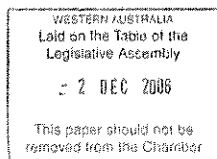


Australian Standard[®]

Safeguarding of machinery

Part 1: General principles



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The following interests are represented on Committee SF/41:

Australian Manufacturing Workers Union
Department for Industrial Affairs
Department of Employment, Vocational Education, Training and Industrial Relations, Qld
Electricity Supply Association of Australia
Ergonomics Society of Australia
Federal Chamber of Automotive Industries
Health and Safety Organisation, Vic.
Metal Trades Industry Association of Australia
National Safety Council of Australia
Safety Institute of Australia
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AS 4024.1—1996

Australian Standard®

Safeguarding of machinery

Part 1: General principles

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PREFACE

This Standard was prepared by the Standards Australia Committee SF/41 on General Principles for the Safeguarding of Machinery as a revision of AS 4024.1(Int)—1992, *Safeguarding of machinery, Part 1: General principles*.

During the preparation of this Standard the Committee retained the concepts provided in BS 5304, *Code of practice for safety of machinery* and considered a number of documents emanating from the International Standards Organization Committee on Safety of Machinery.

It is intended that this Standard contain the general underlying principles for the safety of machine systems in general, whilst leaving requirements unique to a particular type of machine in a Standard covering the guarding of that class of machine. Therefore, within the Standard, emphasis has been placed on the principles of risk control relative to the hazards associated with machine systems in general, without regard to a specific type. In this way, it is hoped that engineers, designers and other persons who may be required to design, build, or evaluate the effectiveness of machine safety systems, will be able to apply the principles to many applications not specifically included herein. Particular emphasis has been placed on the selection of appropriate safeguarding methods.

The content of the Standard is presented in a logical sequence, starting with the basic principles to be followed and leading to hazard recognition and risk assessment.

The Sections dealing with the selection of risk control measures, machine and control system design and safeguarding introduce a hierarchy of guarding, which become increasingly stringent as the perceived risk increases.

All phases of machine life are considered and sections dealing with installation and maintenance are included because during these phases, the risk of injury is frequently higher than that experienced during normal production phases. The importance of safe working practices as part of the overall machine system is emphasized.

The Standard applies ergonomic principles to machinery and workplace design, with the intended result that this will lead to improved safety and operational efficiency.

Developments are constantly being introduced and experience being gained. This not only serves to counter the dangers associated with new technologies and manufacturing methods but also to improve the safety of traditional types of machinery. Users of this Standard should therefore make themselves aware of any new codes of practice which may be published from time to time and any other relevant new developments.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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STANDARDS AUSTRALIA

Australian Standard

Safeguarding of machinery

Part 1: General principles

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard identifies the hazards and risks arising from the use of industrial machinery and describes methods for the elimination or minimization of these hazards and risks, as well as the safeguarding of machinery and the use of safe working practices. The Standard describes and illustrates a number of safety principles and provides guidelines by which it is possible to assess which measure or methods it is practicable to adopt in particular circumstances. Although reference is made to specific types of machine, specific recommendations are not given for every type of machine or application.

Reference is made to non-mechanical hazards but these are not covered in detail.

1.2 OBJECTIVE The objective of this Standard is to enable designers, manufacturers, suppliers, employers and users of machinery to minimize the risks to health and safety of employees and others working with or otherwise near machinery.

1.3 APPLICATION This Standard is intended for those who design, manufacture, supply, install, use, maintain or modify machinery, machinery guarding or safety devices.

The Standard is also intended to be used by those concerned with information, instruction and training in safe working practices, and identifies the existence of Standards for a number of particular classes of machine.

Alternative methods of providing safety to those given may be used provided that the level of safety offered by the alternative is at least equivalent to that provided by the methods given in this Standard.

Some regulatory authorities have specific requirements relating to the forms that guarding may take and to the order in which guarding techniques may be considered. Users of this Standard should therefore make themselves aware of any specific requirements in the jurisdiction where the machinery will be used.

This Standard may still be used in these jurisdictions to identify the most appropriate level of system integrity required, and to provide guidance in other aspects of machine system safety.

1.4 REFERENCED AND RELATED DOCUMENTS The following documents are referred to in this Standard:

- | | |
|------|---|
| AS | |
| 1219 | Power presses—Safety requirements |
| 1318 | Use of colour for the marking of physical hazards and the identification of certain equipment in industry |
| 1319 | Safety signs for the occupational environment |
| 1345 | Identification of the contents of piping conduits and ducts |

AS

- 1543 Electrical equipment of industrial machines
- 1657 Fixed platforms, walkways, stairways and ladders—Design, construction and installation
- 1680 Interior lighting
- 1680.1 Part 1: General principles and recommendations
- 1893 Code of practice for the guarding and safe use of metal and paper cutting guillotines
- 2671 Fluid power—Hydraulic systems and components
- 2788 Fluid power—Pneumatic systems and components
- 2865 Safe working in a confined space
- 3000 Electrical Installations—Buildings, structures and premises (known as SAA Wiring Rules)

AS/NZS

- 1337 Eye protectors for industrial applications

IEC

- 617 Graphical symbols for diagrams
- 617-7 Part 7: Switchgear, controlgear and protective devices

Worksafe Australia

Exposure standards for atmospheric contaminants in the occupational environment

Related documents Attention is drawn to the following related documents:

SAA HB

- 9 Occupational personal protection
- 59 Ergonomics—The human factor—A practical approach to work systems design.

1.5 DEFINITIONS For the purpose of this Standard, the definitions below apply.

1.5.1 Administrative controls—that part of a risk-minimization system which utilizes procedures (including permits to work, process or work instructions and safe work practices) and other similar means to protect persons working in close proximity to or with machinery who would otherwise be exposed to risk.

1.5.2 Control device—a means by which commands or instructions are initiated from, or communicated between an operator and a machine, or between elements of a machine to ensure that an appropriate and intended outcome to a specific circumstance eventuates.

1.5.3 Control system—a structured group of control devices for the purpose of effectively managing the operation of machinery, including safety functions.

NOTE: There may be multiple control systems within specific machinery, each of which has control over discrete functional blocks. The control systems in these machines operate in an integrated fashion providing overall operational management of the machine functions, including safeguarding.

1.5.4 Danger—a state or condition in which personal injury is reasonably foreseeable.

1.5.5 Danger zone—any zone within or around machinery in which any person is subject to a risk to health or safety.

1.5.6 Designer—a person who designs plant for use in a workplace, or plant intended to be used in a workplace, or is responsible for the design.

1.5.7 Exposed person—means any person wholly or partially in a danger zone.

1.5.8 Failure to danger—any failure of the machinery, its associated safeguards, control circuits or its power supply that leaves the machinery in an unsafe condition.

1.5.9 Failure to safety—any failure of the machinery, its associated safeguards, control circuits or its power supply that leaves the machinery in a safe condition.

1.5.10 Guard—a physical barrier that prevents or reduces access to a danger point or area.

1.5.11 Hazard—a source of potentially damaging energy or a situation that may give rise to personal injury or disease.

1.5.12 Integrity—the ability of devices, systems and procedures to perform their function without failure or defeat.

1.5.13 Interlock—a safety device that connects a guard or machine element with the control system or the power system of the machinery.

1.5.14 Lifting attachments—equipment which helps to make up or use a lifting device, such as eyebolts, shackles, rings and eyebolts.

1.5.15 Machinery—an assembly of linked parts or components, at least one of which moves with the appropriate actuators, control and power circuits joined together for a specific application in processing, treatment, moving or packaging of materials. This includes an assembly of machines, which in order to achieve the same end, are arranged and controlled so that they function as an integral unit.

1.5.16 Minimize—to reduce to the lowest practicable level.

1.5.17 Negative mode—with electrical contacts normally open.

1.5.18 Operator—the person or persons given the task of installing, operating, adjusting, maintaining, cleaning, repairing or transporting machinery.

1.5.19 Positive mode—with electrical contacts normally closed.

1.5.20 Practicable—practicable having regard to—

- (a) the severity of the hazard or risk in question;
- (b) the state of knowledge about that hazard or risk and any ways of removing or mitigating that hazard or risk;
- (c) the availability and suitability of ways to remove or mitigate that hazard or risk; and
- (d) the cost of removing or mitigating that hazard or risk.

1.5.21 Risk—the combination of the probability and the degree of possible injury or damage to health arising from exposure to any danger zone.

1.5.22 Safe working practice—a system of working that minimizes the risk of injury.

1.5.23 Safeguard—a guard or safety device designed to protect persons from danger.

1.5.24 Safety device—a device including presence-sensing devices, other than a guard, that eliminates or reduces danger.

1.5.25 Scotch block—a rigid bar or block which moves into the space between two machine elements to prevent their closure.

1.5.26 Shall—indicates that a statement is mandatory.

1.5.27 Should—indicates a recommendation.

SECTION 2 GENERAL GUIDANCE

2.1 PRINCIPLES OF MACHINE SAFETY The basic principles for reducing risk are as follows:

- (a) Identification of all hazards.
- (b) Assessment of the risks.
- (c) Elimination or minimization of hazards by design features.
- (d) Elimination or minimization of risks by design features.
- (e) Use of safeguards.
- (f) Use of administrative controls, e.g. safe working practices.

The interaction of people with a machine in all aspects of its use shall be carefully considered. The interfaces between people and machines shall be designed with full consideration of ergonomic factors.

Where the creation of a hazard during the design stage cannot be avoided, reducing the scale of injury that can be caused shall be considered, e.g. by reducing speeds or forces.

2.2 EXISTING MACHINERY Where existing machinery has been designed without taking hazards into consideration, every attempt shall be made to identify and eliminate those hazards. Where a hazard cannot be eliminated or avoided, other measures for minimizing the risk of injury shall be sought. These measures include reducing the scale of injury, providing safeguards and safe working practices.

Unless a danger point or area is safe by virtue of its position, the machinery shall be provided with appropriate safeguarding which minimizes danger as far as is reasonably practicable.

2.3 SELECTION OF RISK CONTROL METHODS Certain risk control methods are more reliable than others. The order of priority is determined by reliability and therefore safeguards shall be considered before safe working practices. It may not always be possible to use the more effective types of safety measures because they are either not practicable or are not suitable for the particular application.

2.4 PHASES OF MACHINE LIFE In considering measures for all the hazards during each relevant phase of machine life, risk assessment techniques will assist in choosing the best possible combination of safety measures. (See Section 5.)

The designer and manufacturer or supplier shall consider hazards associated with all phases of machine life, which include—

- (a) design;
- (b) construction;
- (c) transport;
- (d) installation;
- (e) commissioning;
- (f) operation, including starting up and shutting down;
- (g) setting or process changeover;
- (h) cleaning;
- (i) adjustment;

- (j) maintenance including breakdown, planned and preventive maintenance; and
- (k) decommissioning and dismantling.

NOTE: These may give rise to conflicting requirements and priority should be given to those phases which give rise to the greatest risk. For example, for manually operated machines on repetition work, this is likely to be the operation phase; however, for fully automated or remote controlled machinery, where there is no access during operation, the maintenance, toolsetting and adjustment phases may require greater emphasis.

2.5 CONSULTATION When planning any process which involves changes to or relocation of existing machinery, or the provision of new machinery, every effort should be made at the design phase to consult with all personnel that will use or maintain it.

Designers should, where it is practicable to do so, visit the site where the machinery will be used to consult with the personnel. The manufacturer should consult the designer when any faults are detected or changes made at any phase in the life of the machine. (See Clause 2.4.)

In this way, foreseeable safety related issues can be addressed at the outset, which will lead to a safer and more productive workplace.

Guidance in evaluating, assessing and selecting the most appropriate design and operational methods is given in this Standard.

SECTION 3 THE APPLICATION OF ERGONOMICS TO THE SAFE USE OF MACHINE SYSTEMS

3.1 GENERAL Since machinery will be used or maintained by people, human factors, i.e. ergonomics, shall be included in the primary design criteria. Accidents with machines have often been attributed to 'unsafe acts', when a more thorough study would have revealed a design deficiency which did not allow for typical foreseeable human characteristics or behaviour. Some general ergonomic principles which are relevant to the design of safe person machine systems are discussed in this Section. Guidance may also be found in HB 59.

Machines will be used within some work systems and a full ergonomic study should encompass the whole system. Machine designers should consider as far as possible the environments in which the machine is likely to be used, bearing in mind that its owners may need to make modifications to adapt it to the system. Owners will also have the control over how the machine is used and maintained. A study of the system shall include not only the person-machine interface, but also the job design, including the way work is assigned to people, any incentive systems, rest breaks, hours of work and shift rosters.

Some human factors which can influence safety and which should be considered in the design of the work system are grouped into the following areas:

- (a) *Anthropometry* Ability of people to reach, and the space they require.
- (b) *Human performance* Reaction times, movement speed and strength.
- (c) *Human error* Limitations of short-term memory, information handling capacity and fatigue.
- (d) *Working environment* Lighting, noise, climate, housekeeping, and atmospheric contaminants.

3.2 ANTHROPOMETRY

3.2.1 General Applications of anthropometry to safety include the following:

- (a) Selection of the minimum height above the floor of a hazard which has to be out of reach (see Figure 3.1(a)).
- (b) Design of barriers to prevent people from entering a dangerous area by reaching over, around or through the barrier (see Figures 3.1(b) to (e)).
- (c) Positioning of controls relative to the operator's work position so that they are within easy reach.
- (d) Design of the workplace and the means of access to the workplace so that there is ample clearance for any person who may work in it.

Anthropometric data are available, but designers should consider carefully whether such data are appropriate to the workforce concerned. The general principles in the use of such data are to place dangerous features out of reach of the 95th percentile of the population, while access should be designed for the largest people. Modifications to available data by actual measurements of the workforce may need to be made and it is always desirable to carry out careful trials with the actual workforce.

3.2.2 Out of reach height The out-of-reach height given in Appendix A is 2500 mm, but consideration should be given to the possibility of people standing on fixed or movable objects. Fixed objects can be fitted with steeply sloping top surfaces to prevent this. However, it is better not to rely on 'safety by position', and to guard dangerous machinery even if access to it would be difficult.



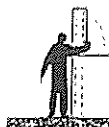
(a) Reaching up



(b) Reaching over barriers



(c) Reaching over barriers



(d) Reaching around



(e) Reaching through

FIGURE 3.1 WAYS OF REACHING INTO A DANGEROUS AREA

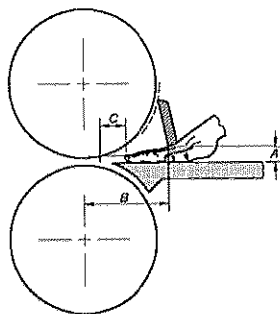
3.2.3 Barriers Guideline values for distances to which people can reach over fixed barriers of various heights are given in Appendix A. These values should be treated as guidelines and modifications considered for particular populations. In most cases, there is little penalty in exceeding the guidelines.

Guidelines for barriers which prevent reaching around to hazards are also given in Appendix A.

3.2.4 Openings in guards Openings are often provided in guards to allow materials to be fed in to the machine, or to provide ventilation or visibility. The problem is illustrated in Figure 3.2.

Guidance for designers in the selection of such (A, B) combinations is provided in Appendix A.

3.2.5 Position of controls Controls should be within easy reach and their operation well within the strength capabilities of the operator. They should not force awkward postures on the operator. Some typical anthropometric data available to designers for the purpose of control positioning are shown in Figure 3.3.



NOTE: The size of opening *A*, is dictated by the thickness of materials to be fed in. It is then necessary to place the guard at the distance *B* to ensure that there is some clearance, *C*, between the closest point to which some part of the body can reach and the danger point.

FIGURE 3.2 MINIMUM CLEARANCES FOR DANGEROUS OPENINGS

3.2.6 Posture The workplace should enable the adoption of a posture which will not produce unnecessary static muscle loads. Static loadings may occur where unnatural postures must be maintained, and induces rapid fatigue.

3.2.7 Space in the workplace The workplace should provide no obstruction to the free movement of the operator or force any constrained posture on the operator. There should be space beneath a bench for the feet of a standing operator and space for the knees of a sitting operator. Where hand movement within a machine is necessary, e.g. using a spanner to make an adjustment, sufficient access and movement space should be provided. Account should also be taken of the eye height of operators so that obstructions to viewing the work are avoided.

Before final manufacture and installation, it may be necessary to construct a mock-up of the workplace for trials and final adjustments, using people who are representative of the operator population.

The workplace should be designed to eliminate the need for operators and others to walk backwards while performing a task.

3.3 HUMAN PERFORMANCE

3.3.1 General Human performance is sometimes underestimated (e.g. the speed with which people can reach into dangerous areas) or over-estimated, (e.g. the speed with which people can react to a dangerous situation and press a stop button, or the speed at which people can take in a flow of information).

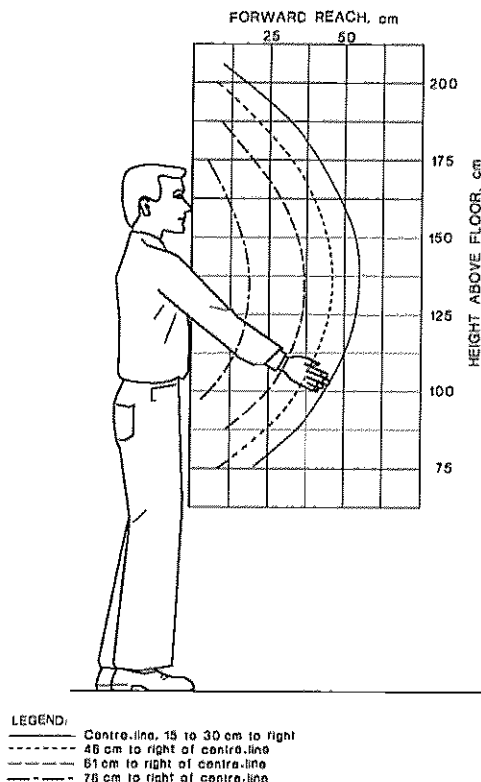


FIGURE 3.3 REACH ENVELOPE FOR 5TH PERCENTILE PERSON
WHEN USING ONE HAND ONLY (FOR CONTROLS ONLY)

3.3.2 Reaction times The simple reaction time, e.g. to press a button in response to a visual stimulus which is either off or on, averages about 0.2 s. This time is greatly increased if a more complex decision is required before action is taken, or if a substantial movement of a limb is required as a response. For example, the reaction time to apply the brake of a car in an emergency is in the range of 0.5 s to 0.75 s, but values as high as 1.5 s have been measured in people who are tired. Also, reactions to unexpected stimuli are much slower than to expected stimuli.

