, etc., used with it, have been marked clearly with their speeds to ensure correct selection and use.

f) Precautions against non-mechanical hazards (for example, toxic materials, radiation, excessive temperatures) should be provided (by, for example, purging, screening, provision of breathing apparatus and/or protective clothing), as necessary.

g) There are also practices relating to approach to mechanical hazards which are relevant to most of the types listed in **4.2**, including:

   1) limiting closeness of approach, for example, in work near overhead travelling cranes, or in taking off work from the rear of a saw Table, and in avoiding the presence in certain areas of a machine's traverse;

2) provision and use of manual handling devices, for example, tongs for forging work, push sticks for circular saws and spindle moulders, or push blocks for planing machines; and

3) provision of jigs and holders for workpieces, for example, for vertical spindle moulding, or for cutting irregular material on circular saws.

h) Emergency stop controls should be located so as to be readily accessible by any persons who might need to operate them.

12.3.3 Isolation of power and dissipation of energy

12.3.3.1 General

Where safeguards are provided to prevent access during most phases of machine life, they might not be effective at all times because of the need to gain access to hazardous areas, for example, for setting-up purposes. Where it is necessary to gain access inside the guards with the guards closed, additional provision will be required (see also **12.3.3.6**). Presence-sensing devices could have been provided to supplement the interlocks, but it is often necessary to rely on safe working practices.

12.3.3.2 External isolation and energy dissipation

Where interlocking guards have been provided and selected in accordance with Section 6, some identified minor interventions, such as adjustment or lubrication, can be carried out safely whilst relying on the interlocks. For all other interventions, e.g. those of longer duration, work on power supplies or control systems, the use of more reliable and secure means is required, i.e. isolation and energy dissipation. The following could be involved.

a) Mechanical power transmission: by isolating clutches, by removal of drive belts or chains or shaft sections. Scotching may also be used.

b) Electrical power: by isolating switch disconnectors (see BS EN 60204-1:2006+A1:2009, **5.5**), by removal of fuses, or by removal of plugs from sockets. Earthing or short-circuiting could also be required. For high voltage equipment, see BS EN 60204-11.

c) Hydraulic or pneumatic power: by isolating valves, by electrical isolation of hydraulic pumps, or by disconnection from pneumatic mains. Open venting to atmosphere could also be required.

d) Services: isolation of water, steam, gas or fuel supplies. Draining, venting or purging could also be required.

e) Process and material supplies: isolation of process lines and line blinding or blanking off. Draining, purging or venting could also be required.

Provision for these facilities ought to have been made at the design stage in accordance with BS EN 1037 (see also **12.3.3.5**).

12.3.3.3 Energy dissipation (see also BS EN 1037)

Any residual energy storage or material in the machine or equipment might also need to be dealt with, as follows.

a) Mechanical power: allow flywheels or high-speed rotating parts, for example, centrifuge bowls, to run down, and minimize the potential energy of other parts.

   Where these options are not practicable, these energy reservoirs should be treated as needing isolation as though they are external sources. For example, scotches, props and catches may be used to support parts which can fall under gravity. These should be of high reliability in view of the nature of the tasks.

b) Electrical power: discharge of capacitors, disconnection of standby batteries, or earthing and short-circuiting of high voltage circuits.

c) Hydraulic power: discharge of accumulators, or relaxation of pressurized pipework.

d) Pneumatic power: discharge of air pressure throughout the system (except where used for support).

e) Services: residual steam, gas or fuel might need to be vented, purged or drained.

f) Excessive temperatures: sufficient time needs to be allowed, e.g. for hot surfaces to cool.

g) Process and material supplies: emptying, venting, purging, draining and/or cleaning could be required before entry.

Where hydraulic or pneumatic [c) and d)] support devices have been provided for mechanical parts, those selected should be of high reliability.

12.3.3.4 Checking for absence of hazards

After external and internal isolation, a check should be made to ensure that no other hazards remain. On occasion, this could involve the use of special instruments or sensors, though this is more often the case with non-mechanical sources of hazards.

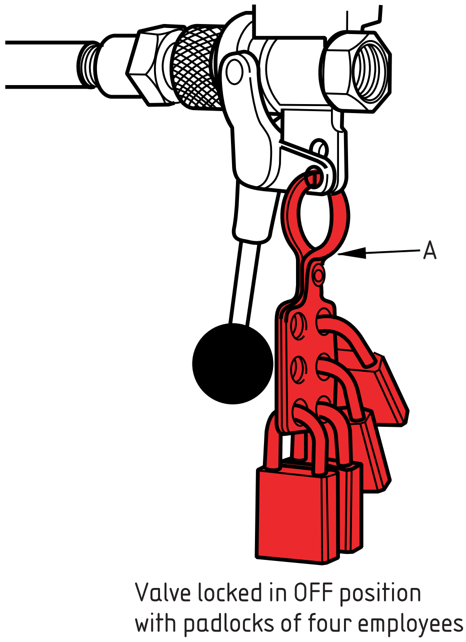
12.3.3.5 Security of safety measures

The isolation of machinery should be appropriately secure to prevent a reconnection of the energy supply. If an isolator cannot remain continuously under the direct control of the person working on the machinery, then it should be locked off and an appropriate warning notice posted at the point of isolation. This is to ensure that subsequent re-energization of the supply is under the control of the person(s) working on the machine, thus averting any risks from re-energization, for example, electric shock, unexpected start-up. It is essential that the effectiveness of an isolation is appropriately verified before work commences on the machine.

Where an item of machinery has several incoming supplies of energy associated with its different functional parts for example, then each of these should be securely isolated, where necessary, to prevent danger.

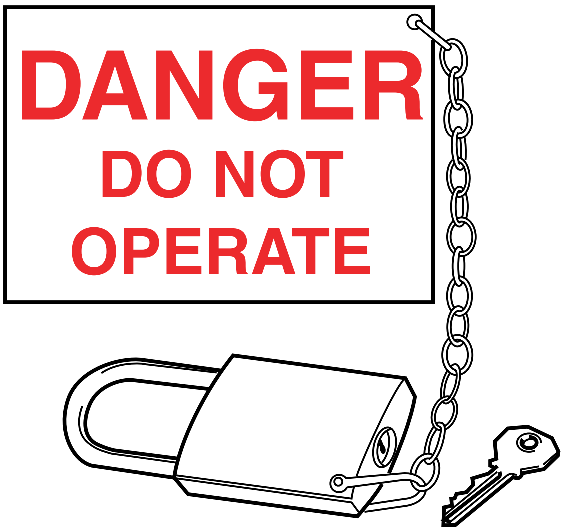
Where more than one person is at risk, each person should have their own means of maintaining the isolation, e.g. by multi-padlockable hasps (see Figure 112) where each person applies an individual padlock (see Figure 113) or a multiple key exchange arrangement where each person removes and retains a key from a multiple key exchange box (see **9.6.5**).

Figure 112 **Multi-padlockable hasp**



Before the hasp A can be released and the valve handle operated, all four padlocks, one per operator who would otherwise be at risk, have to be removed.

Figure 113 **Example of padlock complete with danger board for locking-off after isolation**



12.3.3.6 Security at interlocking access gates

Where whole-body access to a hazardous area can be gained through an interlocking gate or door, a device that prevents inadvertent closing of the door should be provided. This could be achieved, for example, by one of the following.

a) Trapped-key bolt. This provides security, unless a person outside the guard closes the door, removes the key and uses this to switch on the power.

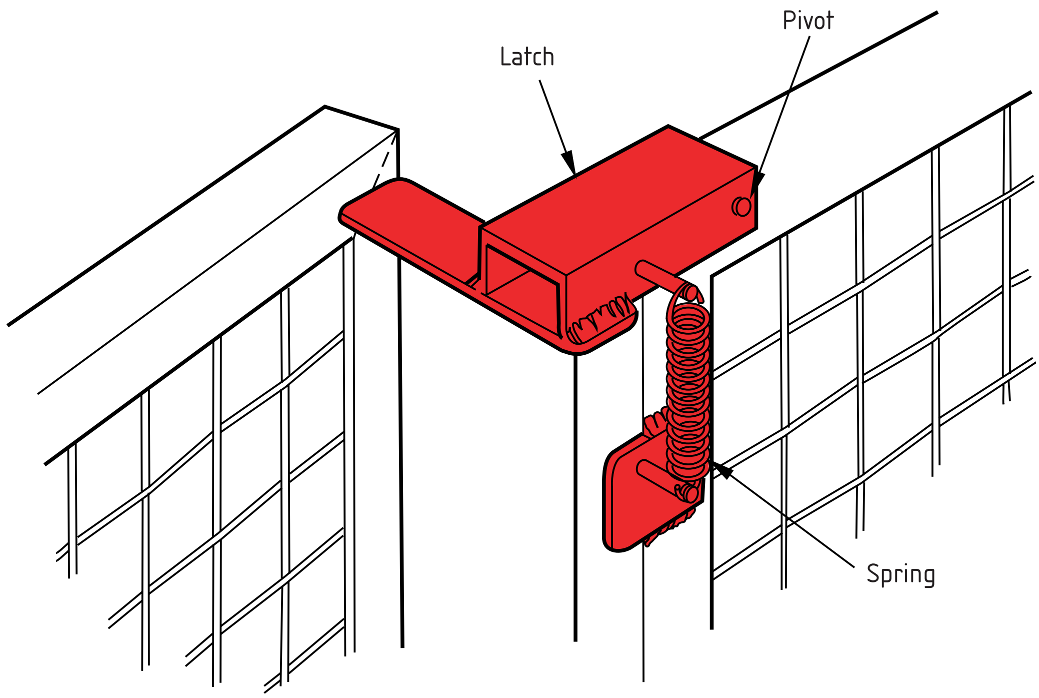
b) Exchange-key bolt. This is similar to the trapped-key bolt, but when the guard is open a second key is released and can be removed by the person entering the enclosure. This prevents the first (exchange) key from being removed and used to switch on the power supply. The second key improves security and is appropriate for higher risk applications.

c) Captive key with lockable operating handle. The operating handle for the captive-key interlock incorporates either an integral lock which, when set in the "off" position, allows the person entering the enclosure to take the key, or a facility to padlock the handle in the "off" position.

d) Tongue-operated switch. Some of these devices have actuators into which a padlock can be inserted thereby preventing operation of the switch by closing the door.

e) Gravity or spring-operated latch. This holds the door in the open position but provides only limited security because the latch is easily lifted allowing the door to close (see Figure 114).

Figure 114 **Gravity or spring-operated latch**



When the door is opened, the latch falls either due to gravity or under the action of a spring. To close the door, a deliberate action to raise the latch is necessary. The latch and interlock (not shown) are arranged to ensure that the interlock continues to interrupt the power source to hazardous parts in the position shown.

12.3.3.7 Tasks

The tasks to be carried out should be organized to minimize risk of harm, and relevant features ought to have been considered at the design stage, for example, attachment points for lifting equipment and provision of safe access facilities.

12.3.4 Practices for restricted operation

Where tasks have to be carried out without full safeguarding, and isolation procedures cannot be fully applied, restricted operation of the machine might be possible by, for example, inching, reduced speed or reduced power. The possible restrictions on machine operation are outlined in **8.6**. The most effective measures possible should be adopted. The safety precautions outlined in **12.3.2** should be applied, and any external and internal power sources and process or service connections which can be isolated should be, in accordance with **12.3.3**. The controls or devices which set the machine in its restricted mode of operation should be given the same consideration in terms of reliability and security as controls or devices which provide for complete isolation and energy dissipation. Certain controls of these types are considered in **5.4.4** and described in Section 8.

12.4 Supervisory control

12.4.1 General

Where safety from mechanical (and other) hazards is dependent on people carrying out safe working practices, it is essential that an appropriate degree of managerial and/or supervisory control is exercised, e.g. control of access to passwords and keys. Where risk is minimal, verbal instructions can be adequate, but as risk increases it becomes essential to define procedures in writing, in order that they can be supervised more rigorously. Where the risk level is high, for example, there is a possibility of serious injury or death if the procedure is not followed correctly, the adoption of a permit to work system is essential. This normally involves specification of the controls measures, etc., for isolation, energy dissipation, and supervisory checks to ensure that these control measures have been applied and any additional protective measures required, such as the availability and use of protective equipment, are applied.