An appropriate reaction time, in conjunction with speed of hand movement and machine stopping time, shall be used by designers to estimate the extent to which a hand-operated emergency stopping switch would provide protection to operators.

3.3.3 Movement speed Some safety devices need to be placed at a certain distance from the danger area of the machine to ensure that the machine would have come to a stop by the time the hand reached the danger zone.

Reaching speeds, or even walking speeds, also need to be considered when a machine takes some time to run down after it has been turned off.

3.3.4 Strength The strength of operators varies widely among the population, and it is important to design any force requirements, e.g. operation of controls, raising of guards, lifting of tools or materials, to be within the capacity of a low percentile of the operator population, rather than using average population strength. Most data available applies to men, but a first approximation for the strength of women may be obtained by multiplying the male data by two-thirds. Where it is necessary to continuously open a guard manually, consideration should be given to the use of power-assisted systems. Guidance on manual handling is given in the National Standards for Manual Handling.

3.3.5 Other characteristics Other human factors which could affect performance, and hence safety, include the senses of vision and hearing and perception, of signals received by these senses, dexterity, fitness, knowledge, experience and language or literacy skills. Designers should be aware of the wide variability of these characteristics among the population and be wary of designing for an average person.

3.4 HUMAN ERROR

3.4.1 General Many human errors are not the result of carelessness or negligence, but follow from normal human characteristics. For example, humans are inquisitive and may seek ways to improve the work process without being aware of the dangers inherent in their actions. Although they may have a low probability, they will inevitably occur from time to time. When they are anticipated by the designer, their consequences can be made harmless.

Where the probability of error arises from repetition work, and the result of the error is potential injury, the designer may use interlocking guards to minimize the risk of injury.

3.4.2 Short-term memory This is easily lost unless quickly reinforced. Thus, after first observing a hazard, its presence may be forgotten if the person is distracted soon afterwards. Vital controls shall be interlocked to ensure that they can only be operated in the correct order or at appropriate times.

3.4.3 Information handling capacity There are strict limits to the rate at which people can absorb information. Vital information may be overlooked if it is presented too quickly or simultaneously with other information. Ideally, a person should be required to monitor only one channel of information at a time. Otherwise, the order of priority for attention should be made clear. Also, rather than sharing attention between two visual inputs, one visual and one audible input is preferred.

NOTE: If stimuli come too slowly to people they may become bored and lose concentration.

3.4.4 Habit People will tend to continue on in an habitual mode despite stimuli which indicate danger. Clear and unambiguous labelling of controls and provision of prominent, simple and unambiguous warning notices can be of some assistance.

Also, they will get used to a particular control arrangement and tend to make mistakes if they have to adapt to another one, particularly in an emergency. Hence, control arrangements should be standardized as much as possible and control locations and directions of operation must be compatible with their effects.

Inadequate knowledge or training and lack of understanding of the work system may lead to inappropriate action.

3.4.5 Fatigue Human performance generally declines and errors increase with fatigue, particularly if there is a lack of mental stimulation. It is therefore important to limit the length of a working day (avoid double shifts for critical work) and provide suitable rest breaks.

Fatigue brought about by forcing operators to adopt a particular posture should be avoided wherever possible. Examples include having to reach or work with the arms above shoulder height or having to stand for prolonged periods with the body weight supported on one leg while activating a foot-operated control.

3.5 THE WORKING ENVIRONMENT

3.5.1 General The general working conditions, if not of an adequate standard, can have an insidious effect in reducing operator performance and increasing errors.

3.5.2 Lighting and vision Ample lighting is needed for the operation of machinery so that machine movements, controls and displays may be easily seen. Certain machines and operations will require lights to be installed within the machine to enable these needs to be met. Guidance on lighting quantities and arrangements is given in AS 1680.1. It is particularly important to avoid sources of glare and distracting backgrounds in the operator's field of view.

Visual ability is also strongly influenced by contrast with the background which should be maximized for displays (instrument dials and signs) and controls. It is also important to arrange the illumination of displays so that excessive light is not reflected back off them, thus veiling the display and preventing it from being easily read. The size of a display should also be adequate. The minimum height of letters or numerals, (h) should be calculated as follows:

$$h = 0.005D$$

where D is the viewing distance and h and D are in the same units.

3.5.3 Noise and hearing Even if the level of noise is below that which might damage hearing, it can contribute to other dangers by masking warning signals and hindering communication. It also contributes to operator fatigue. The need to wear hearing protection when noise levels would otherwise damage hearing creates similar problems. Thus, noise reduction techniques can pay off by improving safety as well as conserving hearing.

When noise levels cannot be further reduced, account should be taken of them in designing any audible alarm system.

3.5.4 Heat and cold The improvement of thermal comfort can also contribute to safety. It has been found that accident rates rise once thermal conditions get outside the comfort zone. Also, protective clothing which may be necessary in hot and cold environments can interfere with free movement, reduce dexterity and increase the risk of being caught in machinery.

3.5.5 Housekeeping An untidy workplace can cause trips and falls. The workplace layout should be thoroughly planned so that spaces are provided for all equipment and materials. Aisles of adequate width should be clearly marked and kept clear.

Spills on the floor, particularly oily liquids, can cause slips and falls. The accumulation of lubricating oils on a floor can often be avoided by more careful attention to detail in machine design. Inevitably, spills will still occur, and when they do they must be promptly soaked up by an appropriate material which avoids an oily residue. Where oily accumulation cannot be avoided, the danger can be reduced by providing a floor surface of adequate roughness.

SECTION 4 IDENTIFICATION OF HAZARDS

4.1 DANGERS FROM MACHINERY A person may be injured at a machine as a result of—

- (a) a contact or entanglement with the machinery;
- (b) being trapped between the machine and any material or fixed structures;
- (c) a contact or entanglement with any material in motion;
- (d) being struck by ejected parts of the machinery;
- (e) being struck by material ejected from the machinery; or
- (f) release of potential energy.

These may be regarded as mechanical hazards. Some machinery may also present non-mechanical hazards in which the dangers are less obvious or tangible (see Clause 4.3).

NOTE: A list of the more commonly encountered hazards is provided in Appendix B.

Movement of machinery parts consists basically of rotating, sliding or reciprocating motion or a combination of these movements. These movements may cause injury by entanglement, friction or abrasion, cutting, shearing, stabbing or puncture, impact or crushing, or a combination of two or more of these. A machine may also draw a person into a position where further injury may occur. Individual machines and individual parts of machines may cause one or more of these types of injury. (See Figure 4.1.)

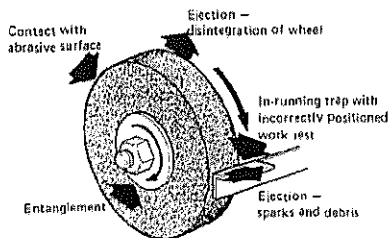


FIGURE 4.1 HAZARDS AT AN ABRASIVE WHEEL

4.2 MECHANICAL HAZARDS

4.2.1 Entanglement The risk of entanglement is increased by loose clothing, gloves, neckties, jewellery, hair, cleaning brushes or rags, medical dressings or materials being handled.

Bodily contact with the following features may lead to entanglement:

- (a) Contact with a single rotating surface (see Figure 4.2), e.g. couplings, spindles, chucks, lead screws, mandrels, bars, or rotating workpieces.

- (b) Catching on projections or in gaps (see Figure 4.3), e.g. fan blades, spoked pulleys, chain wheels, gear wheels and flywheels, mixer and beater arms, spiked cylinders, belt fasteners, projecting keys, set screws, cotter pins on shafts or slat conveyors.
- (c) By catching between two parts (see also Clause 4.2.8).
 - (i) Between counter-rotating parts (see Figure 4.4), e.g. gear wheels, rolling mills, mixing rolls and calenders, or material being drawn between two rolls.
 - (ii) Between rotating and tangentially moving parts, e.g. a power transmission belt and its pulley, a chain and chain wheel, a rack and pinion, metal, paper, rope, and a reeling draw or shaft, batch-up, reel-up, or a conveyor belt and its driving pulley or any bend pulley.

Some mechanisms contain a combination of sliding and turning movements such as those used in certain cam gear designs, e.g. the mechanism on the side of some flat-bed printing machines.

- (iii) Between rotating and fixed parts (see Figure 4.5). Examples of such rotating and fixed parts are spoked handwheels or flywheels and the machinery bed, screw or worm conveyors and their casings, revolving mixer and mincing mechanisms in casings having unprotected openings, Z-blade and ribbon-blade mixers, extruder screw and barrel, or the periphery of an abrasive wheel and an incorrectly adjusted work rest.
- (d) Catching in materials in motion (see Figure 4.6), e.g. in centrifuges, tumble driers, dough mixers, or swarf from machining operations.

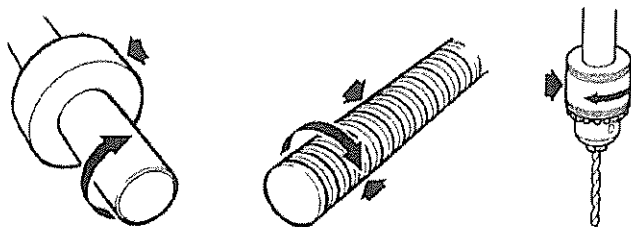


FIGURE 4.2 ENTANGLEMENT CAUSED BY CONTACT WITH A SINGLE ROTATING SURFACE

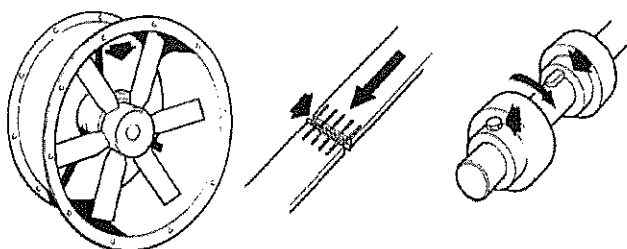


FIGURE 4.3 ENTANGLEMENT CAUSED BY CATCHING ON PROJECTIONS OR IN GAPS

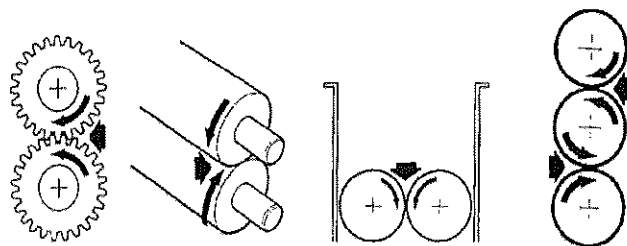


FIGURE 4.4 DRAWING-IN HAZARDS BETWEEN TWO COUNTER-ROTATING PARTS

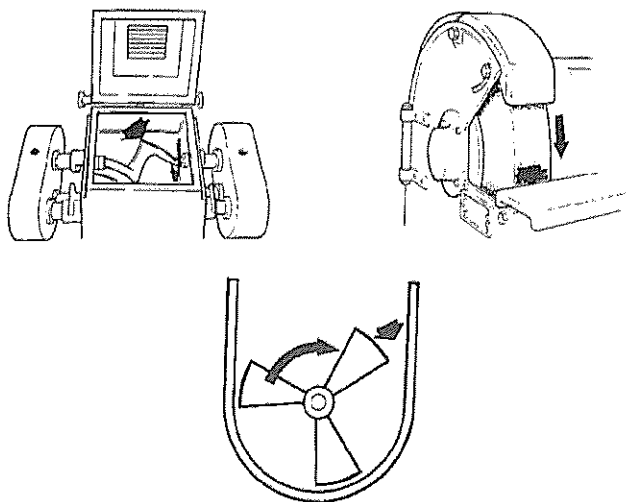


FIGURE 4.5 ENTANGLEMENT CAUSED BY CATCHING BETWEEN ROTATING AND FIXED PARTS

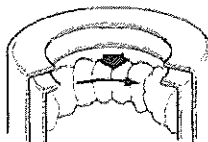


FIGURE 4.6 ENTANGLEMENT CAUSED BY CATCHING IN MATERIALS IN MOTION

4.2.2 Friction and abrasion Friction burns can be caused by relatively smooth parts operating at high speed, e.g. the rim of a centrifuge basket at the edge of the casing opening. Other examples of friction or abrasion hazards include the periphery of an abrasive wheel, belt sanding machines (see Figure 4.7), material running onto a reel or shaft, a conveyor belt and its drums or pulleys (see also Clause 4.2.8 and Figure 4.15), and fast-moving ropes or belts.

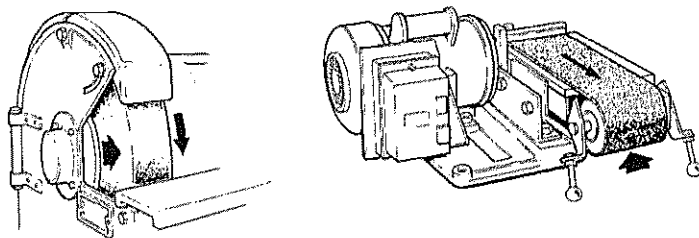


FIGURE 4.7 FRICTION AND ABRASION HAZARDS

4.2.3 Cutting Examples of cutting hazards include all kinds of cutting tools, circular saws, milling cutters, routers, spindle moulders, planing and tenoning machines, hand-saw blades, rotary knives, disc blades, water jet cutting, high-energy laser or edges of moving sheet material (see Figure 4.8). The cutting effect may be aggravated by the body being unable to move away from the cutter.

4.2.4 Shear Parts of the body may be sheared in the following ways:

- (a) Between two machine parts (see Figure 4.9), e.g. the table of a metal planing machine and its bed, the blade of a guillotine, nip points between connecting rods or links and rotating wheels, oscillating pendulum movements, or scissor lifts in shear.
- (b) Between a machinery part and a workpiece (see Figure 4.10), e.g. transfer mechanisms, the tool of a broaching machine.

4.2.5 Stabbing and puncture The body may be penetrated by the following:

- (a) Flying objects (see Figure 4.11) which include the following:
 - (i) Ejection of parts of machinery, e.g. the flying shuttle of a loom, a loose cutter on a vertical spindle milling machine, broken tooling on a press or the bursting of an abrasive wheel.
 - (ii) Ejection of material, e.g. flying swarf, ejection of a workpiece, molten metal ejection from a diecasting machine, sparks generated in a welding process, explosive-powered tools, or debris from rotary mowers and hedgecutters.
- (b) Rapidly moving parts of machinery or pieces of material (see Figure 4.12), e.g. sewing machines, drilling machines.

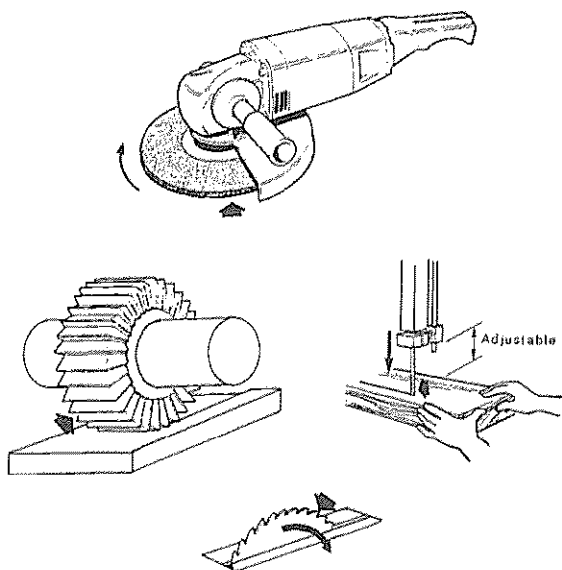


FIGURE 4.8 CUTTING HAZARDS

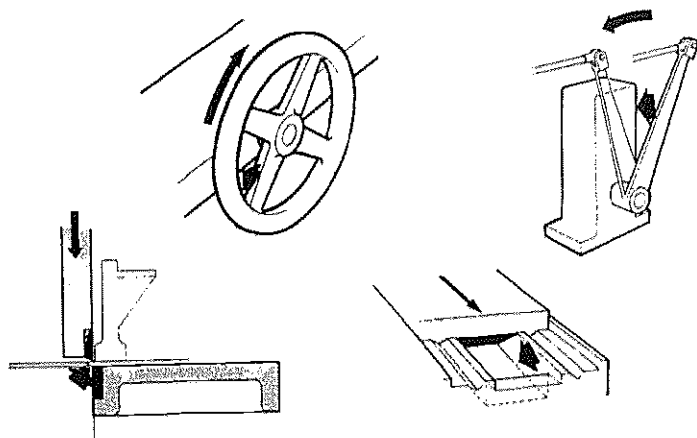


FIGURE 4.9 SHEAR HAZARDS BETWEEN TWO MACHINE PARTS

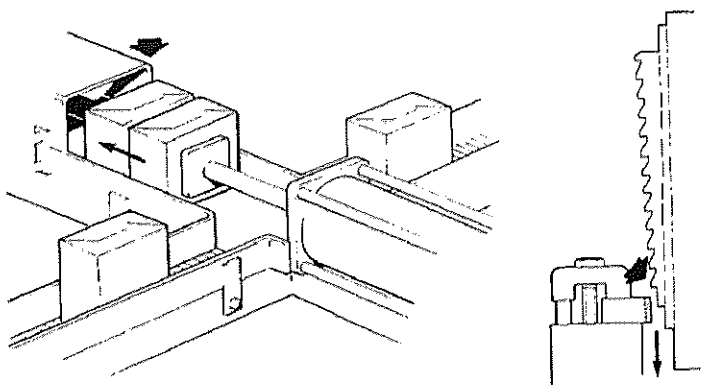


FIGURE 4.10 SHEAR HAZARDS BETWEEN A MACHINERY PART AND A WORKPIECE

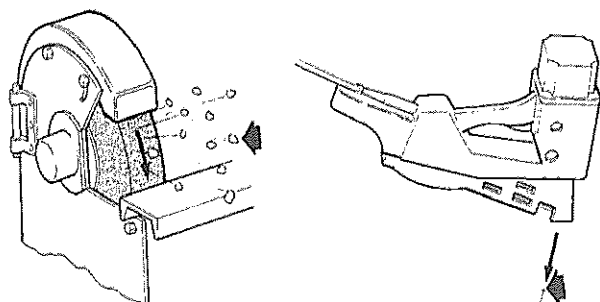


FIGURE 4.11 STABBING AND PUNCTURE BY FLYING OBJECTS

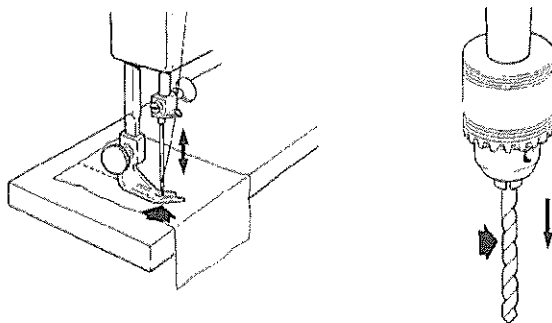


FIGURE 4.12 STABBING AND PUNCTURE BY MOVING PARTS OF MACHINERY OR PIECE OF MATERIAL

4.2.6 Impact Impact hazards are caused by objects which act against the inertia of the body but do not penetrate it (see Figure 4.13), e.g. the traversing motion of a machinery part, oscillating pendulum movements or being struck by projections or moving counterweights.

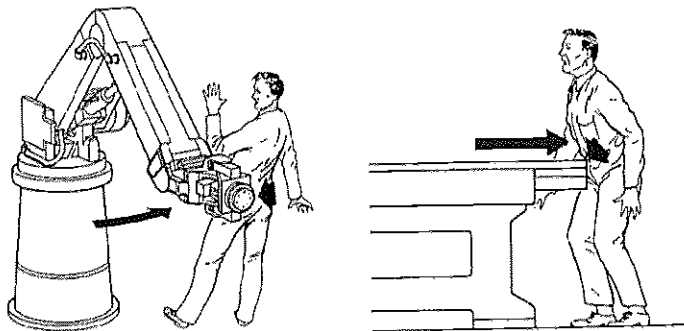


FIGURE 4.13 IMPACT HAZARDS

4.2.7 Crushing Crushing occurs when one part of machinery moves against another with a part of the body in between (see Figure 4.14), e.g. the ram of a forging hammer, the tools of power presses, the callipers of spot welding machines, garment press closure, the closing nip between two platen motions, hand-fed platen machines, foundry moulding machines, counterweights. The traversing motion of a machinery part, e.g. the table of a machine tool and a fixed structure not being part of the machinery may also create this type of hazard, as may a scissor hoist or table.

4.2.8 Drawing-in (see also Clause 4.2.1) Shearing or crushing injuries can be caused when a part of the body is drawn into a running or in-running nip formed in the following ways:

- In-running nips between two counter-rotating parts, e.g. meshing gears, rolling mills, mixing rolls, press rolls, reel and carriage rolls, calenders, dough brakes and moulders.
- In-running nips between a rotating surface and a tangentially moving surface (see Figure 4.15), e.g. power transmission belt and pulley, chain and chain wheel, rack and pinion.
- Running nips between a rotating surface and a tangentially moving surface where material, e.g. metal, paper, cable or rope, runs onto a reel, drum or shaft.

4.2.9 Compressed air or high pressure fluid injection Injection of fluids through the skin can cause tissue damage similar to crushing. Examples are compressed air jets, diesel fuel injectors, paint sprayers and high pressure hydraulic systems.

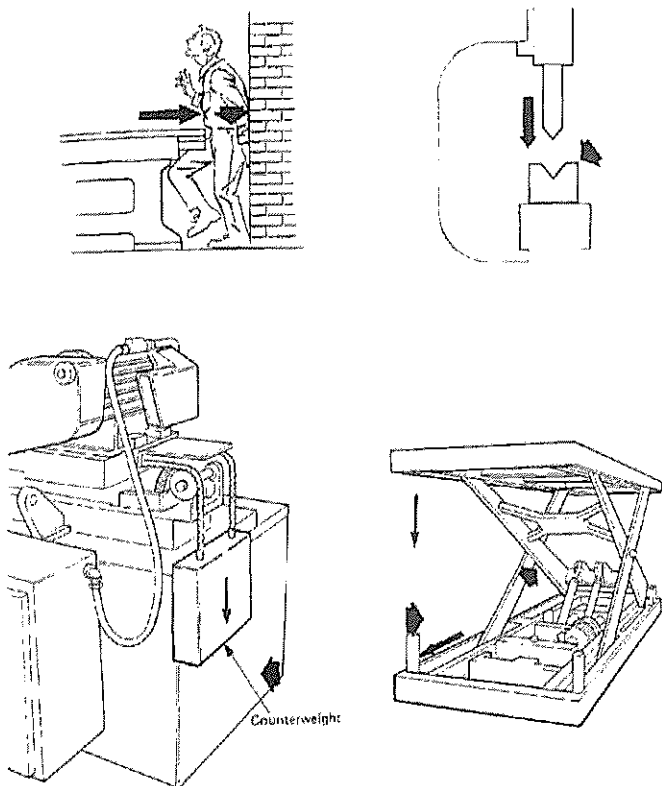


FIGURE 4.14 CRUSHING HAZARDS

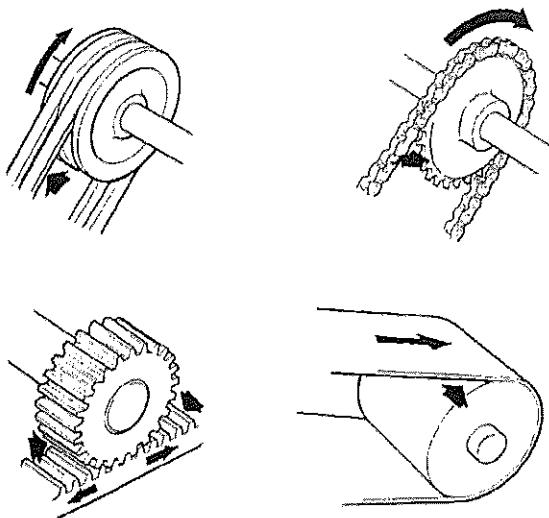


FIGURE 4.15 DRAWING-IN HAZARDS BETWEEN ROTATING AND TANGENTIALLY MOVING SURFACES

4.2.10 Material ejected from the machine Failure of the machine or seizing of machine component parts can result in the expulsion of parts of the machine or material with the potential to cause serious injury. Similarly, failure of the machine control system can cause the release of material being processed. Examples are the disintegration of an abrasive wheel, the seizure of a brake or clutch, bursting of high pressure material supply lines, or the failure of work holding devices and clamps.

4.2.11 Release of potential energy Unexpected release of potential energy such as the energy stored in springs, the release of pressure, and objects falling under the force of gravity may cause injury. Examples include falling counterweights, parts falling from conveyors or racks, unrestrained keys falling from keyways.

4.3 NON-MECHANICAL HAZARDS

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

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

- (a) Access which can give rise to—
 - (i) slips, trips, falls;
 - (ii) falling or moving objects; and
 - (iii) obstructions and projections.
- (b) Handling and lifting.
- (c) Electricity (including stored charges and static electricity)—
 - (i) shock; and
 - (ii) burns.
- (d) Chemicals that are—
 - (i) toxic;
 - (ii) carcinogenic;
 - (iii) irritant;
 - (iv) flammable;
 - (v) corrosive; or
 - (vi) explosive.
- (e) Fire and explosion.
- (f) Noise and vibration.
- (g) Pressure and vacuum.
- (h) Extremes of temperature.
- (i) Inhalation of atmospheric contaminants, including mist, fumes, vapour gases and dust.
- (j) Suffocation.
- (k) Ionizing and non-ionizing radiation, including laser light and welding operations.
- (l) Biological, e.g. viral and bacterial.

4.3.3 Linking mechanical and non-mechanical hazards The safeguards adopted to eliminate or mitigate personal harm from non-mechanical hazards and safeguards to prevent injury from the mechanical hazards identified in Clause 4.2 may be combined or linked together to minimize the total risk level, e.g. acoustic guards to prevent access and contain or absorb noise, welding curtains to protect against radiation, spatter and burns.

SECTION 5 RISK ASSESSMENT

5.1 RISK ASSESSMENT Risk assessment is a series of logical steps to enable the examination in a systematic way of the hazards associated with machinery. Risk assessment is followed when necessary by risk minimization. When the process of risk assessment and risk minimization are repeated, it provides the iterative means for minimizing hazards as far as is practicable. (See Figure 5.1.)

Risk assessment includes:

- (a) *Risk analysis*, i.e.
 - (i) determination of the limits of the machinery;
 - (ii) hazard identification; and
 - (iii) risk estimation.
- (b) *Risk evaluation* Risk analysis provides the information required for risk evaluation which in turn allows judgement to be made on the safety of machine systems.

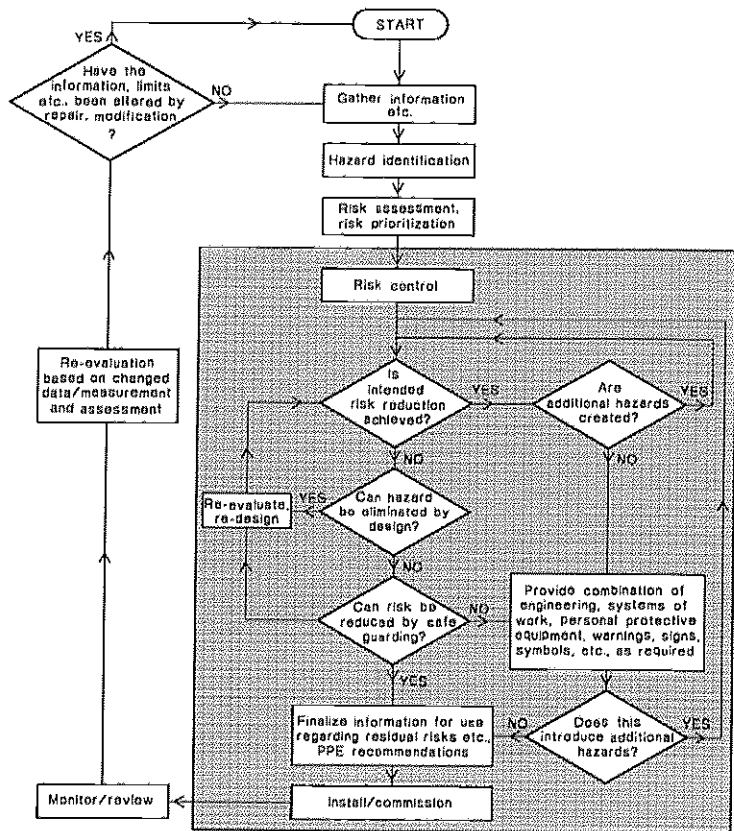
Risk assessment relies on judgemental decisions. These decisions shall be supported by qualitative methods complemented, as far as possible, by quantitative methods. Quantitative methods are particularly appropriate when the foreseeable severity and extent of harm are high.

Quantitative methods are useful to assess alternative safety measures and to determine which gives better protection.

NOTE: The application of quantitative methods is restricted by the amount of useful data which is available. Therefore, in many applications only qualitative risk assessment will be possible.

The risk assessment procedure shall be conducted in such a manner so that it is possible to document—

- (i) the intended use of the machinery for which the assessment has been made (specifications, limits and similar);
- (ii) the hazards, hazardous situations and hazardous events identified;
- (iii) pertinent information used (accident histories and experience gained from risk reduction applied to similar machines);
- (iv) the objectives to be achieved by the risk control method;
- (v) the safety measures implemented to eliminate identified hazards or reduce risks; and
- (vi) the residual risk for the individual hazards by specifying any relevant assumptions which have been made (loads and safety factors).



NOTE: Risk reduction and selection of appropriate safety measures are not part of risk assessment.

FIGURE 5.1 THE ITERATIVE PROCESS TO ACHIEVE SAFETY

5.2 INFORMATION FOR RISK ASSESSMENT The information for risk assessment and any qualitative and quantitative analysis shall include the following as appropriate:

- (a) The design limits of the machine system.
- (b) Requirements for the phases of machinery life. (See Clause 2.4.)
- (c) Design drawings or other means of establishing the nature of the machinery.
- (d) Information concerning power supply.
- (e) Accident or incident history, if available.
- (f) Any information about damage to health. The information shall be updated as the design develops and when modifications are required.

Comparisons between similar hazardous situations associated with different types of machinery are often possible, provided that sufficient information about hazards and accident circumstances in those situations is available.

The absence of an injury or incident history, a small number of incidents or low severity of injury shall not be taken as an automatic presumption of a low risk.

For quantitative assessment, data from databases, handbooks, laboratories and manufacturer's specifications may be used provided that there is confidence in their suitability. Uncertainty associated with this data shall be indicated in the documentation.

Data based on the consensus of expert opinion derived from experience may be used to supplement qualitative data (see Appendix C).

5.3 DETERMINATION OF THE LIMITS OF MACHINE SYSTEM Risk assessment shall take into account—

- (a) the phases of machinery life (see Clause 2.4);
- (b) the design limits of machinery, including the intended use and operation of the machinery, as well as the consequences of reasonably foreseeable misuse or malfunction.

In addition, risk assessment shall take into account, as appropriate, the following:

- (i) The full range of foreseeable uses of the machinery by persons identified by sex, age, dominant hand usage, or limiting physical abilities (e.g. visual or hearing impairment, size, strength);
- (ii) The anticipated level of training, experience or ability of the foreseeable user such as—
 - (A) trained and skilled maintenance personnel or technicians;
 - (B) trained operatives;
 - (C) trainees and juniors; and
 - (D) general public.
- (iii) Exposure of other persons to the hazards of the machinery where it can be reasonably foreseen.

5.4 HAZARD IDENTIFICATION All hazards, hazardous situations and hazardous events associated with the machinery shall be identified. Guidance on hazard identification is given in Section 4. A list of the more frequently encountered hazards may be found in Appendix B. Several methods are available for the systematic analysis of hazards. Examples are given in Appendix C.

5.5 RISK ESTIMATION

5.5.1 Processes After hazard identification, risk estimation shall be carried out for each hazard by determining the elements of risk given in Clause 5.5.2. When determining these elements, it is necessary to take into account the aspects given in Clause 5.5.4.

5.5.2 Elements of risk The risk associated with a particular situation or technical process is derived from a combination of the following elements:

- (a) The severity of harm.
- (b) The probability of occurrence of that harm, including the following:
 - (i) The frequency and duration of the exposure of persons to the hazard.
 - (ii) The probability of occurrence of a hazardous event.
 - (iii) The technical and human possibilities to avoid or limit the harm (e.g. awareness of risks, reduced speed, emergency stopping device, enabling device).

The elements are shown in Figure 5.2 and additional details are given in Clauses 5.5.3 and 5.5.4.

Several methods are available for the systematic analysis of these elements.

NOTE: In many cases these elements cannot be exactly determined, but can only be estimated. This applies especially to the probability of occurrence of possible harm. The severity of possible harm cannot be easily established in some cases (e.g. in the case of damage to health due to toxic substances or psychological stress). With a view to improving this situation, additional auxiliary quantities or so-called risk parameters can be used to facilitate the estimation of risk. The type of risk parameter which is especially suited in this case depends, in the main on the type of hazard involved.

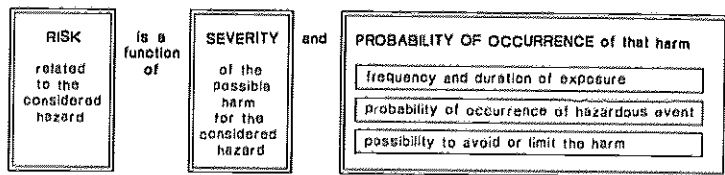


FIGURE 5.2 ELEMENTS OF RISK

5.5.3 Severity (degree of possible harm) The severity can be estimated by taking into account—

- (a) nature of what is to be protected—
 - (i) persons;
 - (ii) property; and
 - (iii) environment.
- (b) severity of injuries (in case of persons)—
 - (i) slight (normally reversible) injury or damage to health;
 - (ii) serious (normally irreversible) injury or damage to health; and
 - (iii) extreme, resulting in death.

- (c) the extent of harm (for each machine).

In the case of persons—

- (A) one person; and
- (B) several persons.

5.5.4 Probability of occurrence of harm The probability of harm occurring can be estimated by taking into account—

- (a) *the frequency and duration of exposure*—
 - (i) need for access (e.g. for production reasons, maintenance or repair);
 - (ii) nature of access (e.g. manual feed of materials);
 - (iii) time spent in the danger zone;
 - (iv) number of persons requiring access; and
 - (v) frequency of access to the danger zone.
- (b) *the probability of occurrence of a hazardous event*—
 - (i) reliability and other statistical data;
 - (ii) accident history; and
 - (iii) risk comparison.

NOTE: The occurrence of a hazardous event can be of a technical or human origin.

- (c) *possibility to avoid or limit harm*—
 - (i) operation by skilled persons;
 - (ii) operation by unskilled persons; or
 - (iii) unattended.
- (d) *the speed of appearance of the hazardous event*—
 - (i) sudden;
 - (ii) fast; or
 - (iii) slow.
- (e) *the awareness of risk*—
 - (i) general information;
 - (ii) direct observation; and
 - (iii) through indicating devices.
- (f) *the human possibility of avoidance (e.g. reflex, agility, possibility of escape)*—
 - (i) possible;
 - (ii) possible under certain conditions; or
 - (iii) impossible.
- (g) *the practical experience and knowledge*—
 - (i) of the machinery;
 - (ii) of similar machinery; or
 - (iii) no experience.

5.5.5 Aspects to be considered when establishing elements of risk

5.5.5.1 Persons exposed Risk estimation shall take into account all persons exposed to the hazards; this includes operators, persons carrying out maintenance and others for whom it is reasonably foreseeable that they could be affected by the machinery.

5.5.5.2 Type, frequency and duration of exposure The estimation of the exposure to the hazard under consideration requires analysis of, and shall account for, all modes of operation and methods of working the machinery. In particular, this affects the need for access during setting, teaching, process changeover or correction, cleaning, fault-finding and maintenance.

When it is necessary to suspend safety functions (e.g. during maintenance), the risk estimation shall account for such a situation.