An equivalent check is normally required on the procedures for putting the equipment back into operation and, on occasion, checks might need to be made during the authorized work.

The task to be carried out, and the individual responsibilities of those involved, might need to be specified in detail on occasion.

12.4.2 Permit to work systems

The most common use of a permit to work system is during maintenance operations. Where a procedure, in the form of a safe system of work, is deemed to be appropriate, management should identify the hazards which are present and develop a safe system of work either to eliminate them or, where this is not possible and as a last resort, ensure that employees are made aware so that personal precautions against harm can be taken. Oral instructions, requests or promises are liable to be misheard, misinterpreted or forgotten and are therefore not a satisfactory basis for action on which lives could depend.

Effective control should be achieved by means of a written system, though even this relies on the human element, for no documentary system can by itself prevent accidents. The system, which is known as a permit to work system, requires formal action on the part of those doing the work, those responsible for it and those authorized by the user to sign such permits. The person responsible for supervising the work should ensure that the person(s) undertaking the work are identified and properly trained, and understand the task involved and the precautions to be taken.

A safe procedure is therefore specified forming a clear record of all the foreseeable hazards that have been considered in advance, together with the appropriate precautions taken in their correct sequence and the starting and finishing times for the task. The formal handbook procedures should be documented as appropriate. Trained supervision is required to ensure that the system operates correctly.

Work in potentially hazardous circumstances can be conducted in safety by the use of this method. The design of a permit to work (see Annex C) depends on the nature and degree of risk, the complexity of the task and the industry to which it relates.

12.5 Information and training

12.5.1 General

All information such as training manuals, instructions for use, instruction placards and warning labels should be presented clearly in English and other languages where necessary, in a logical sequence with good illustrations and using standard symbols.

12.5.2 Instruction placards and warning labels

Appropriate warning labels should be provided on machinery for:

a) maintenance, for example, to indicate lifting procedures or the exposure of hazardous parts prior to the removal of guards; and

b) operation of the machine, for example, to indicate maximum speeds, or to inform about safe working procedures, e.g. the need to wear eye or ear protection.

Warning labels should be legible, clear and concise using, where practicable, standard symbols and colours. Attention is drawn to BS EN ISO 7010 and the Safety Signs Regulations [17].

Instruction placards can be used in the area adjacent to the machinery to explain the legal requirements, for example, statutory notice outlining the dangers associated with abrasive wheels, or to carry reference information on machinery operation.

12.5.3 Installation, operation and maintenance instructions

Where possible, information relating to the operation and maintenance of the machine should be available, with particular reference to the following:

a) lifting and moving, including the weight of the machine and its attachments, with an of indication where it should be lifted;

b) start-up, including preparation before start-up;

c) operation, including description of controls and function;

d) close-down;

e) setting/process changeover/programming (particularly robots);

f) adjustment;

g) cleaning;

h) lubrication, refuelling, recharging;

i) maintenance and inspection requirements and schedules;

j) repair, including information on foreseeable failures and fault finding; and

k) emergency procedures.

For machinery supplied with tooling for a specific workpiece or a range of workpieces, the user should review the original safeguards if tooling and/or workpiece considerations change.

12.5.4 Training

12.5.4.1 General

Supervisors and work people, particularly young people, should be trained formally in the correct knowledge and application of safe practices at their machinery. This is particularly important for those phases of machine life where risk is higher, for example, due to the removal of safeguards. Safety training should, where possible, form part of an integral programme covering all aspects of the work to be undertaken.

Users should make themselves aware of any training courses offered on the operation and maintenance of the machinery by the supplier.

12.5.4.2 Training procedures

12.5.4.2.1 Machinery operators

Machinery operators should be trained in the following:

a) machinery safety procedures, including emergency procedures;

b) the correct and safe way of doing the job;

c) knowledge and understanding of the hazards they face;

d) understanding the purpose and function of the safeguards which protect them, in particular, where adjustable guards are used that might not afford completely effective safeguarding, e.g. on some woodworking and milling machines, it is essential that the operator is instructed in safe working practices;

e) reporting faults immediately, including guard defects;

f) wearing and care of protective clothing and equipment; and

g) need for good housekeeping.

12.5.4.2.2 Plant engineers and maintenance staff

Plant engineers and maintenance staff should be trained in the following:

a) principles of safeguarding machinery;

b) electrical and mechanical safety, and presence/nature of other hazards;

c) precautions during maintenance work, including safe systems of work and, where necessary, permit to work and lock-off systems, for example padlock, captive key or interlock key exchange, and emergency procedures; and

d) wearing and care of protective clothing and equipment.

12.5.5 Personal protection

User instructions for machinery might include the provision of personal protective equipment to minimize the risk of harm, such as special clothing, including protective head and foot wear, hearing defenders, eye protection or breathing apparatus. All those required to wear personal protective equipment should be given training in its proper use, care and maintenance.

Users should be made aware of the requirements of the Personal Protective Equipment Regulations [16] when equipment is provided.

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Annex A (normative) Ergonomic data

NOTE 1 The information given in this Annex is based on that given in BS EN ISO 13857.

*NOTE 2 Where children might have access to machinery, the application of the data, e.g. reach distances through openings, needs to be handled with care (see BS EN ISO 13857:2008, **4.2.4.2** and Table 5).*

A.1 Reaching upwards (see Figure A.1)

If there is a low risk from the hazardous area when reaching upwards then the height of the hazardous area should be 2 500 mm or more.

If there is a high risk from the hazardous area, then either the height of the hazardous area, *h*, should be 2 700 mm or more, or other safety measures should be used.

A.2 Reaching over protective structures

A.2.1 General

Where practicable, distance guards used as perimeter fences around hazardous areas should be a minimum of 1 800 mm high. The data given in **A.2.2** for barriers less than 1 800 mm high may only be used where the 1 800 mm height is not reasonably practicable.

NOTE Barriers are not foolproof and they cannot prevent access to persons intent on gaining access. Therefore, as a person's intent on reaching a hazardous part increases, e.g. by climbing on chairs, ladders or the barrier itself, the protection provided by a barrier erected in accordance with Table A.1 decreases.

A.2.2 Reaching over

When reaching over an edge, for example on machine frames or barriers, the safety distance should be obtained from Figure A.2, Table A.1 and Table A.2.

If there is a low risk from a hazardous area when reaching over a protective structure, the values given in Table A.1 should be used as a minimum. There should be no interpolation of the values in Table A.1 or Table A.2 (see examples of where values of Table A.1 have been used). Consequently, when the known values of *a*, *b*, or *c* are between two values given in Table A.1 or Table A.2, the values to be used are those which provide the highest level of safety.

If there is a high risk from the hazardous area when reaching over a protective structure, then either the values in Table A.2 or other safety measures should be used.

EXAMPLE 1

The height of the hazardous area, *a*, is 1 500 mm and its horizontal distance, *c*, from the proposed protective structure is 800 mm.

Using Table A.1 the height of the protective structure, *b*, should be at least 1 800 mm.

EXAMPLE 2

The height of the protective structure, *b*, is 1 300 mm and the height of the hazardous area, *a*, is 2 300 mm.

Using Table A.1 the horizontal distance, *c*, of the protective structure from the hazardous area should be at least 600 mm.

EXAMPLE 3

For a high risk, the height of the protective structure, *b*, is 1700 mm and the horizontal distance, *c*, from the hazardous area is 850 mm.

Using Table A.2 the hazardous area should not be between 1000 mm and 2400 mm high.

A.3 Reaching round

When reaching round the edges of a protective structure in any position the safety distance for freely articulating body parts of persons over the age of 14 is given in Table A.3.

The radius of the movement about a fixed edge is determined by the reach of given body parts. The safety distances assigned should be respected as a minimum if the body part concerned is to be prevented from reaching a hazardous area.

Of special importance is a hazardous area which can be reached when these body parts are introduced through slots.

When applying safety distances it should be assumed that the basic joint component of the relevant body part is in fixed contact with the edge. The safety distances apply only if it is ensured that further advance or penetration of the body part towards the hazard is excluded.

A.4 Reaching through regular openings

Safety distances, s_r, for persons aged 14 and above reaching through regular openings should be obtained from Table A.4.

The dimensions of openings, *e*, correspond to the side of a square, the diameter of a round opening and the narrowest dimension of a slot opening. For persons aged between 3 and 14 years old, see BS EN ISO 13857:2008, **4.2.4.2** and Table 5.

Figure A.1 **Safety distance for reaching upwards**

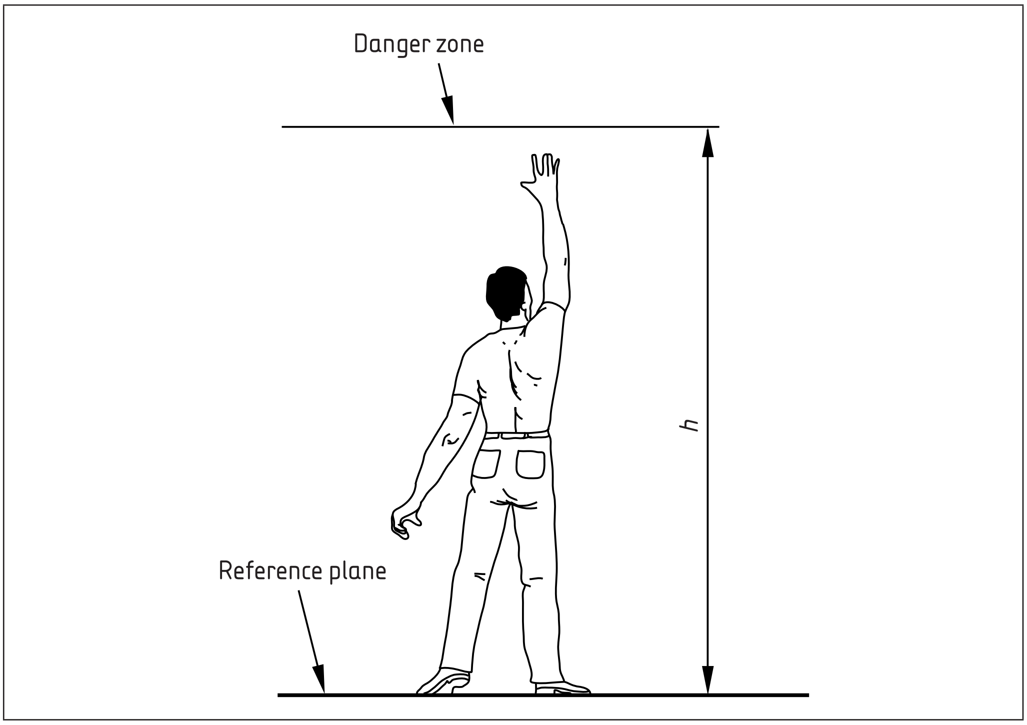
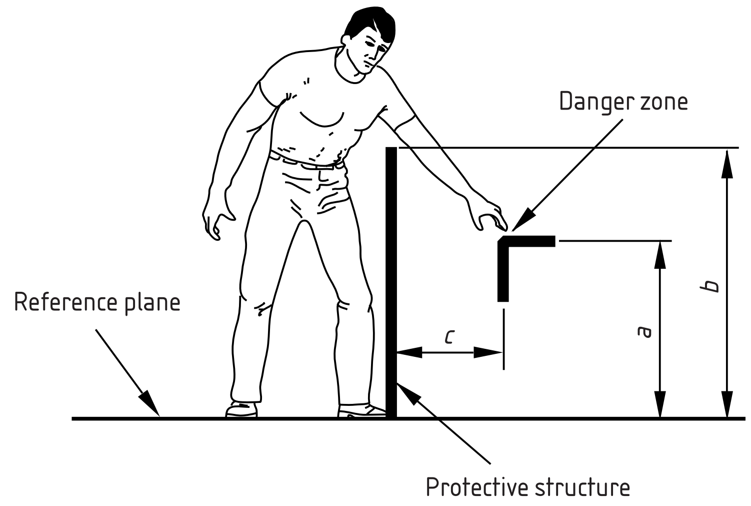


Figure A.2 **Diagram showing dimensions *a*, *b* and *c* used in Table A.1 and Table A.2**