5.5.5.3 Relationships between exposure and effect When establishing the relationship between an exposure to a hazard and its effects, risk estimation shall, as far as practicable, be based on appropriate, recognized data.

NOTE: Accident data may be available to indicate the probability and severity of injury associated with the use of a particular type of machinery with a particular type of safety measure.

5.5.5.4 Ergonomics Risk estimation shall not be restricted to technical factors. Risk can be affected by the relationship between people and their working environment, such as those related to interaction with the machinery, interaction between persons, psychological aspects and anthropometric effects and a greater or lower capacity to be aware of risks in a given situation (see Section 3.). This situation depends on the training, experience and ability of the operator and others who can be affected.

The estimation of the ability of exposed persons shall take account of the following aspects:

- (a) The design of the machinery in relation to ergonomic principles.
- (b) Natural or developed ability to execute the required tasks.
- (c) Awareness of risk.
- (d) Level of confidence in carrying out the required task without intentional or unintentional deviation.
- (e) Resistance to incentives to deviate from prescribed and necessary safe working practices.

Training, experience and ability can affect the risk. However, none of these factors are to be used as a substitute for hazard elimination, risk reduction by design or safeguarding, where these measures can be implemented.

5.5.6 Reliability of safety functions Risk estimation shall take account of the reliability of components and systems. In particular, those identified as part of safety critical functions (see Table 10.2) should receive special attention. Estimation shall—

- (a) identify the circumstances which could result in harm (e.g. component failure, power failure, electrical disturbances);
- (b) when appropriate, use quantitative methods to compare alternative safety measures; and
- (c) provide information to allow for the selection of appropriate safety functions, components and devices.

When more than one safety related device contributes towards a safety function, the selection of these devices shall be consistent when considering their reliability and their performance (see Section 10).

When safety measures include work organization, correct behaviour, attention, application of personal protective equipment, skill or training, the relatively low reliability of such measures as compared to proven technical measures shall be taken into account in the risk estimation.

5.5.7 Ability to defeat or circumvent risk control methods Risk estimation shall account for the ease with which a particular risk control method can be defeated or circumvented. The estimation shall also take account of the incentive to defeat or circumvent the system and whether—

- (a) the risk control method slows down production, or interferes with any other activities or preference of the user;
- (b) the risk control method is difficult to use;
- (c) persons other than the operator are involved; and
- (d) the risk control method is not recognized or accepted for its function.

The ability to defeat the risk control method can be dependent on both the type of safety measure and its design details.

The use of programmable electronic systems introduces an additional possibility of defeat or circumvention if access to safety related software is not properly designed and monitored. Risk estimation shall identify where safety related functions are not separated from other machine functions and the extent to which access is possible. This is particularly important when remote access for diagnostic or process correction purposes is required.

When carrying out risk estimation, consideration needs to be given to the possible defeat or circumventing of adjustable guards and programmable trip devices.

5.5.8 Ability to maintain risk control methods Risk estimation shall consider whether the risk control methods can be maintained in the condition necessary to provide the required level of protection.

NOTE: If the risk control methods cannot be easily maintained in correct working order, this can encourage the defeat or circumvention of the safety measure to allow for continued use of the machinery.

5.5.9 Information for use Risk estimation shall take account of the information for use to be supplied with the machinery.

5.6 RISK EVALUATION After estimating the risks, a risk evaluation is necessary to determine if risk reduction is required or whether safety has been achieved. If risk reduction is required, then appropriate risk control method shall be selected and applied, and the procedure repeated. During this iterative process, it is important for the designer to check whether additional hazards are created when new risk control methods are applied. If additional hazards do occur, they shall be added to the list of identified hazards.

The achievement of the risk reduction objectives (see Clause 5.7) and a favourable outcome of risk comparison (see Clause 5.8) give confidence that the risk of injury has been minimized as far as is practicable.

5.7 ACHIEVEMENT OF RISK REDUCTION OBJECTIVES Achievement of the following conditions will indicate that the risk reduction process can be concluded if the following occurs:

- (a) The hazard has been eliminated or the risk minimized by—
 - (i) design or by the substitution of less hazardous materials and substances; or
 - (ii) safeguarding in accordance with the state of the art.

- (b) The safeguarding selected is of a type which has been proven to give adequate protection for its intended use.
- (c) The type of safeguarding selected is appropriate for the application in terms of—
 - (i) probability of defeat or circumvention;
 - (ii) severity of harm; and
 - (iii) hindrance to the execution of the required task.
- (d) The information on the intended use of the machinery is sufficiently clear.
- (e) The operating procedures for the use of the machinery are consistent with the ability of personnel who use the machinery or other persons who can be exposed to the hazards associated with the machinery.
- (f) The recommended safe working practices for the use of the machinery and the related training requirements have been adequately described.
- (g) The user is sufficiently informed about the residual risks.
- (h) If personal protective equipment is recommended to cope with residual risks, the need for such equipment and the training requirements for its use have been adequately described.
- (i) Additional precautions are sufficient.

5.8 COMPARISON OF RISK As part of the process of risk evaluation, the risk associated with the machinery can be compared with those of similar machinery, provided the following criteria apply:

- (a) Similar machinery demonstrates acceptable risk reduction in accordance with the state of the art.
- (b) The intended use and technologies employed by both machines are comparable.
- (c) The hazards and the elements of risk are comparable.
- (d) The technical targets are comparable.
- (e) The conditions for use are comparable.

The use of this comparison method does not eliminate the need to follow the risk assessment process as described in this Standard for the specific conditions of use (e.g. when a bandsaw used for cutting meat is compared with a bandsaw used for cutting wood, the risk associated with the change of material shall be assessed).

SECTION 6 MACHINERY DESIGN

6.1 GENERAL. The aim of designers shall be to produce machinery that is economical to use and safe to construct, install, operate and maintain, consistent with the requirements of current legislation.

The addition of safeguards after the design stage may result in unnecessary expense, reduced production and inefficient safeguard performance. If the necessary safeguards are not designed at the start, it is possible that no action will be taken later and the machine will then present an unnecessarily high risk of injury.

The interface between persons and the safety related parts of control systems shall be designed and installed so that no person is endangered during all intended use and foreseeable misuse of the machine.

Ergonomic principles should be used so that the machine and the control system, including safety related parts, are easy to use and the operator is not tempted to act in a hazardous manner.

As a guide in establishing the appropriate safety systems and safeguards, designers shall, where practicable, survey similar machines in use and incorporate safety features at least equivalent to the state of the art in machinery.

In addition to considering the safety of machinery operators, designers shall take into account the safety of other people who may be exposed to risk. Particular attention should be paid to the needs of maintenance personnel, toolsetters, cleaners and the like.

Wherever practicable, dangerous parts shall be eliminated or effectively enclosed in the initial design (see Figure 6.1).

At the design stage the need to expose any dangerous parts during operation, examination, lubrication, adjustment and maintenance shall be minimized as far as is reasonably practicable.

Manufacturers of machines designed to carry out a range of tasks shall manufacture a range of guards suitable for the range of tasks envisaged for the use of each machine. This may require consultations between the designer and users, who may include production, quality assurance, safety, maintenance and engineering staff.

6.2 ELIMINATION OF HAZARDS BY DESIGN

6.2.1 Entanglement Entanglement hazards may be reduced by minimizing 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. Projections such as set screws, bolts or keys on any exposed revolving machine part should be sunk, shrouded or otherwise effectively guarded. Guards for rotating shafts should be fixed guards of solid construction. However, guards of the loose tube type or of bellows construction may be used satisfactorily in some applications, e.g. to cover lead screws for lathes or tensile testing machines.

NOTE: The ergonomic criteria given in Section 3 should not be regarded as giving complete protection against entanglement. Openings which prevent body parts from entering may still permit loose clothing or hair to reach the danger point.

6.2.2 Friction and abrasion Friction and abrasion hazards may be minimized by reducing speed or distance of movement, force, torque and inertia, and by use of surfaces that are as smooth as possible. Personal damage arising from contact with a moving surface can be aggravated by abutting surfaces which may prevent removal of the hand from the danger area, e.g. a badly adjusted work rest on a bench grinder.

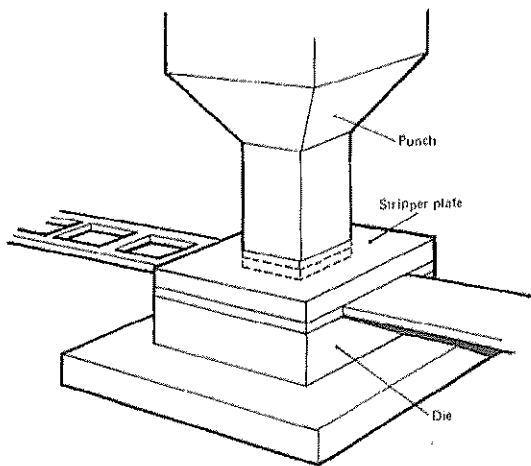


FIGURE 6.1 ENCLOSED TOOLS AT A POWER PRESS

6.2.3 Cutting Cutting hazards may be minimized by reducing speed or distance of movement, force, torque and inertia, and by increasing corner radii on machine parts. Abutting surfaces should be avoided. Processing materials in a way which avoids leaving unfinished edges is also effective in reducing the hazard.

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

- Filling the gaps, such that the shear trap is minimized (see Figures 6.1 and 6.2).
- Reducing the maximum clearance between moving parts so that parts of the body cannot enter the gap.
- Increasing the minimum clearance between the shearing parts, such that parts of the body can enter the gap safely.

Since the technique of separating the shearing parts relies upon moving body parts out of the way, the technique should only be used on low speed machinery, and after considering which parts of the body may be inserted in the trap. Separating the shearing parts is often eliminated after detailed consideration of other hazards has been made, and the technique is not effective against double-shear traps. Guidance on safety distances is given in Appendix A.

Where the creation of a shear trap is unavoidable, it may be possible to restrict reach past the trap, and so reduce the degree of injury possible. Speed and forces of moving parts creating the shear action can often be adjusted.

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

Enclosed tools are designed and constructed to be intrinsically safe, there being insufficient space between parts in the tool set which may trap to permit entry of any part of a hand. They should be used whenever the operation allows, as they provide a high standard of protection and eliminate the need for further guarding. The use of enclosed tools is usually practicable when blanking operations from strip are carried out and when more than one operation is combined in a single set of tools. Enclosure can be achieved by arranging for the stripper plate, which is attached to the die, to be sufficiently thick to prevent the punch from being withdrawn from it, and by making the feed opening below the stripper plate so small that fingers cannot reach through it to the punch. (See also Figure 6.1.)

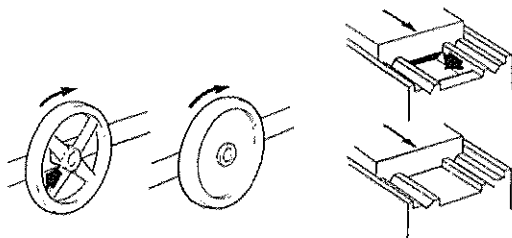


FIGURE 6.2 REMOVAL OF SHEAR TRAP BY DESIGN

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

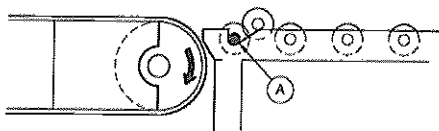
Reducing the sharpness, speed, force or torque and inertia will reduce the risk of impact, stabbing and puncture injuries; however, such reductions will not normally eliminate the need for appropriate guarding.

Where there is a risk of small or sharp ejected objects penetrating the skin, sheet material shall, where practicable, be used instead of mesh for guards.

6.2.6 Crushing Crushing injuries, like shear injuries, are due to the relative motion of two objects with a body part in between and are affected by similar considerations.

6.2.7 Drawing-in Drawing-in, leading to entanglement, shear or crushing, is aggravated by speed or distance of movement, force, torque, inertia, weight or tension, e.g. in a belt or in material being reeled up. Surface roughness and any tendency to adhesion will have a similar effect as will being engulfed by loose, moving material. Adjacent parts of structures may increase injuries sustained.

Figure 6.3 depicts the use of free idler rollers on a conveyor to reduce the risk of drawing-in.



NOTE: The possibility of trapping at the junction of a powered conveyor and an idle roller conveyor can be avoided by making the first idle roller free to move away along an incline 'A' cut in the sides of the conveyor. The angle of the incline is so arranged as to prevent lateral movement of the roller during the passage of goods from the belt to the idle roller conveyor. Care should be taken to ensure that the weight and dimensions of the loads being conveyed do not prevent the roller from lifting. In some installations more than one free roller may be required. This solution is not effective where the rollers are powered.

FIGURE 6.3 CONVEYOR—FIRST IDLER ROLLER FREE TO PREVENT DRAWING-IN

6.3 CONTROL DEVICES AND SYSTEMS

6.3.1 Position Control devices shall be positioned and spaced so as to provide safe and easy operation and there should be ample clearance between each control and other parts of the machinery. Control devices should be so placed that the operator can reach them easily without stretching or moving from a 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 shall be shrouded, gated or so positioned that they cannot be operated inadvertently. Start controls should be positioned where all workstations of a machine can be seen. If this is not possible then a safe work practice is necessary to ensure that the start up of the machine will not put any person at risk.

A stop control shall be positioned near each start control.

Where more than one control station is provided, these should be arranged to take account of any increased risk to people who may be affected by the operation of one of the controls. This may be achieved by providing positive control circuit selection at the control system master station to override all other controls except for emergency stop, so that the start control can be transferred from one position to another. (See also Clause 6.12.)

Handles, handwheels and levers should be positioned so that when the operator is operating them it is impossible to operate any other control inadvertently. Two-hand controls shall be placed, separated and protected so as to prevent them from being operated by any means other than two hands (see Clause 9.3.3).

Foot-operated controls, other than for emergency stop, shall be adequately shrouded or otherwise arranged to prevent 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 6.4). Pedals should not be designed so that a leg has to be held up without support for prolonged periods.

On large machines the installation of a number of cycle start and stop control devices should be interlocked so that activation at one point cannot create a hazard at another. Where multiple start and stop controls are provided, a visual or audible warning signal prior to machine start or movement should be provided.

It shall not be possible to initiate any cycle start while any interfacing or interlocking guard is in an unsafe or open position.

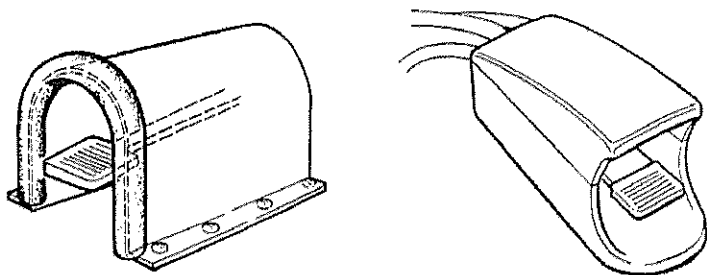


FIGURE 6.4 PEDALS PROTECTED FROM ACCIDENTAL OPERATION BY MEANS OF A COVER

6.3.2 Identification Controls should be clearly identifiable and readily distinguishable from each other by varying their separation, size, shape, colour or feel, and by labelling the controls with either words or symbols to identify the function or consequence of use of the control (see AS 1543). The use of direction arrows on or adjacent to controls to indicate the direction of movement is useful.

Where practicable, controls for different motions should be operated from different positions. For example, the operating handle for a cross-slide automatic feed should be separated from the handle of a traversing feed.

Controls for starting or stopping a machine should be permanently marked with the appropriate symbol to clearly identify their function. The word START or STOP as appropriate, may be added.

Stop and emergency stop controls should be coloured red (see also Clause 6.3.7).

6.3.3 Operation The direction of movement of a control should correspond with the direction of motion being controlled. For example, where a handle or handwheel controls a sliding part, clockwise rotation should direct movement of the part away from the operator to the right or in an upward direction. A lever movement towards or away from the operator should result in a corresponding movement of the controlled part.

Where practicable, the mode and direction of movement of controls should be so varied as to prevent inadvertent operation of the wrong control.

Clutch control levers should be provided with adequate means of retaining them in a safe position.

6.3.4 Controls for machinery setting or adjustment and for feeding material

6.3.4.1 General Generic terms for controls for machinery setting or adjustment and for feeding material include inch, micro-inch, pulse-inch, coarse-inch, jog and slow crawl. The definitions and usage of these terms can vary according to the type of machine and industry. Inch and coarse-inch are often used to describe a setting speed which has the same speed as the machine running speed. Operating instructions for the machine should define the meaning of these terms.

6.3.4.2 Hold-to-run control Where a guard has to be displaced or removed for machine adjustment or material feeding and it is necessary for the machinery to be in motion, the setter shall be protected where practicable, by a hold-to-run control with the machinery running at setting speed or crawl speed or by a limited movement device (see Clause 6.3.5). Where the machinery is equipped with a crawl speed, this speed shall be set as low as practicable.

A hold-to-run control shall permit movement of the machinery while the control is held in a set position. Hold-to-run controls for remote operation of machinery may be used only where it is not practicable to provide effective guarding and where there is no danger from overrun of the dangerous parts when the control has been released. The control shall return automatically to the stop position when released.

A two-hand control (see Clause 9.3.3) may be used as a hold-to-run control but it should be emphasized that this control only protects the person operating the control.

In addition to its value as a safety device during setting, a hold-to-run control, if placed at sufficient distance from the dangerous parts, also provides a means of ensuring that a machinery operator is in a position of safety when the machinery is operating normally (see Clause 7.3(g)).

6.3.5 Limited movement devices

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

Care shall be taken that the fitting of a limited movement device does increase the overall safety of the machinery and that this will not be outweighed by an increased risk of failure of other components or associated control circuits. These devices shall only be used in conjunction with an efficient means of stopping the dangerous parts.

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

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

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

In any event, limited movement devices shall be installed in such a manner as to prevent unauthorized adjustment of any setting. Systematic maintenance arrangements should be instituted to ensure regular checking and any necessary resetting.

6.3.5.2 Timed impulse device A timed impulse device is simple to apply but the resultant movement of the machinery may vary for a given setting of the control, depending on—

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

6.3.5.3 Controlled movement device Controlled movement devices are designed to give a reasonably accurate predetermined movement in which stopping is effected as soon as the required movement has taken place. Once properly set, they are only affected to a very limited extent by factors such as ambient temperature or varying load on the machine. Movement of the machinery shall be transmitted by gearing, chain drive or other form of positive coupling to the device itself.

6.3.6 Handles and handwheels Where a handle or handwheel is provided to manually operate a mechanism which can also be driven by mechanical power, the handle or handwheel should be designed so as not to rotate when the power drive is operating. Where this is not possible, handwheels should be of the solid type without spokes or projections or be provided with handgrips of restricted size that are suitable for the required force.

6.3.7 Emergency stop device

6.3.7.1 General An emergency stop device is a device which, regardless of the power source, e.g. electrical, pneumatic or hydraulic, requires deliberate action to bring a machine to rest when danger is recognized. The emergency stop should not be used for normal stopping. Emergency stops shall not be relied on as a means of isolation or immobilization.

An emergency stop device when operated shall stop the machine as quickly as possible and apply a brake where provided. An emergency stop is not an alternative to guarding. Care should be taken that the operation of the emergency stop does not, in itself, increase the risk of injury from another source. Handles, bars and push-buttons used for actuating the emergency stop should be coloured red and suitably marked, prominently located and readily accessible from all operator positions. Push-buttons shall be of the mushroom head latch-in, or lock-in manual reset type.

While push-buttons are the preferred form of emergency stop device, other devices providing equivalent levels of safety are acceptable.

Where there is more than one control or workstation, an emergency stop push-button shall be positioned at each station. Emergency control between and around the workstation may also be provided by use of trip wires or pressure-sensitive cables. In these circumstances it may be desirable to incorporate a visual indicator. The emergency stop should be located within easy reach.

All emergency stops on a machine shall remain active at all times.

Release or resetting of the emergency stop device shall not cause the machine to operate. Restarting shall only be possible by operation of the normal start control.

6.3.7.2 Latch-in emergency stop devices Where the stop/start controls are remotely located, push-buttons and switches actuating emergency stop devices shall be of the latch-in type so that the machinery cannot be restarted until they have been reset manually. A latch-in emergency stop device incorporating a key-locking mechanism may provide a higher degree of control in certain applications such as where more than one operator is present at a machine. These devices require the latching mechanism to be reset using a key.

6.3.7.3 Disconnection of main power supply In some installations an emergency stop device may be utilized to stop all the machinery by disconnecting the main power supply. Where electrodynamic braking is used for emergency stopping, disconnection of the main power supply shall occur only after the machine has stopped. Release of the emergency stop device shall not re-energize the machinery.

6.3.7.4 Emergency stop trip wires At a long machine, instead of a number of separate emergency stop devices, it is sometimes more effective to install an emergency stop wire or rope along the whole length of the machine. A pull on the wire in any direction, or breakage or slackening of the wire, shall bring the machine to rest. The arrangement should be such that after manual operation, resetting is necessary. Where emergency stop trip wires are used (see Figure 6.5), they are not a substitute for guarding and should not be confused with the trip devices described in Clause 9.2.

Trip wires should be located in such a manner as to be clearly visible, readily accessible and positioned so that they can be used not only at the operator's normal control station but at other appropriate points. Trip wire sleeving or covering should be coloured red.

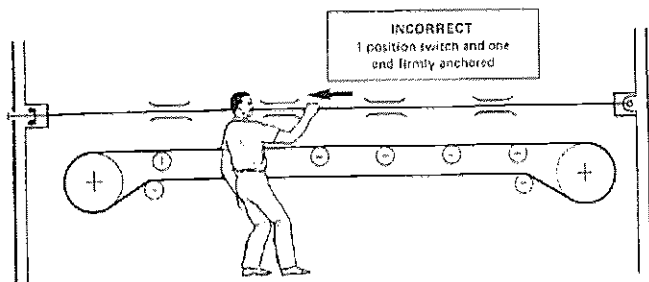
The system should be designed so that the failure of a single spring is a failure to safety, causing the emergency stop to operate. The system should operate with the application of a force not exceeding 70 N by a movement normal to the axis of the wire not exceeding 300 mm. As the movement of the wire and the force to operate the system could be affected by the design of the trip wire supports and the distance between them, care should be taken to ensure that the wire is free to move through the supports at all times, particularly at changes of direction, without becoming disengaged from them. Where, in the case of long trip wires, more than one switching device is necessary, a visual indicator should be incorporated to show which device has operated. The indicator can be at a central position or at an individual device.

6.3.8 Warning signals On installations where the main operating station or start control is in a position from which the people in the vicinity of dangerous parts of the machinery cannot be seen clearly, audible and visual warnings shall be operated through a suitable interlock for a predetermined time before the machinery starts to operate. Where practicable, start-up should result in a progressive speed increase to full running speed. Adjacent machines should be provided with distinguishable audible signals.

Where malfunction of the machinery creates a hazard, suitable warning signals shall be given. These signals shall be given automatically and shall be both auditory and visual.

Auditory and visual warnings may be provided in addition to, but not as substitution for, physical safeguards.

Auditory and visual warnings shall be either monitored or shall fail to safety.



(a) Emergency stop wire installed incorrectly

This shows an incorrect installation with a switch at one end and the wire firmly anchored at the other. The device will be inoperative if the trip wire is pulled in the direction shown.

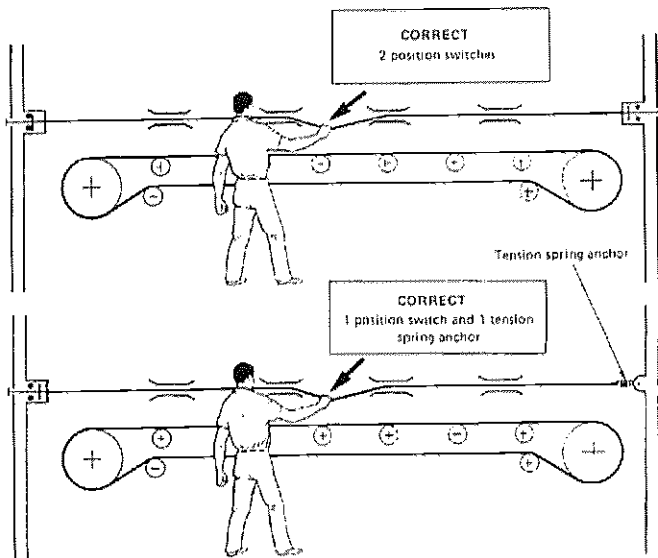


FIGURE 6.5 EMERGENCY STOPPING OF LONG MACHINES

6.4 INDICATORS Indicators or displays should only give important information, and the amount of information shown should be the minimum required.

Where necessary, a qualitative, quantitative or check reading indicator should be provided to warn of danger. Such indicators should be designed to fail to safety. Explanations of these indicators are as follows:

- (a) *Qualitative*—shows a satisfactory or unsatisfactory state, e.g. a temperature gauge which indicates cold-normal-hot.
- (b) *Quantitative*—provides numerical data and as such requires precision in reading, e.g. a pressure gauge. A quantitative indicator should not be used if a qualitative one would suffice.
- (c) *Check reading*—gives information automatically or when demanded as to the state of the equipment, e.g. an indicator light or an audible alarm.

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

6.6 BRAKING SYSTEM

6.6.1 General Braking systems shall be so designed as to bring dangerous moving parts to rest with a consistent performance as quickly as possible. As the braking capacity required is related to the momentum of the moving parts, their momentum shall be kept as low as the application permits. The possibility of inserting a clutch mechanism should be considered as a means of limiting the momentum to be dealt with by the brake. In machinery utilizing a flywheel, the flywheel should be disconnected, e.g. by a suitable clutch, before braking. Rotating parts and equipment fastened to rotating parts shall be so secured as to prevent dislodgment as a consequence of the brake action. Adequate precautions shall be taken to prevent disengagement of screwed components due to reversed torque following brake application.

All braking systems shall be designed to fail to safety.

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

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

The arrangements for maintaining the correct alignment of brake components shall be such as to minimize the risk of binding.

Where the effectiveness of braking could be adversely affected by contamination, e.g. by the ingress of moisture or oil, consideration shall 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.

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

Complete instructions concerning the setting of the brake should be available. These instructions should include—

- (i) the length to which any springs should be compressed; and
- (ii) the method for setting the operating mechanism.

In certain applications it is essential that the brake is disengaged only when torque is available at the driving motor, e.g. the hoist motion of a crane. The electrical circuit should therefore be so designed that failure of the supply in part of the circuit cannot cause loss of control of the motor while leaving the brake disengaged. Precautions should also be taken against the possibility of a similar danger being caused by failure of one phase of a three-phase supply.

When compressed air or hydraulic means are used to apply mechanical brakes, a reservoir/accumulator, connected as close as possible to the brake, shall be provided to ensure a sufficient supply of fluid in the event of failure of the main supply. The reservoir/accumulator should have a low-pressure device to switch off the machinery if the pressure in the reservoir/accumulator falls below a safe limit and the feed should be fitted with a non-return valve.

6.6.3 Electrodynamic braking systems

6.6.3.1 General Electrodynamic braking systems are arrangements by which electromagnetic forces are used directly to bring any moving parts to rest, e.g. within the drive motor itself. Such systems have widespread application but it should be borne in mind that they generally fail to danger in the event of supply failure. They should be connected in such a way that their power supply is maintained when emergency stop controls are used.

6.6.3.2 Reverse plugging Reverse plugging is a method of braking whereby the electrical connections to a motor are changed so that a reverse torque is applied and the machine is brought rapidly to rest. The changeover contactor should be so controlled that it will open when the machinery stops, otherwise the machinery will restart in the reverse direction.

6.6.3.3 Direct current injection Direct current (d.c.) injection consists of disconnecting the motor stator windings from the a.c. supply and reconnecting them to a d.c. supply. This has a powerful braking effect and is superior to reverse plugging (see Clause 6.6.3.2) because there is no tendency to restart in the reverse direction.

6.6.3.4 Regenerative braking for a.c. motors (capacitor braking) Regenerative braking for a.c. motors operate by—

- (a) disconnecting the motor from the a.c. supply and reconnecting it to a capacitor bank to assist in maintaining self-excitation of the motor; and
- (b) improving the braking effect during the final stages of deceleration by short-circuiting the motor terminals.

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

6.7 SAFETY CATCHES, OVERRUN, RUN-BACK AND FALL-BACK PROTECTION DEVICES Where risk of injury may arise, a safety device should be incorporated in the design to restrain any moving machinery part which may run beyond its normal stopping position due to gravity, to the fall-back of a crankshaft, to the failure of a counterweight system or any other similar failure (see Clause 6.15).

All such devices should be designed to minimize the risk of injury.

6.8 SUSPENDED EQUIPMENT

6.8.1 Secondary means of support Where indicated by a risk assessment, a secondary means of support is required on all suspended equipment where failure of the primary support would result in the equipment falling.

Where fitted, the secondary support shall be independent of the primary support and shall not normally bear any working load. It shall be designed to withstand any shock-loading imposed in the event of failure of the primary support and shall be fitted such that the distance through which the equipment may fall is minimized.

6.8.2 Counterweights and similar devices Counterweights which may fall upon or trap persons shall be suitably safeguarded. The movement of the counterweights shall be safeguarded to provide complete protection against injury, particularly in the event of a power system failure.

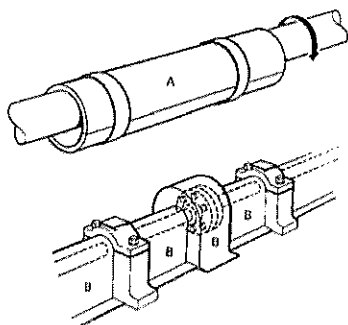
Duplication of the flexible connections (chain or cable) between the mass and all balance weights is good practice provided each connection is capable of safely bearing the full load of the balance weight.

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

6.9 ROTATING SHAFTS, SPINDLES AND COUPLINGS Every projection such as a set screw, bolt or key on any exposed revolving part of machinery should be sunk, shrouded or otherwise effectively guarded. Suitable means of guarding a shaft and coupling are shown in Figure 6.6.

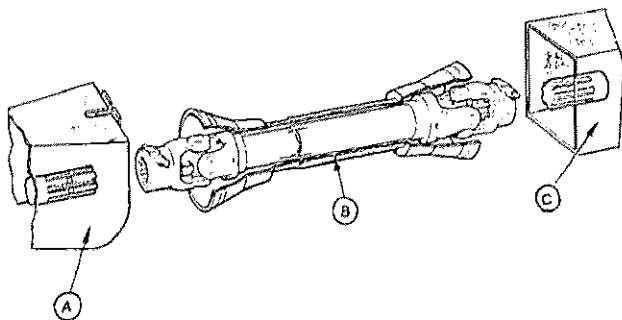
Telescopic guards are a suitable alternative in some applications, e.g. a power take-off is responsible for many accidents due to persons becoming entangled with the rotating universal joints and telescopic shafts.

Telescopic guards provide protection against the danger of contact with a rotating shaft, whether plain, splined or screwed and is particularly useful, when, as shown in Figure 6.8, it is fitted to a traversing part of a machine. It also protects the shaft against the ingress of dust and swarf. Where bellows guards are used on long shafts, they should be supported at intervals by internal bushes.



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

FIGURE 6.6 GUARDING OF SHAFTS AND COUPLINGS



NOTE: The guard shown 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.

FIGURE 6.7 POWER TAKE-OFF DRIVES

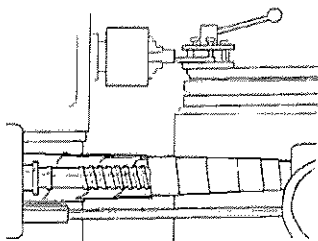


FIGURE 6.8 TELESCOPIC GUARD

6.10 FEEDING AND TAKE-OFF DEVICES The use of automatic equipment to move components, materials and substances into and out of machine tools and process machinery should be considered, as such equipment reduces the hazards to persons at the various operating points and diminishes the risk of injury when materials would otherwise need to be moved manually. Examples are robots, tongs, chutes, slides, indexing tables, transfer mechanisms, automatic feeds, magazines, suction or magnetic devices, push rods or air blast.

Care shall be taken to ensure that the use of automatic feeders does not introduce further trapping hazards between the devices and parts of the machine or materials being processed. Suitable safeguards shall be provided if there is the possibility of any danger arising from moving parts.

6.11 HYDRAULIC AND PNEUMATIC SYSTEMS Hydraulic and pneumatic equipment shall be in accordance with the safety recommendations given in AS 2671 and AS 2788.

When designing hydraulic circuits, all possible methods of failure including control supply failure, shall be considered. Components shall be selected, applied, fitted and adjusted so that in the event of a failure, maximum safety of personnel is the prime consideration, and damage to equipment is minimized (see also Clause 4.2.9).

All components within the system shall operate within the manufacturer's specification. All parts of the system should be protected against over-pressure. The system shall be designed and constructed so that components are located where they are accessible and can be safely adjusted and serviced. Circuits shall be designed, constructed and adjusted to minimize surge pressures and so minimize hazards.

Where special site conditions exist, such as the possible existence of a fire hazard and protection for electrical devices, the design of the system should take account of these conditions.

For methods of interlocking of hydraulic and pneumatic systems, see Section 10.

6.12 ELECTRICAL SYSTEMS The electrical equipment should comply with the safety requirements of AS 1543, and wiring should comply with AS 3000. Advice on programmable control systems and methods of interlocking is given in Clause 6.22.

6.13 WORKHOLDING DEVICES

6.13.1 Power loss during operation Where power-operated workholding devices are supplied, they shall be designed so in the event of a failure of the power supply to the system, the workpiece remains clamped.

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

Clamping movements shall be designed such that it is not possible to trap any part of the body between the workholding device and any other element of the machine or workpiece. Typical methods to meet this requirement include restricting the gap between the opened clamp and the workpiece to not greater than 6 mm, or by enclosing the clamp in a suitable guard.

6.13.3 Prevention of inadvertent unclamping of the workpiece The design of the control system shall be such that the power operating system for the workholding device cannot be operated to unclamp the workpiece while it is dangerous to do so.

6.14 LIFTING, HANDLING AND TRANSPORT Machinery which cannot be moved or transported manually should be equipped with, or be capable of being equipped with, suitable devices for transport by means of lifting attachments. Transport personnel should be able to reach the lifting attachments safely or provision for automatic attachment should be fitted. The lifting attachments should be arranged so that the machinery cannot be tipped during correct lifting. Weight details should be given on the machine, on its packaging or on transport documentation.

All machinery elements, including added fixtures, should be provided with means for their safe removal and replacement. Shape, size and weight can permit these operations to be carried out manually and with safety.

Parts of machinery which can be removed during machine operation, e.g. tools and devices which on account of their weight cannot be lifted manually, should be permanently marked with weight details affixed so that they are clearly legible and visible, and information as to whether the details refer to the removable part, or to the complete machine.

When a machine is provided with lifting attachments gear and appliances, e.g. for workpiece loading, unloading, tool mounting or delivery, the supplier shall provide details of the working load limit and notify the user of the need to obtain a certificate of test and examination as specified by relevant legislation.

Lifting attachments and appliances shall be marked with the working load limit.

Eyebolts and eyebolt holes should be identified to prevent mismatching or misuse since an eyebolt which is capable of supporting a sub-assembly might not be capable of supporting the mass of the whole machine.

6.15 MECHANICAL RESTRAINT DEVICE

6.15.1 General A mechanical restraint device is a device which applies mechanical restraint to a dangerous part of machinery which has been set in motion due to failure of the machinery controls or of other parts of the machinery. Figure 6.9 depicts a typical mechanical restraint device.

6.15.2 Downstroking platens Sudden loss of pressure at certain points in the hydraulic system of a downstroke press can cause the platen to fall under gravity. On small machines, the weight of the platen and speed of descent may be insufficient to cause danger, but on large machines protection against such a failure should be provided by means of one or more scotch blocks capable of supporting the weight of the ram, platen and tool, inserted automatically when the platen has returned to the top of its stroke.

Figure 6.10 shows a downstroking hydraulic press with an interlocking guard which incorporates mechanical restraint (scotching).

A suitable alternative is to use a pilot-operated check valve and counterbalance valve assembly to connect to the lower end of the hydraulic cylinder (see Clause 10.19.2).

Where a scotch block operates in conjunction with an interlocking guard, the scotch block 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.