Key

a Height of the hazard zone

b Height of the protective structure

c Horizontal distance to the hazard zone

Table A.1 **Low risk values of *a*, *b* and *c* for Figure A.2**

Dimensions in millimetres

Height of hazardous area *a* [B]	**Height of protective structure *b*** [A]									
	1 000	1 200	1 400	1 600	1 800	2 000	2 200	2 400	2 500	2 700
	Horizontal distance to hazardous area *c*									
2 700	0	0	0	0	0	0	0	0	0	0
2 600	900	800	700	600	600	500	400	300	100	0
2 400	1 100	1 000	900	800	700	600	400	300	100	0
2 200	1 300	1 200	1 000	900	800	600	400	300	0	0
2 000	1 400	1 300	1 100	900	800	600	400	0	0	0
1 800	1 500	1 400	1 100	900	800	600	0	0	0	0
1 600	1 500	1 400	1 100	900	800	500	0	0	0	0
1 400	1 500	1 400	1 100	900	800	0	0	0	0	0
1 200	1 500	1 400	1 100	900	700	0	0	0	0	0
1 000	1 500	1 400	1 000	800	0	0	0	0	0	0
800	1 500	1 300	900	600	0	0	0	0	0	0
600	1 400	1 300	800	0	0	0	0	0	0	0
400	1 400	1 200	400	0	0	0	0	0	0	0
200	1 200	900	0	0	0	0	0	0	0	0
0	1 100	500	0	0	0	0	0	0	0	0

[A] Protective structures less than 1 000 mm in height are not included because they do not sufficiently restrict movement of the body.

[B] For hazardous areas above 2 500 mm refer to A.1.

Table A.2 **High risk values of *a*, *b* and *c* for Figure A.2**

Dimensions in millimetres

Height of hazardous area *a* C)	Height of protective structure *b* A), B)									
	1 000	1 200	1 400	1 600	1 800	2 000	2 200	2 400	2 500	2 700
	Horizontal distance to hazardous area *c*									
2 700	0	0	0	0	0	0	0	0	0	0
2 600	900	800	700	600	600	500	400	300	100	0
2 400	1 100	1 000	900	800	700	600	400	300	100	0
2 200	1 300	1 200	1 000	900	800	600	400	300	0	0
2 000	1 400	1 300	1 100	900	800	600	400	0	0	0
1 800	1 500	1 400	1 100	900	800	600	0	0	0	0
1 600	1 500	1 400	1 100	900	800	500	0	0	0	0
1 400	1 500	1 400	1 100	900	800	0	0	0	0	0
1 200	1 500	1 400	1 100	900	700	0	0	0	0	0
1 000	1 500	1 400	1 000	800	0	0	0	0	0	0
800	1 500	1 300	900	600	0	0	0	0	0	0
600	1 400	1 300	800	0	0	0	0	0	0	0
400	1 400	1 200	400	0	0	0	0	0	0	0
200	1 200	900	0	0	0	0	0	0	0	0
0	1 100	500	0	0	0	0	0	0	0	0

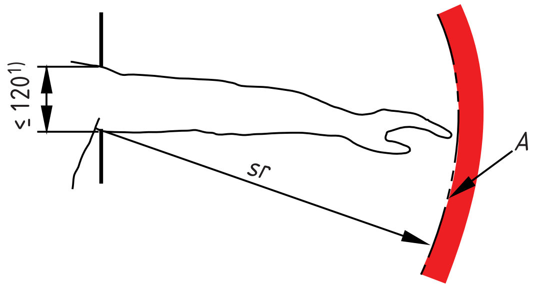
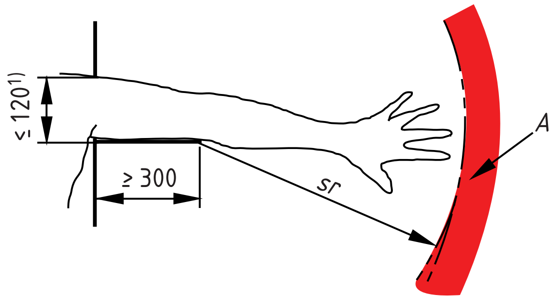
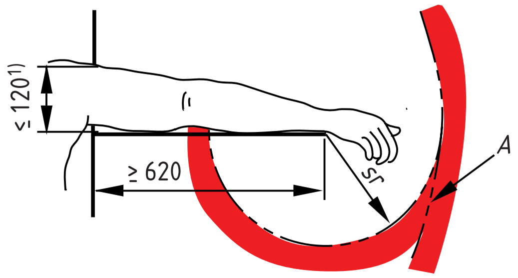
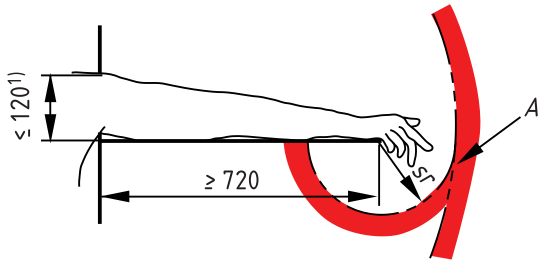
A) Protective structures less than 1 000 mm in height are not included because they do not sufficiently restrict movement of the body.

B) Protective structures lower than 1 400 mm should not be used without additional safety measures.

C) For hazardous areas above 2 700 mm refer to A.1.

Table A.3 **Safety distances**

Dimensions in millimetres

Limitation of movement	Safety distance s_r	Illustration
Limitation of movement only at shoulder and armpit	≥850	
Arm supported up to elbow	≥550	
Arm supported up to wrist	≥230	
Arm and hand supported up to knuckle joint	≥130	

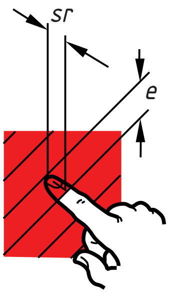
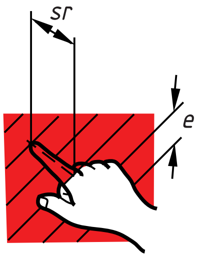
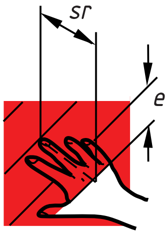
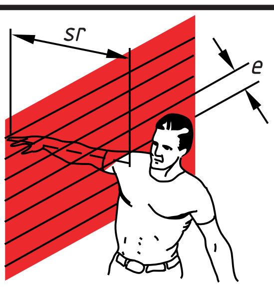
A) Range of movement of the arm.

s_r radial safety distance

1) Either the diameter of a round opening, or the side of a square opening, or the width of a slot opening.