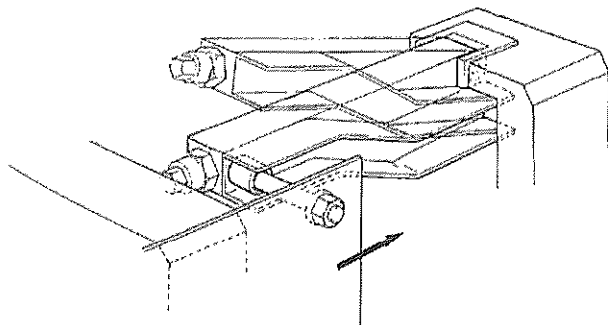


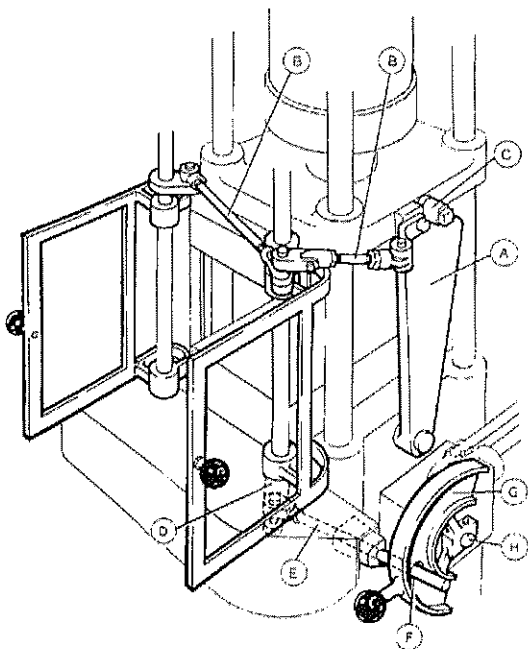
FIGURE 6.9 AUGMENTING AN INTERLOCKING GUARD WITH A MECHANICAL RESTRAINT DEVICE

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

Where the failure of an automatic lubrication system could cause a danger to the operator, such a lubrication system shall incorporate a suitable indication of its correct functioning or warning of a malfunction (or both).

In the event of automatic lubrication system failure, means may be required to stop the machine as soon as practicable. (See also Clause 6.21.3.)

6.17 STABILITY Machines shall be designed to be stable, i.e. not capable of being unintentionally moved by vibration, wind pressure, impact or other foreseeable external forces. If this recommendation cannot be fulfilled by design or stable weight distribution, then stability shall be achieved by special safety measures. For example, movement of parts of the machine may be restricted; indicators, alarms or interlocks to prevent tipping may be provided; or the machine may be securely anchored to a foundation. Both static and dynamic stability shall be considered. Where special safety measures are required, a warning should be provided on the machine and in the operator's manual.



NOTE: 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 a projection (C) secured to the top platen. At the same time a link (D) attached to the guard pivot forces a spindle (E) through a hole (F) in the 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 the spindle (E) is withdrawn from the hole (F) and the scotch (A) swings clear of the projection (C). The press is then free to operate, the doors being held closed by the spindle (E) when the valve plate (G) is rotated. Fixed guarding at the sides and rear of the press are not shown in the illustration.

FIGURE 6.10 MECHANICAL RESTRAINT

6.18 LIGHTING Local lighting on the machine for the illumination of the work area shall be provided when the construction of the machine or its guards render the normal lighting inadequate for the safe and efficient operation of the machine. Local lighting should also be provided in areas of regular maintenance which are likely to be poorly lit, e.g. the inside of certain electrical compartments where electrical isolation is necessary for access.

Fluorescent lighting may be used provided that any stroboscopic effects do not conceal a hazard, create a distraction or cause annoyance.

If the position of the lighting has to be adjusted, its location shall be such that it does not cause danger to the machine operator while adjustment is being made.

See Clause 11.7 for general lighting of the workplace.

6.19 HYGIENE Machinery used in certain industries, notably for the processing of food and pharmaceuticals, should be so designed that it is not only safe to use but can be readily and safely cleaned. (See also Clause 11.3.)

6.20 SAFETY COLOURS AND SYMBOLS Colours may be used to draw attention to a hazard. For example, certain parts of machines could be painted a distinguishing colour which will only be visible when a danger exists. Such finishes shall be non-toxic when used in the food processing and pharmaceuticals industries.

Such painting shall be confined to the inside surfaces of hinged covers which, when open, expose machine parts which are dangerous when in motion, e.g. rotating shafts, gears or belts. The outside of such covers should not be painted the same distinguishing colour.

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

If it is not practicable to apply the distinguishing colour to an element of the machine structure, then the dangerous items themselves may be painted. An example could be a dangerous element hiding the adjacent machine structure. The whole of the dangerous part need not be painted; it is sufficient to paint areas such as the ends of shafts, rims of pulleys and edges of blades.

Where safety colours and symbols are used, they should adopt a bold, recognizable, consistent pattern or symbol using standardized colours and should comply with AS 1318, AS 1319 and AS 1345.

6.21 ACCESS

6.21.1 Operating stations The controls shall be so positioned relative to the machinery that the operator has adequate vision for control of the process being undertaken. The operator shall have adequate room in the working position and have all controls placed within comfortable range. Where it is necessary for an operator to stand or sit on machinery when it is being operated, a platform or seat should be provided and so designed and situated as to protect an operator from any fixed or moving part which may cause injury. Other considerations include the transmission of vibration to the operator.

Seats shall provide adequate support and shall be fitted with back rests or be shaped to prevent an operator from slipping off the seat. Suitable footrests should be provided, where necessary.

Access to dangerous parts of transfer mechanisms, conveyors and similar will also require consideration, usually on a larger scale than in the case of single-operation processes. In large automated processes, particular attention shall be given to safe means of access such as walkways, conveyor bridges or crossover points.

6.21.2 Platforms and steps Where work platforms are used, they should be so designed as to prevent hazards and provide a level standing space of adequate size with a firm foothold. The stepping areas shall be made from materials which remain as slip-resistant as practicable under working conditions, and suitable guardrails, posts and toe-boards shall be provided.

An access ladder with handholds and where necessary fitted with hoops or a stairway with handrails or some other suitable means should be provided to give safe and convenient access.

Recommendations for the design and general construction of factory stairways, ladders and handrails are given in AS 1657.

6.21.3 Access for adjustment, lubrication and maintenance Machinery should be designed to enable all routine adjustments, lubrication and maintenance to be carried out without removing the safeguard and without extensive dismantling of machinery components. Lubrication and routine maintenance facilities should be incorporated outside the danger area, wherever practicable.

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

Where necessary, machines shall have built-in platforms, ladders or other facilities to provide safe access for any adjustment, lubrication or maintenance and care shall be taken to ensure that such platforms or ladders do not give access to exposed dangerous parts of machinery or other equipment such as overhead cranes (see also Clause 6.21.2).

6.22 ASSURANCE OF SYSTEM INTEGRITY

6.22.1 General Design errors which compromise the intended integrity of a system can occur during any phase of the design process (see Figure 6.11).

The system shall be designed in a manner that will reduce the possibility of errors being introduced. It should be checked during all phases to confirm freedom from error. The higher the level of integrity required and the more complex the system, the greater will be the extent of the check. This applies both to systems where the logic is entirely determined by permanent connections, e.g. a hard-wired electrical relay logic system, and to software or other programmable systems. However, the increasing complexity of typical programmable electronic systems highlights the difficulties faced by the designer who needs to assure system integrity.

Programmable systems shall provide a level of performance at least equal to that afforded by conventional hard-wired safety systems.

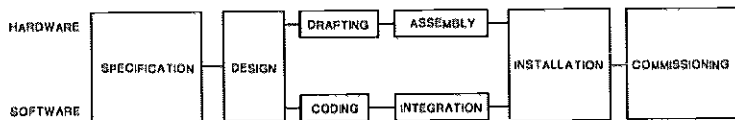


FIGURE 6.11 PHASES IN THE DESIGN PROCESS

6.22.2 Re-programmable systems Systems intended to be capable of re-programming present additional assurance problems if safety is affected. Such systems include—

- disc, cam or drum arrangements operating switches, valves or linkages;
- selector switches or valves affecting otherwise hardwired logic;
- card readers;
- punch tape readers;
- magnetic tapes or discs; and
- electronic or optical storage.

These memory or storage arrangements may be used in conjunction with a variety of control media: in control, interlocking or emergency systems (or both). Ways of preventing inadvertent or deliberate alteration of the stored program should be considered. These should encompass both reliability and security of the storage system and include the following measures:

- (i) Pinned cams.
- (ii) Embedded software, e.g. read-only memory (ROM).
- (iii) Locks restricting access.
- (iv) Password access to software.

6.22.3 Relationship between safety, reliability and availability for machinery The concepts of safety, reliability and availability can be described as follows:

- (a) Safety of a machine is the ability of a machine to perform its function, to be transported, installed, adjusted, maintained, dismantled and disposed of under conditions of intended use specified in the instruction handbook (and, in some cases, within a given period of time indicated in the instruction handbook) without causing injury or damage to health.
- (b) Reliability is the ability of a machine or components, or equipment, to perform a required function without failing, under specified conditions and for a given period of time.
- (c) Availability is the ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.

Safety looks at the causes and consequences of possible accidents (injury or damage to health). Safety requirements are concerned with making a system which does not cause accidents. The safety requirements ensure that the system does not reach a hazardous or unsafe state, when an event could cause an accident. Moreover it should be transparent from the safety requirements, what actions ought to be taken, if an unforeseen event in the environment leads to an unsafe state.

From the point of safety it does not matter if the system does not serve its purpose, as long as the safety requirements are not violated. On the other hand, it is possible that the system is highly reliable, but unsafe, e.g. a system with formally verified software but where a safety related situation had not been properly specified.

Availability influences the safety. The availability of a system implies that the safety related reliability is performed, otherwise the safety device can be defeated. The designer has the responsibility to decide, for each application, the relationship between availability, reliability and safety to ensure that an acceptable residual risk is achieved.

SECTION 7 SELECTION OF SAFEGUARDS

7.1 GENERAL When a hazard or risk cannot be eliminated or avoided by design, the provision of safeguards shall be considered. Four critical factors to be considered in the selection process are—

- (a) the severity of potential injury;
- (b) the frequency of access or entry to the danger zone and/or the time of exposure to the hazard;
- (c) the possibility of avoiding the hazard; and
- (d) the type process and operating requirements.

In general terms there are three types of access or entry to machinery—

- (i) operational access;
- (ii) maintenance access; and
- (iii) casual access

7.2 ACCESS

7.2.1 Operational access Operational access is related to the day-to-day operation of machinery and takes account of such activities as loading and unloading of parts, adjustments, inspection, housekeeping or tool changing, e.g. cutters or die-setting. The frequency of access may vary from a few hundred times per hour for part loading or unloading to a few times per day for other activities and the duration of access may range from a few seconds to a number of minutes.

Safeguarding for operational access is generally a selection from moving guards and safety devices. (see Sections 8, 9 and 10).

7.2.2 Maintenance access Maintenance access relates to keeping machinery in operational order and encompasses such activities as repair, cleaning and major tool change. The frequency of access is generally as required and the duration may vary from a number of minutes to many days.

Safeguarding for maintenance is generally selected from stationary guards and administrative controls (see Sections 8, 14 and 15).

7.2.3 Casual access Casual access relates to the ability of persons to gain entry to a danger zone where they are not normally required to be as part of their work. This type of access is sometimes overlooked as the natural tendency is to concentrate on more obvious operational and maintenance access. Such access may include—

- (a) the need for an operator to gain access for maintenance operations; and
- (b) the ability of other persons, e.g. passersby, to inquisitively, or unwittingly, enter a danger zone.

Safeguarding for casual access will generally be selected from stationary guards (refer Section 8).

7.2.4 Safeguarding An hierarchical illustration of machine safeguards is shown in Figure 7.1. Although this Section is primarily concerned with the selection of physical safeguards, the use of various administrative controls is always an essential complementary element and should be developed in conjunction with the selection of safeguards, e.g. training will be common to all safeguarding systems and the safe use of machinery.

In the majority of cases the hazards present in machinery are of a mechanical origin and consequently pose a risk of serious injury to exposed persons. This is of particular importance when access to the point of operation also provides access to the danger area. The possibility of avoiding the hazard should not be overestimated as machinery movements are often rapid and unexpected, and human response times relatively slow.

For these reasons the highest practicable level of guarding should be selected.

The fundamental issues involved in guarding a machine are shown in Figure 7.2 which depicts a hypothetical machine in which several hazards are present. Where access to the machine during operation is not required, a stationary guard, in this case a fixed guard around the machine, will provide complete protection from the hazards (see Figure 7.2(b)). Such an approach would satisfy safeguarding requirements for maintenance and casual access.

Should it be necessary to feed material such as a bar of steel into the machine, an aperture may be provided in the fixed guard, provided the appropriate anthropometric reach data (see Appendix A) are satisfied.

It must be recognized that a fixed guard should only be used where manual access to the danger area is not required during operation of the machinery. Furthermore, as fixed guards by definition are not interlocked, their removal in no way impairs the potential for the machine to be inadvertently started or to commence motion if the primary sources of power remain energized. For this reason the removal of fixed guarding shall always be accompanied by administrative controls, in this case isolation and safe work procedures (see Sections 14 and 15).

An important consideration is where clearing of jammed parts or correcting a machine malfunction is concerned. In these cases it is important that the selection and design of the safeguard enables these functions to be carried out in a safe and proficient manner, otherwise there will be a high level of frustration for the operator, and ultimately a modification of the guard in some way to allow ready access, or to it not being securely fixed in position.

In addition, these activities often result in persons placing parts of their bodies in the danger zone for significant periods of time. Where this is likely, such access should be treated as a maintenance access unless special administrative controls are developed and rigidly complied with.

As the need for manual access arises or increases in frequency, these safety procedures for the removal of a fixed guard increases in importance until interlocking should be used. The requirements for interlocking and administrative controls become more stringent as the level of risk increases (see Sections 5 and 10).

Should operational access be required, a moving guard will provide adequate protection. This may take the form of a hinged or sliding screen (see Figures 7.2(e) and (d)) which is interlocked with the machine power source or control system (refer Sections 8 and 10).

Where provision for machine rundown time is required before access can be gained, a guard retaining device interlocked in such a way that the guard is only released once motion has ceased, may be used (see Figure 7.2(f)). Typical examples could be a motion sensor or a time delay device.

The spacing and orientation of the grille shown in Figure 7.2(f) may, subject to the appropriate anthropometric reach data (see Appendix A), provide for the feeding of material into and out of the machine. This has the added advantage over the approach suggested for the fixed guard referred to above in that, should manual access be required from time to time, opening of the guard will prevent any potential for the machine to be cycled.

In many situations, a combination of safeguards is required. The safeguarding shown in Figures 7.2(c) and (d) is a combination of fixed and interlocked guards. If, in conjunction with the fixed guard a mechanical feed unit is employed to feed a workpiece into the machine thereby removing the need for operational access to the primary danger point, a trip device may be required to protect against the secondary danger of entrapment between the mechanical feed device and the fixed guard.

Based on the type of process, the access required and the hazards involved, any number of other safeguards may be selected. Each selection should be subject to a risk assessment, and the requirements of the particular safeguard set out in this Standard.

Guidance on the selection of safeguards is provided in Figure 7.3. Where selection of a safeguard which falls into the possible category on the matrix is contemplated, further guidance may need to be sought from specialists in the field of machinery safety.

7.3 OPERATIONAL ACCESS (WHERE ACCESS IS REQUIRED DURING NORMAL OPERATION) Where access to the danger area is required for operational purposes, safeguards may be selected from the following:

- (a) *Interlocking guard* (see Clause 8.2.3).
- (b) *Automatic guard* (see Clause 8.2.2.2), capable of removing a person from the danger area before danger can arise. It should not itself constitute a source of danger due to its speed of operation, or shape.
- (c) *Fenceguard* (see Clause 8.2.1.4).
- (d) *Trip device* (see Clause 9.2).
- (e) *Adjustable guard* (see Clause 8.2.1.5), fitting where the danger point cannot always be completely enclosed, e.g. on certain machine tools such as horizontal and vertical milling machines, grinding machines and woodworking machines.
- (f) *Self-adjusting guard* (see Clause 8.2.2.3), acceptable where it is operated by the workpiece and the danger area is enclosed before and after the operation by the guard and during the operation by the guard or the workpiece (or both).

Guards should be removable or adjustable only with the aid of tools not normally available to operators.

- (g) *Two-hand control device* (see Clause 9.3.3).
- (h) *Hold-to-run control* (see Clause 6.3.4.2), an alternative to a two-hand control. Placed out of reach of the danger area, it protects the person operating the control but does not protect other persons.

Where hold-to-run controls are pendant mounted, they shall be used in conjunction with safe working practices. Pendant-mounted controls should be interfaced with the primary machine controls.

When persons require access to the danger area, e.g. for machine setting or process correction, operational safeguards may not be fully effective. The safeguards provided for the protection of the operator may provide the same measure of safety for setters. However, this protection may not be available to persons who—

- (i) are forced to disturb the safeguarding requirements effective during production operations in order to carry out their work; or
- (ii) may be out of sight and therefore exposed to danger if the machinery is switched on.

In these circumstances, safe working procedures such as isolation should be used, augmented where necessary with additional safeguards. The use of such procedures will require planning and discipline by all concerned. (See Section 14.)

7.4 MAINTENANCE ACCESS (WHERE ACCESS IS NOT REQUIRED DURING NORMAL OPERATION) Where access to the danger area is required for maintenance such as cleaning or repairs, safeguards may be selected from the following:

- (a) *Fixed guard*—(see Clause 8.2.1.2), including, where necessary, feeding and take-off devices (see Clause 6.10) or a false table. Openings in a guard should be in accordance with data given in Appendix A.
- (b) *Distance guard*—(see Clause 8.2.1.3), including a barrier of adequate height or a tunnel guard.
- (c) *Interlocking guard*—(see Clause 8.2.3).
- (d) *Trip devices*—(see Clause 9.2).