Table A.4 **Safety distances, s_r, through regular openings of size *e***

Dimensions in millimetres

Part of body	Illustration	Opening	Safety distance s_r		
			Slot	Square	Round
Fingertip		$e \leq 4$	≥2	≥2	≥2
		$4 \leq e \leq 6$	≥10	≥5	≥5
Finger up to knuckle joint		$6 \leq e \leq 8$	≥20	≥15	≥5
		$8 \leq e \leq 10$	≥80	≥25	≥20
Hand		$10 \leq e \leq 12$	≥100	≥80	≥80
		$12 \leq e \leq 20$	≥120	≥120	≥120
		$20 \leq e \leq 30$	≥850 A)	≥120	≥120
Arm up to junction with the shoulder		$30 \leq e \leq 40$	≥850	≥200	≥120
		$40 \leq e \leq 120$	≥850	≥850	≥850

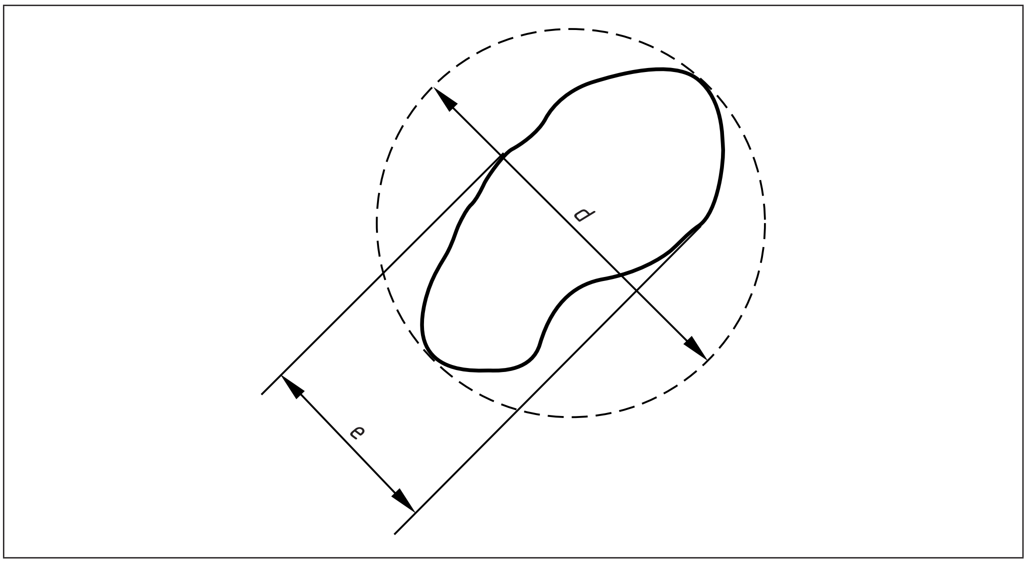
The lines within the Table delineate that part of the body restricted by the opening size.

A) If the length of the slot opening ≤65 mm the thumb acts as a stop and the safety distance may be reduced to 200 mm.

A.5 Openings of irregular shape

To choose a safety distance for an opening of irregular shape, Table A.4 should be used, applying either the smallest circular aperture, *d*, that describes the opening, or the narrowest slot with parallel sides, *e*, that contains the opening (see Figure A.3). The smallest safety distance arrived at using this method may be employed.

Figure A.3 **Safety distances for openings of irregular shape**



Annex B (informative)

Common types of failures associated with safety-related interlocking control systems

a) **Mechanical systems**

   1) Mechanical devices, components and elements (e.g. cam, follower, chain, clutch, brake, shaft, screw, pin, guide, bearing):

      - wear/corrosion;
      - untightening/loosening;
      - fracture;
      - deformation by overstressing;
      - stiffness/sticking;
      - Pressure coil springs:
      - wear/corrosion;
      - force reduction by setting and fracture;
      - fracture;
      - stiffness/sticking;
      - loosening;
      - deformation by overstressing.

b) **Pneumatic systems**

   1) Directional control valves:

      - change of switching times;
      - non-switching (sticking at the end or zero position) or incomplete switching (sticking at a random intermediate position);
      - spontaneous change of the initial switching position (without an input signal);
      - leakage;

   2) Stop (shut-off) valves/non-return (check) valves/quick action venting valves/shuttle valves, etc.:

      - non-opening, incomplete opening, non-closure or incomplete closure (sticking at an end position or at an arbitrary intermediate position);
      - spontaneous change of the initial switching position (without an input signal);
      - for shuttle valves: simultaneous closing of both input connections;
      - leakage;
      - change in the leakage flow rate over a long period of use;
      - bursting of the valve housing or breakage of the moving component(s), as well as breakage/fracture of the mounting or housing screws;

   3) Flow valves:

      - change in flow rate without any change in setting device;
      - change in the flow rate in the case of non-adjustable, circular orifices and nozzles;
      - for proportional flow valves: change in the flow rate due to an unintended change in the set value;

- spontaneous change in the setting device;
- unintended loosening (unscrewing) of the operating element(s) of the setting device;
- bursting of the valve housing or breakage of the moving component(s) as well as the breakage/fracture of the mounting or housing screws;