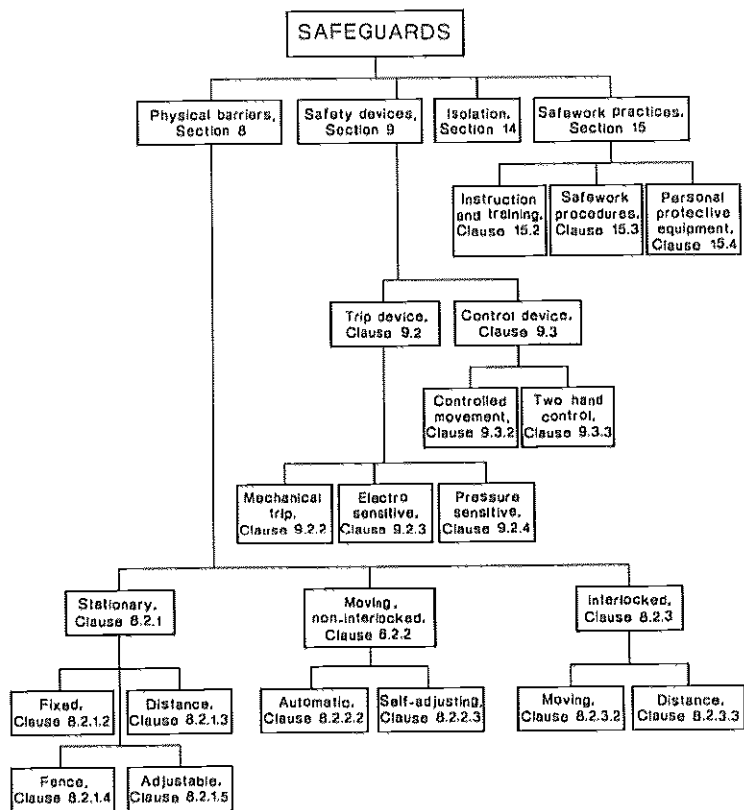


FIGURE 7.1 HIERARCHY OF SAFEGUARDS

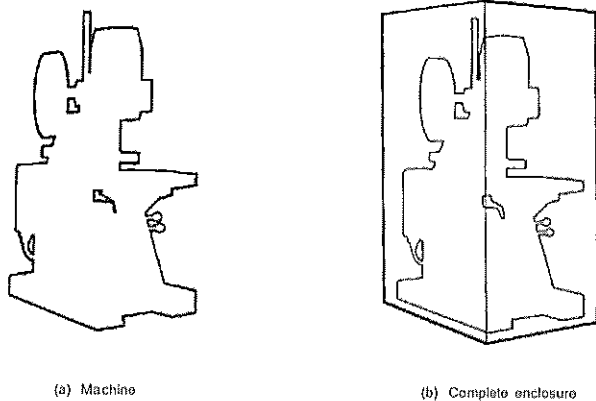
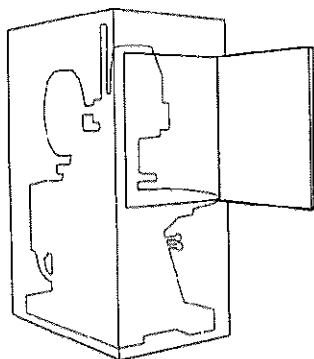
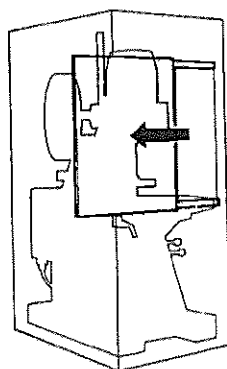


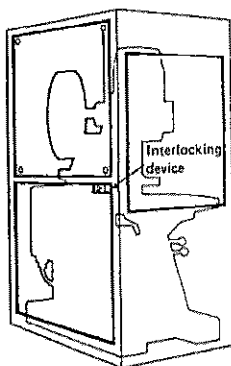
FIGURE 7.2 (in part) METHODS OF GUARDING MACHINERY



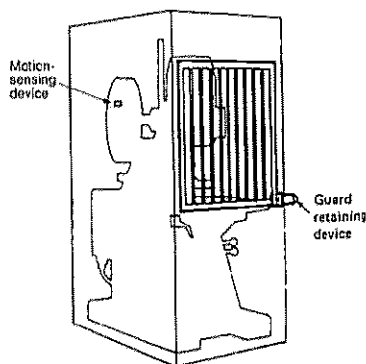
(c) Hinged guard



(d) Sliding guard

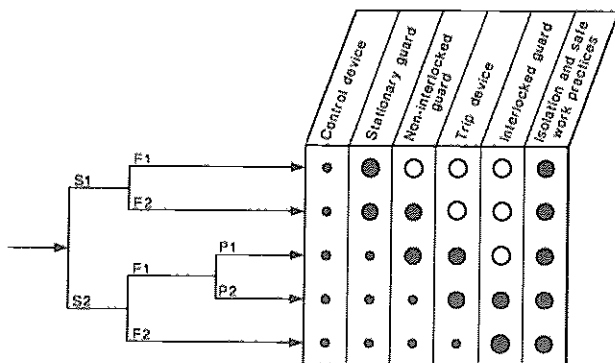


(e) Removable guard and interlock



(f) Removable grille and motion-sensing device

FIGURE 7.2 (In part) METHODS OF GUARDING MACHINERY



LEGEND:

S Severity of injury

S1, Slight (normally reversible) injury

S2, Serious (normally irreversible) injury, including death

F Frequency of exposure and/or exposure time to the hazard

F1, Seldom to quite often and/or the exposure time is short

F2, Frequent to continuous and/or the exposure time is long

P Possibility of avoiding the hazard

P1, Possible under specific conditions

P2, Scarcely possible

● Preferred

◐ Possible, or used in combination with higher categories

○ Over dimensioned

NOTE: Appendix F provides additional guidance in the selection of parameters S, F and P.

FIGURE 7.3 SELECTION OF SAFEGUARDS

SECTION 8 PHYSICAL BARRIERS — DESIGN AND CONSTRUCTION

8.1 GENERAL The primary function of this safeguard is to provide a physical barrier which prevents access to dangerous areas of a machine. These may vary from parts of the machine, e.g. devices or gears, to the point of operation where the process work of the machine is carried out.

In designing physical barriers, the method of construction should be selected to take account of the mechanical and other hazards involved. The design should take into account the physical size of the guard as well as its mass, the distance through which the guard must be moved during opening or closing and the frequency of opening. The design should provide the minimum interference with activities during operation and other phases of machine life, in order to reduce any incentive or the ability to defeat the safeguard.

Physical barriers should preferably be designed to follow the contour of the machinery. Where this is not practicable, e.g. for maintenance or because of machine geometry, measures shall be taken to reduce the need for presence within the enclosure. Additional safety measures may also be required to protect personnel. These may be safety devices or safe working practices (or both). (Refer Sections, 7, 9, 14 and 15.)

Physical barriers shall only be able to be removed or adjusted with the aid of tools not normally available to operators.

When viewing the workstation through a physical barrier it can be preferable for the barrier surfaces to be painted in a dark, non-reflective colour so that the visual contrast between the barrier and workstation can be maintained.

Information regarding working environment considerations is given in Section 11.

8.2 TYPES OF PHYSICAL BARRIERS

8.2.1 Stationary guards

8.2.1.1 General A stationary guard is a physical barrier which has no moving parts and offers protection only while the guard is in its correct position. In some cases, a stationary guard may have adjustable sections or fingers which are fixed securely after adjustment.

If the guard can be opened, removed or adjusted, this should only be possible with the aid of a tool. Preferably, the fastenings should be of the captive type. The guard shall be securely fixed in position when the machinery is in motion or is likely to be in motion. Where guards have to be removed periodically, e.g. for maintenance or cleaning, they should be designed so that the time required for their removal and replacement is minimized. Ideally, the removal of a single fixing with the appropriate tool should give the access required.

An interlocking device may also be used to provide an additional measured safety (see Clause 8.2.3).

8.2.1.2 Fixed guard A fixed guard is a stationary guard which prevents access to the dangerous parts of machinery by enclosure or by providing a rigid barrier (see Figure 8.1). Where a fixed guard is used to safeguard a chain or belt drive, the guard shall fully enclose the drive.

Fixed guards should not incorporate any means of retention which creates the impression of the guard being securely fixed, when they are not so fixed e.g. key slots, or hooks.

Hinged guards may be used; however, this use should be restricted to those instances where guard weight or restricted access for removal is a consideration.

Fixed guards for preventing access to in-running nips are shown in Figures 8.2 to 8.7.

The principle shown in Figure 8.7 can be used in other applications, e.g. feeding parts into a press tool.

Another application of a fixed guard is that shown in Figure 8.8. A particular difficulty in preventing access to dangerous parts of machinery arises when a power-operated feed table, which may 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 not only the danger of a person gaining access through it to the danger point, but also of the person being trapped between the material or work holder and the edge of the opening as the feed table moves forward.

A solution lies in the use of a false table which 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.

A fixed guard may also totally enclose a machine (see Figures 7.2 and 8.9).

It is often possible in this application for the guard to serve other purposes, for example dust or noise control.

When it is necessary for work to be fed through the guard, openings shall be sufficient only to allow the passage of material and not create a trap between the material and the guard or allow bodily access to the danger zone. If access to the dangerous parts cannot be prevented by the use of a plain opening, then a tunnel of sufficient length should be provided (see Clause 8.4.2 and Figures 8.10 and 8.11).

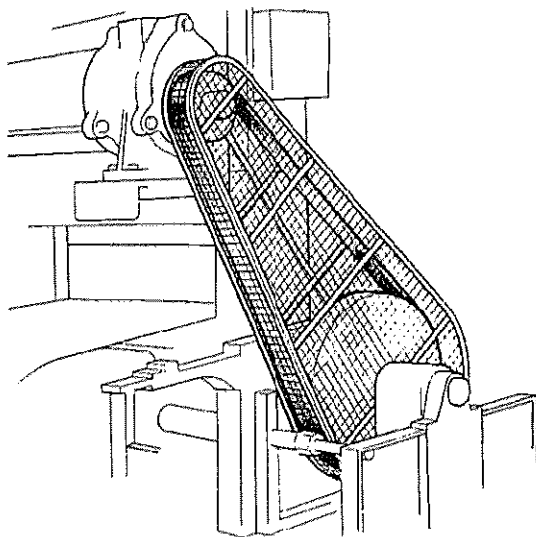


FIGURE 8.1 FIXED ENCLOSING GUARD CONSTRUCTED OF WIRE MESH AND ANGLE SECTION PREVENTING ACCESS TO TRANSMISSION MACHINERY

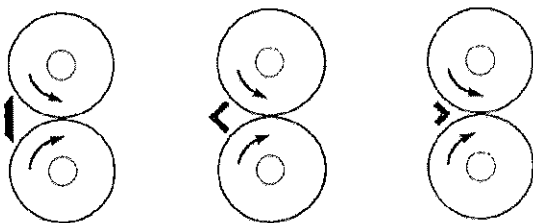


FIGURE 8.2 USE OF FLAT PLATE OR ANGLE SECTION TO PREVENT ACCESS TO IN-RUNNING NIPS

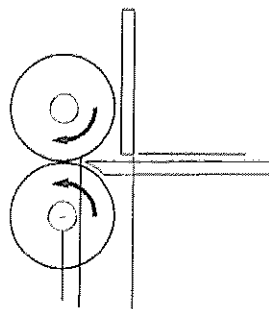


FIGURE 8.3 FEEDING MATERIAL TO A PAIR OF ROLLERS

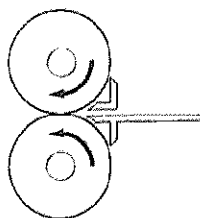


FIGURE 8.4 SMALL HORIZONTAL TABLE, STIFFENED TO PREVENT DEFLECTION

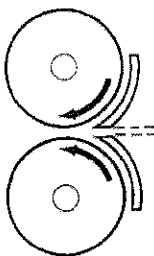


FIGURE 8.5 USE OF FIXED CURVED METAL PLATES TO PREVENT ACCESS TO IN-RUNNING NIPS

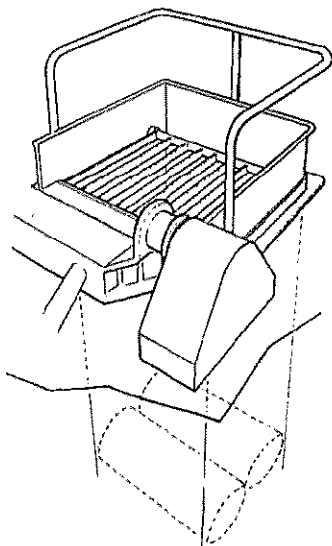


FIGURE 8.6 FEEDING OF BULK MATERIAL FROM THE FLOOR ABOVE THE MACHINE

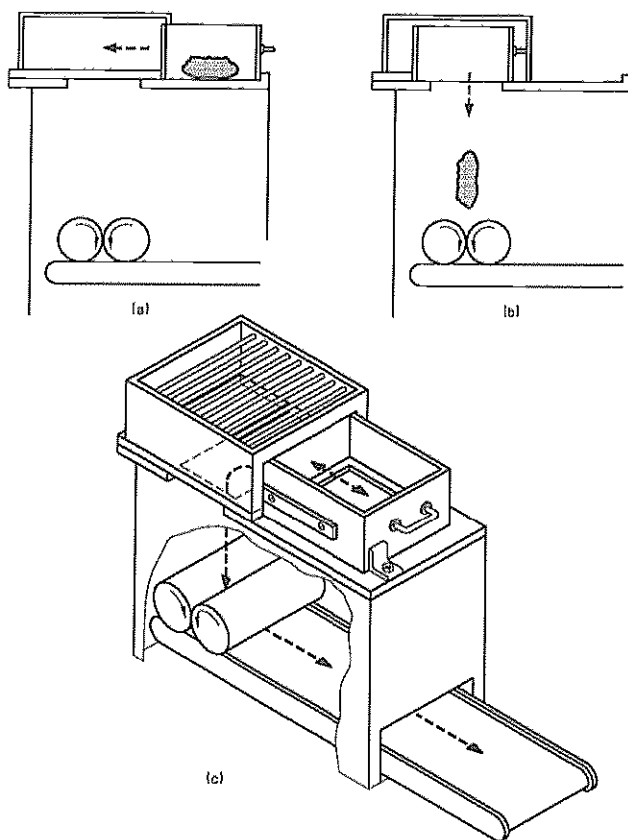


FIGURE 8.7 CAPTIVE DRAWER

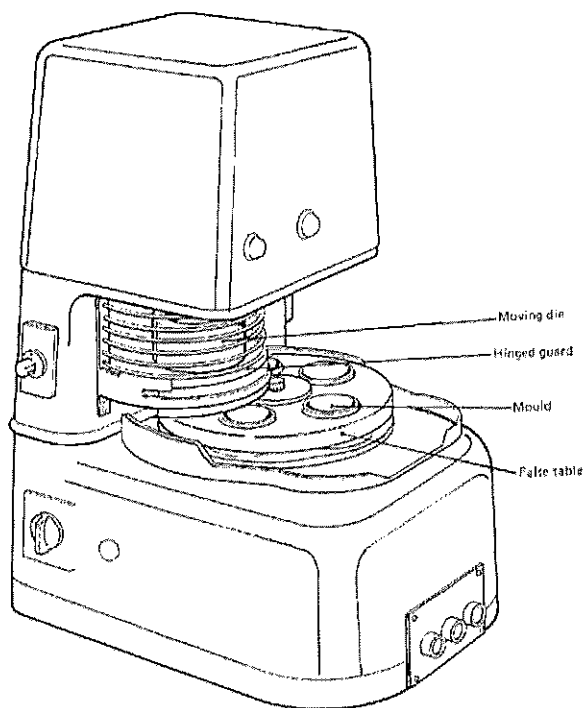


FIGURE 8.8 FALSE TABLE AND INTERLOCKING GUARD APPLIED TO A ROTATING TABLE

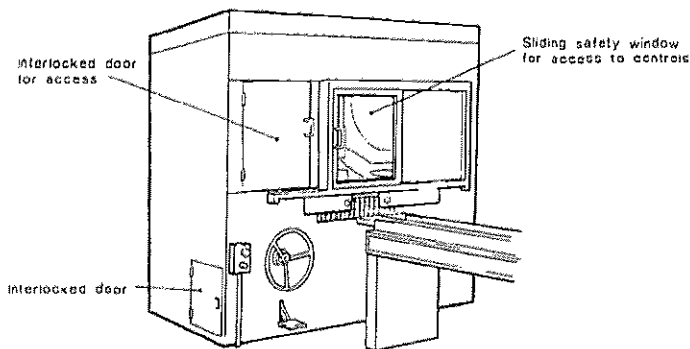


FIGURE 8.9 FIXED ENCLOSING GUARD

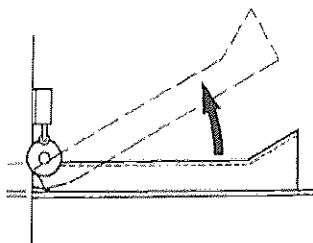


FIGURE 8.10 TUNNEL GUARD

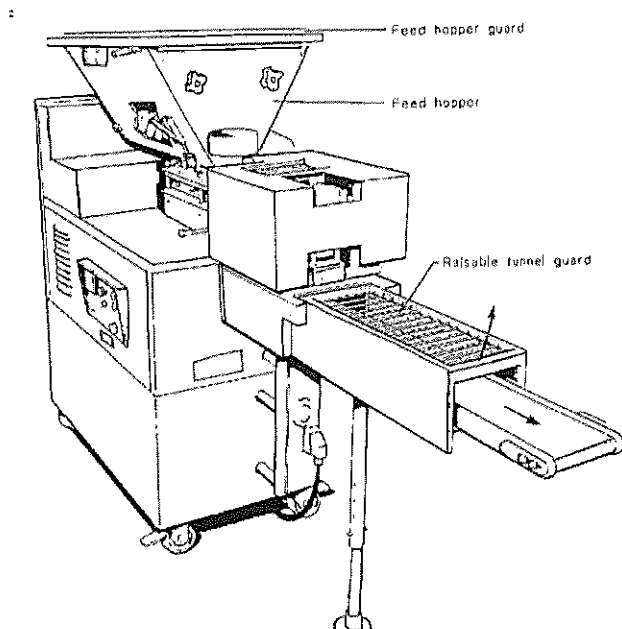


FIGURE 8.11 INTERLOCKING TUNNEL GUARD ON FOOD PREPARATION MACHINERY

8.2.1.3 Distance guard A distance guard is a stationary guard which does not completely enclose a hazard but which reduces access to the danger point by virtue of its physical dimensions and its distance from the hazard (see Figure 8.12). Reference should be made to Appendix A and Clause 8.4 for appropriate anthropometric data.