4) Pressure valves:
   - non-opening or insufficient opening when exceeding the set pressure (sticking or sluggish movement of the moving component);
   - non-closing or insufficient closing if pressure drops below the set value (sticking or sluggish movement of the moving component);
   - change of the pressure control behaviour without changing the setting device
   - for proportional pressure valves: change in the pressure control behaviour due to unintended change in the set value;
   - spontaneous change in the setting device;
   - unintended unscrewing of the operating element of the setting device;
   - leakage;
   - change of the leakage flow rate, over a long period of use;
   - bursting of the valve housing or breakage of the moving component(s), as well as breakage/fracture of the mounting or housing screws;
5) Pipework:
   - bursting and leakage;
   - failure at the connector (e.g. tearing off, leakage);
   - clogging (blockage);
   - kinking of plastic pipes with a small nominal diameter;
6) Hose assemblies:
   - bursting, tearing off at the fitting attachment and leakage;
   - clogging (blockage);
7) Connectors:
   - bursting, breaking of screws or stripping of threads;
   - leakage (loss of airtightness);
   - clogging (blockage);
8) Pressure transmitters and pressure medium transducers:
   - loss or change of air/oil-tightness of pressure chambers;
   - bursting of the pressure chambers as well as fracture of the attachment or cover screws;
9) Compressed air treatment: Filters:
   - blockage of the filter element;
   - rupture or partial rupture of the filter element;
   - failure of the filter condition indicator or monitor;
   - bursting of the filter housing or fracture of the cover or connecting elements;

10) Compressed-air treatment: Oilers:
    - change in the set value (oil volume per unit time) without change to the setting device;
    - spontaneous change in the setting device;
    - unintended unscrewing of the operating element of the setting device;
    - bursting of the housing or fracture of the cover, fixing or connecting elements;
11) Compressed air treatment: Silencers:
    - blockage (clogging) of the silencer;
12) Accumulators and pressure vessels:
    - fracture/bursting of the accumulator/pressure vessel or connectors or stripping of the threads of the fixing screws;
13) Sensors:
    - faulty sensor;
    - change of the detection or output characteristics;
14) Information processing: Logical elements:
    - faulty logical element (e.g. AND element, OR element, logic-storage element) due to, e.g. change in the switching time, failing to switch or incomplete switching;
15) Information processing: Time-delay devices:
    - faulty time-delay device, e.g. pneumatic and pneumatic/mechanical time and counting elements;
    - change of detection or output characteristics;
    - bursting of the housing or fracture of the cover or fixing elements;
16) Information processing: Converters:
    - faulty converter;
    - change of the detection or output characteristics;
    - bursting of the housing or fracture of the cover or fixing elements.

c) Hydraulic systems

1) Directional control valves:
    - change of switching times;
    - non-switching (sticking at an end or zero position) or incomplete switching (sticking at a random intermediate position);
    - spontaneous change of the initial switching position (without an input signal);
    - leakage;
    - change in the leakage flow rate over a long period of use;
    - bursting of the valve housing or breakage of the moving component(s) as well as breakage/fracture of the mounting or housing screws;
    - for servo and proportional valves: hydraulic faults which cause uncontrolled behaviour;

2) Stop (shut–off) valves/non-return (check) valves/shuttle valves, etc.:
   - change of switching times;
   - non-opening, incomplete opening, non-closure or incomplete closure (sticking at an end position or at an arbitrary intermediate position);
   - spontaneous change of the initial switching position (without an input signal);
   - for shuttle valves: simultaneous closing of both input connections;
   - leakage;
   - change in the leakage flow rate over a long period of use;
   - bursting of the valve housing or breakage of the moving component(s), as well as breakage/fracture of the mounting or housing screws;
3) Flow valves:
   - change in the flow rate without change in the setting device;
   - change in the flow rate in the case of non-adjustable, circular orifices and nozzles;
   - for proportional flow valves: change in the flow rate due to an unintended change in the set value;
   - spontaneous change in the setting device;
   - unintended loosening (unscrewing) of the operating element(s) of the setting device;
   - bursting of the valve housing or breakage of the moving component(s), as well as the breakage/fracture of the mounting or housing screws;
4) Pressure valves:
   - non-opening or insufficient opening (spatially and temporarily) when exceeding the set pressure (sticking or sluggish movement of the moving component);
   - non-closing or insufficient closing (spatially and temporarily) if the pressure drops below the set value (sticking or sluggish movement of the moving component);
   - change of the pressure control behaviour without changing the setting device;
   - for proportional pressure valves: change in the pressure control behaviour due to unintended change in the set value;
   - spontaneous change in the setting device;
   - unintended unscrewing of the operating element of the setting device;
   - leakage;
   - change of the leakage flow rate over a long period of use;
   - bursting of the valve housing or breakage of the moving component(s), as well as breakage/fracture of the mounting or housing screws;
5) Metal pipework:
   - bursting and leakage;
   - failure at the connector (e.g. tearing off, leakage);
   - clogging (blockage);

6) Hose assemblies:
   - bursting, tearing off at the fitting attachment and leakage;
   - clogging (blockage);
7) Connectors:
   - bursting, breaking of screws or stripping of threads;
   - leakage (loss of the leak-tightness);
   - clogging (blockage);
8) Filters:
   - blockage of the filter element;
   - rupture of the filter element;
   - failure of the bypass valve;
   - failure of the dirt indicator or dirt monitor;
   - bursting of the filter housing or fracture of the cover or connecting elements;
9) Energy storage:
   - fracture/bursting of the energy storage vessel or connectors or cover screws as well as stripping of the screw threads;
   - leakage at the separating element between the gas and the operating fluid;
   - failure/breakage of the separating element between the gas and the operating fluid;
   - failure of the filling valve on the gas side;
10) Sensors:
   - faulty sensor;
   - change of the detection or output characteristics.

d) Electrical systems

1) Conductors/cables:
   - short circuit between any two conductors;
   - short circuit of any conductor to an exposed conductive part or to earth or to the protective bonding conductor;
   - open circuit of any conductor;
2) Printed circuit boards/assemblies:
   - short circuit between two adjacent tracks/pads;
   - open circuit of any track;
3) Terminal block:
   - short circuit between adjacent terminals;
   - open circuit of individual terminals;
4) Multi–pin connector:
   - short circuit between any two adjacent pins;
   - interchanged or incorrectly inserted connector when not prevented by mechanical means;

- short circuit of any conductor to earth or a conductive part or to the protective conductor;
- open circuit of individual connector pins;

5) Switches: Electromechanical position switches, manually-operated switches (e.g. push-button, reset actuator, DIP switch, magnetically-operated contacts, reed switch, pressure switch, temperature switch):
   - contact will not close;
   - contact will not open;
   - short circuit between adjacent contacts insulated from each other;
   - simultaneous short circuit between three terminals of change-over contacts;
6) Switches: Electromechanical devices (e.g. relay, contactor relays):
   - all contacts remain in the energized position when the coil is de-energized (e.g. due to mechanical fault);
   - all contacts remain in the de-energized position when power is applied (e.g. due to mechanical fault, open circuit of coil);
   - contact will not close;
   - contact will not open;
   - simultaneous short circuit between the three terminals of a change-over contact;
   - short circuit between two pairs of contacts and/or between contacts and coil terminal;
   - simultaneous closing of normally open and normally closed contacts;
7) Switches: Proximity switches:
   - permanently low resistance at output;
   - permanently high resistance at output;
   - interruption in power supply;
   - no operation of switch due to mechanical failure;
   - short circuit between the three connections of a change-over switch;
8) Switches: Solenoid valves:
   - does not energize;
   - does not de-energize;
9) Discrete electrical components: Transformers:
   - open circuit of individual winding;
   - short circuit between different windings;
   - short circuit in one winding;
   - change in effective turns ratio;
10) Discrete electrical components: Inductances:
   - open circuit;
   - short circuit;
   - random change of value $0.5\ L_N < L < L_N$ + tolerance, where L_N is the nominal value of the inductors;

11) Discrete electrical components: Resistors:
    - open circuit;
    - short circuit;
    - random change of value $0.5\ R_N < R < 2\ R_N$, where R_N is the nominal value of resistance;
12) Discrete electrical components: Resistor networks:
    - open circuit;
    - short circuit between any two connections;
    - short circuit between any connections;
    - random change of value $0.5\ R_N < R < 2\ R_N$, where R_N is the nominal value of resistance;
13) Discrete electrical components: Potentiometers:
    - open circuit of individual connection;
    - short circuit between all connections;
    - short circuit between any two connections;
    - random change of value $0.5\ R_P < R < 2\ R_P$, where R_P is the nominal value of resistance;
14) Discrete electrical components: Capacitors:
    - open circuit;
    - short circuit;
    - random change of value;
    - $0.5\ _{CN} < C < C_N$ + tolerance, where C_N is the nominal value of capacitance;
    - changing value tan, δ;
15) Electronic components: Discrete semiconductors (e.g. diodes, Zener diodes, transistors, triacs, thyristors, voltage regulators, quartz crystal, phototransistors, light-emitting diodes [LEDs]):
    - open circuit of any connection;
    - short circuit between any two connections;
    - short circuit between all connections;
    - change in characteristics;
16) Electronic components: Optocouplers:
    - open circuit of individual connection;
    - short circuit between any two input connections;
    - short circuit between any two output connections;
    - short circuit between any two connections of input and output;
17) Electronic components: Non–programmable integrated circuits:
    - open circuit of each individual connection;
    - short circuit between any two connections;
    - stuck-at-fault (i.e. short circuit to 1 and 0 with isolated input or disconnected output) – static “0” and “1” signal at all inputs and outputs, either individually or simultaneously;

- parasitic oscillation of outputs;
- changing values (e.g. input/output voltage of analogue devices);

18) Electronic components: Programmable and/or complex integrated circuits:
    - faults in all or part of the function, including software faults;
    - open circuit of each individual connection;
    - short circuit between any two connections;
    - stuck-at-fault (i.e. short circuit to 1 and 0 with isolated input or disconnected output). Static "0" and "1" signal at all inputs and outputs, either individually or simultaneously;
    - parasitic oscillation of outputs;
    - changing value, e.g. input/output voltage of analogue devices;
    - undetected faults in the hardware which go unnoticed because of the complexity of the integrated circuit.

e) General

- failure, interruption or variation of power supply;
- circuits faults (e.g. earth, short, open, etc.) causing, for example, unexpected start-up or failure to stop;
- malfunction due to the environment, e.g. mains borne or radiated electrical disturbances (this is normally less of a problem with electromagnetic and electromechanical devices than electronic devices);
- malfunction due to vibration;
- component failures leading to change of characteristic or loss of function;
- misalignment between position switches and their means of actuation.

Annex C (informative) Essentials of a permit to work form

The essential elements of a permit to work form are listed in Figure C.1. If a permit does not cover these it is unlikely to be fully achieving its purpose.

Figure C.1 **Example of a permit to work form**

1 Permit title	**2 Permit number** Reference to other relevant permits or isolation certificates
3 Job location	
4 Machine identification	
5 Description of work to be done and its limitations	
6 Hazard identification (including residual hazards introduced by the work)	
7 Precautions necessary (person(s) who carries out precautions, e.g. isolations, should sign that precautions have been taken)	
8 Protective equipment	
9 Authorization (Signature confirming that isolations have been made and precautions taken, except where these can only be taken during the work. (Date and time duration of the permit.)	
10 Acceptance (Signature confirming understanding of work to be done, hazards involved and precautions required. Also confirming permit information has been explained to all workers involved.)	
11 Extension/shift handover procedures (Signatures confirming checks made that machine plant remains safe to be worked upon, and new acceptor/workers made fully aware of hazards/precautions. New expiry given.)	
12 Hand back (Signed by acceptor certifying work completed. Signed by issuer certifying work completed and machine ready for testing and recommissioning.)	
13 Cancellation (certifying work tested and machine satisfactorily recommissioned)	
Print name(s)	**(Signature(s) – Name(s) should be legible)**

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BS EN ISO 5674, *Tractors and machinery for agriculture and forestry – Guards for power take-off (PTO) drive-shafts – Strength and wear tests and acceptance criteria*

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BS EN ISO 14120, *Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards* [3)]

BS EN ISO 14122, *Safety of machinery – Permanent means of access to machines and industrial plants*

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

DD CLC/TS 62046, *Safety of machinery – Application of protective equipment to detect the presence of persons*

ISO 13854, *Safety of machinery – Minimum gaps to avoid crushing of parts of the human body*

Other documents

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[2] GREAT BRITAIN. The Provision and Use of Work Equipment Regulations (PUWER) 1998. Statutory Instrument No. 2306. London: The Stationery Office.

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Harmonized standards on machinery

An up-to-date list of harmonized standards supporting the Machinery Directive [15] can be found at: http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/machinery/index_EN.htm

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