A distance guard may completely surround a machine and is then called a fence guard.

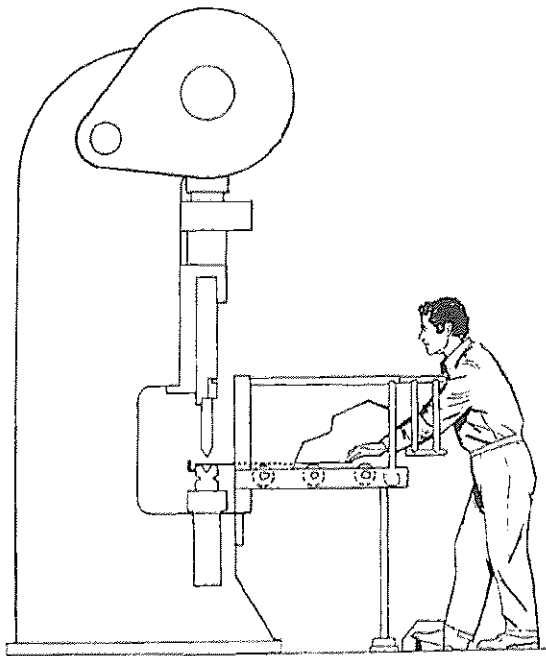


FIGURE 8.12 FIXED DISTANCE GUARD FITTED TO A PRESS BRAKE

8.2.1.4 Fence guard A fence guard is a stationary guard which completely surrounds a machine (see Figure 8.13). It may incorporate portion of the machine as part of the fence (see Figure 8.14). The distance from the danger area and height of fence guards shall be in accordance with Appendix A. Fence guards are often fitted with an interlocked gate (or gates) interlocked to the machine controls (see Clause 8.2.3).

8.2.1.5 Adjustable guard An adjustable guard is a stationary guard which is adjustable as a whole or which incorporates an adjustable part or parts. The adjustment remains fixed during a particular operation. (See Figures 8.15 to 8.17.)

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

Adjustment should only be carried out when dangerous movements have completely stopped.

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 so that the opening can be varied in height and width to suit the dimensions of the work in hand. It is essential in such cases that the adjustment is carefully carried out by a suitably trained person. Close supervision is necessary to ensure that the clearance between an adjustable guard and the work in hand is reduced to a practical minimum. Regular maintenance of the fixing arrangements is necessary to ensure that the adjustable element of the guard remains firmly in place once positioned. The guard should be so designed that the adjustable parts cannot easily become detached and mislaid.

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

A particular consideration with guarding that is adjustable or contoured around a workpiece is the size of the opening in the guard when the workpiece is not in place, which may allow access to the danger area. Additional guarding may be required to prevent this access.

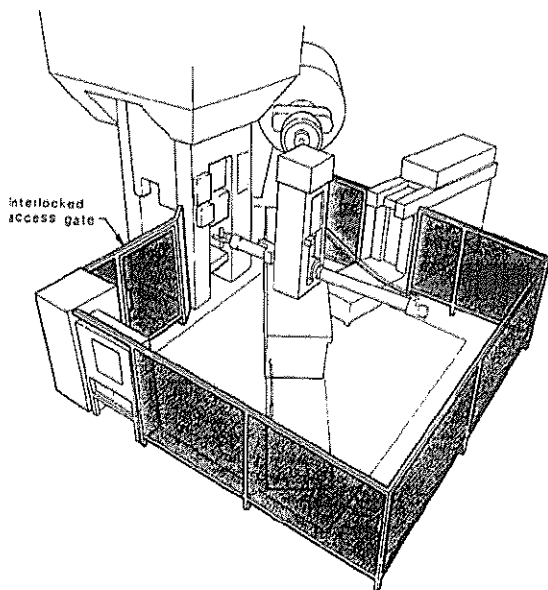


FIGURE 8.13 GUARDING AN INDUSTRIAL ROBOT
WITH A PERIMETER-FENCE GUARD

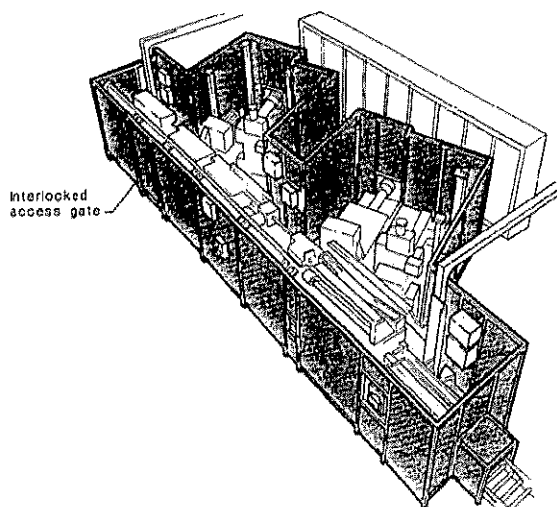


FIGURE 8.14 CLOSE CONTOUR PERIMETER-FENCE GUARD

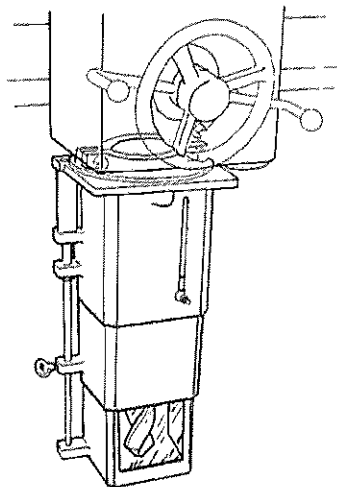


FIGURE 8.15 ADJUSTABLE GUARDS FOR A RADIAL OR PEDESTAL DRILLING MACHINE

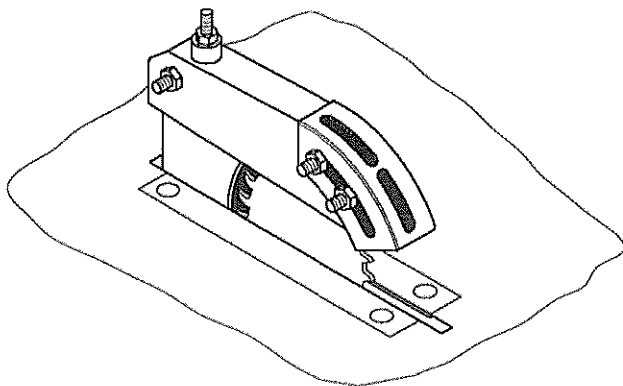


FIGURE 8.16 ADJUSTABLE GUARD ON A CIRCULAR SAWING MACHINE

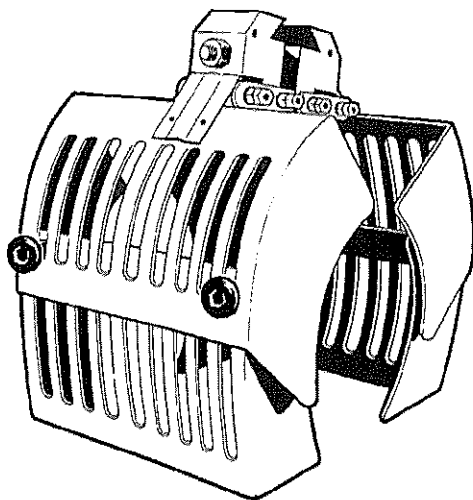


FIGURE 8.17 ADJUSTABLE GUARD FOR THE CUTTERS
OF HORIZONTAL MILLING MACHINES

8.2.2 Moving non-interlocking guard

8.2.2.1 General A moving non-interlock guard is a physical barrier which moves or has moving parts. It may incorporate adjustable sections within the moving parts to accommodate varying workpieces or operating conditions. Adjustment shall be in accordance with the appropriate anthropometric reach data (see Appendix A).

The guard is mechanically connected to the machine in such a way that as the machine moves or as the workpiece moves, the guard also moves and takes up a safe position.

Because these guards are not interlocked to the machine controls or power source, their removal, incorrect adjustment or other failure does not impair the potential for the machine to be operated or to allow access to dangerous parts when the machine is operating. Therefore, this type of guarding requires stringent compliance with setting and maintenance procedures.

8.2.2.2 Automatic guard An automatic guard is a guard which is moved into position automatically by the machine, thereby removing any part of a person from the danger area. In some applications this type of guard is known as a 'push away guard'. (See Figure 8.18.)

The guard may be used only where the velocity of the guard movement does not introduce any further danger.

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

The movable part of the guard should be positively actuated by the movement of the dangerous part of the machinery. The mechanism should be so designed that it will withstand long use with minimum maintenance, although it is essential that periodic inspection of the mechanism is carried out and provision is made for any necessary adjustments to ensure that the guard operates safely and correctly.

For specific applications of this type of guard to power presses and paper-cutting guillotines, see AS 1219 and AS 1893.

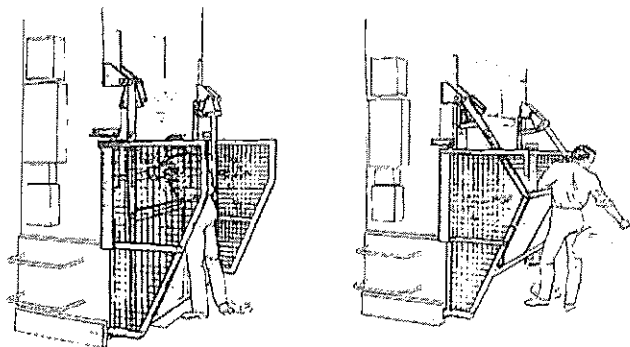


FIGURE 8.18 AUTOMATIC GUARD FOR A POWER PRESS

8.2.2.3 Self-adjusting guard A self-adjusting guard is a movable guard which, either wholly or in part, adjusts itself to accommodate the passage of material (see Figure 8.19).

This type of protection is designed to prevent access to any dangerous parts until actuated by the movement of the workpiece, i.e. the guard is opened by the passage of the workpiece at the beginning of the operation and returned to the safe position on completion of the operation.

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

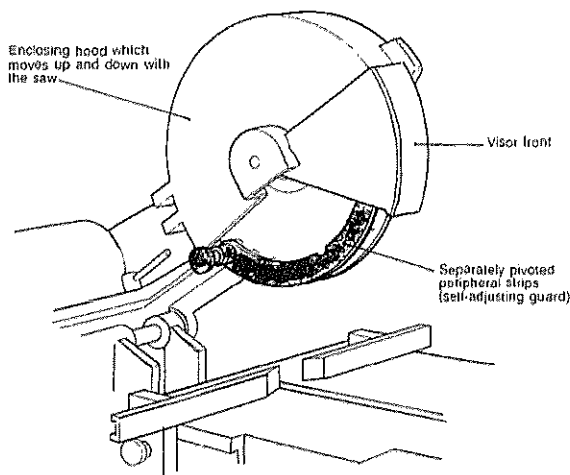


FIGURE 8.19 SELF-ADJUSTING GUARD ARRANGEMENT FOR SNIPPER CROSS-CUTTING SAWING MACHINERY

8.2.3 Interlocking guard

8.2.3.1 General An interlocking guard is a physical barrier which is interconnected with the power or control system of the machine. Interlocking guards provide an effective safeguard where access to the point of operation is required between each cycle of the machine or where regular access is needed. They are frequently used in combination with stationary guards to provide a total physical barrier safeguarding system.

An interlocking guard shall be so connected to the machine controls that—

- until the guard is closed the interlock prevents the machinery from operating; and
- either the guard remains locked closed until the risk of injury from the hazard has passed or opening the guard causes the hazard to be eliminated before access is possible.

The interlocking system may be either mechanical, electrical, hydraulic, pneumatic or any combination of these. The type and mode of operation of the interlock shall be considered in relation to the process to which it is applied (see Section 10). The interlocking system shall be designed to fail to safety and shall not be defeatable.

8.2.3.2 Moving interlocking guard A moving interlocking guard is a guard which has a movable part and whose movement is interconnected with the power or control system of the machine (see Section 10).

Interlocking rise and fall screens which are capable of inflicting injury in the event of their falling under gravity shall be provided with a suitable anti-fall device (see Figures 8.20 and 8.21). Some interlocking guards may be power driven and adequate steps shall be taken to avoid injury due to the movement of the guard. (See Figure 8.22.)

A moving interlocking guard for preventing access to an in-running nip is shown in Figure 8.23.

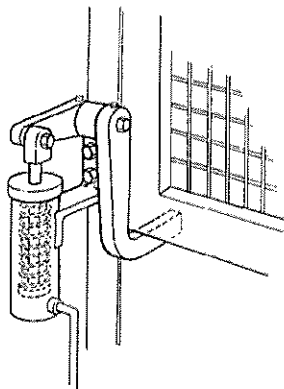
A moving interlocking guard may be used to initiate the operation of machinery without the use of an additional start control. The machinery controls shall be interlocked so that—

- (a) until the guard is closed the machinery cannot operate;
- (b) final closure of the guard initiates operation of the machinery; and
- (c) the guard is locked or held closed during dangerous motion.

After initiating a machinery cycle by closing the guard, the guard may be held closed mechanically until the dangerous motion has stopped. Alternatively, the operator commonly holds the guard closed until the operation is complete and then allows it to open by the action of a return spring or counterbalance. If the guard is lifted during the closing motion of the machine, the machine shall stop.

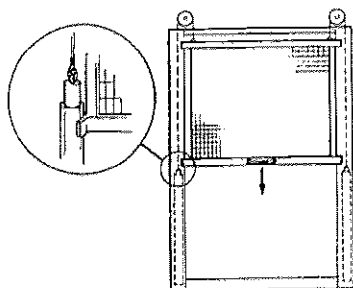
This application is particularly suitable for machinery cycles of short duration where dangerous motion can be rapidly stopped such as a small mechanical, pneumatic or hydraulic press (see Figure 8.24). However, because failure of an interlocking valve fitted in the positive mode may lead to an unintended stroke, the interlocking valve should be fitted in the negative mode. To make deliberate defeat of the interlocking valve more difficult, it should be located so that it is only accessible after removing a fixed cover. A locking bolt should also be fitted such that the downstroke is initiated by the movement of the bolt and the bolt should be prevented from moving by the guard when in any position other than closed.

A presence sensing system may be used as a control guard. (See also Clauses 9.2.3 and 9.2.4.)



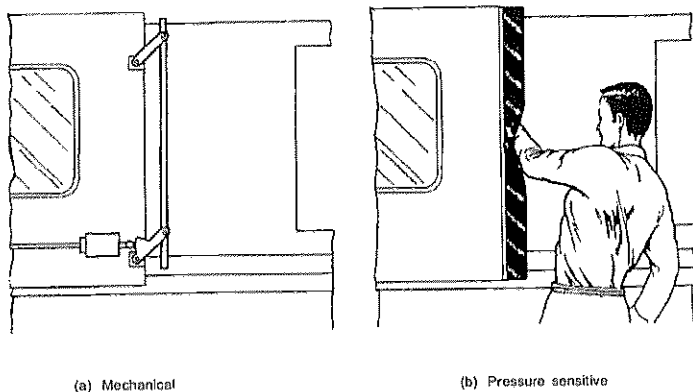
The hook is actuated by a single-acting, spring return air cylinder, air pressure being used to disengage the hook, and the return spring to engage it.

FIGURE 8.20 SAFETY HOOK TO PROTECT AGAINST GRAVITY FALL OF AN AIR-OPERATED GUARD WHICH HAS NO BALANCE WEIGHT



NOTE: Balance weight is enclosed to prevent obstruction.

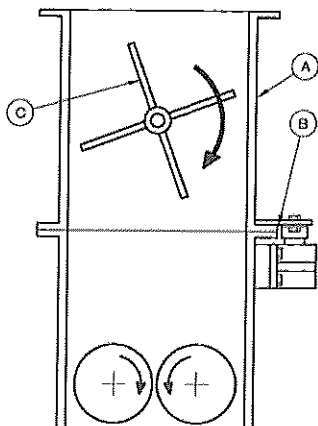
FIGURE 8.21 BALANCE WEIGHTS TO REDUCE THE EFFORT REQUIRED TO OPEN A RISE AND FALL GUARD



(a) Mechanical

(b) Pressure sensitive

FIGURE 8.22 POWER-OPERATED GUARDS AND DOORS



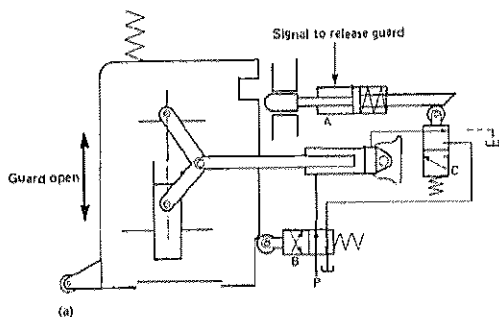
NOTE: The hopper extension (A) is provided with a magnetic switch (B) which automatically cuts off power to the rolls if the extension is removed. Supported within the extension is a rotary gate (C). Material loaded into the hopper extension falls onto the gate causing it to rotate and discharge the material into the nip below.

FIGURE 8.23 HOPPER EXTENSION

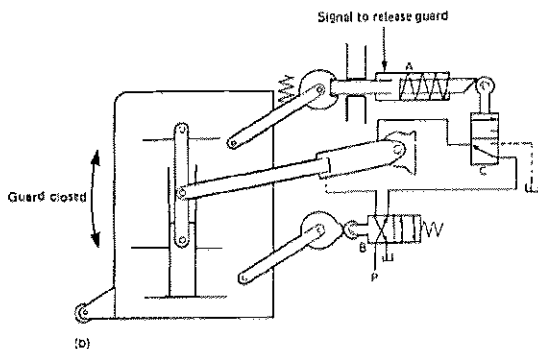
8.2.3.3 Interlocking distance guard An interlocking distance guard is an interlocking guard which does not completely enclose a hazard but which prevents access by virtue of its physical dimensions and its distance from the hazards, e.g. an interlocking access gate or a removable section in a perimeter-fence type guard. (See Figures 8.13 and 8.14.)

An interlocking distance guard often takes the form of a barrier located at a safe distance from the nearest trapping point. Initial movement of the barrier actuates the stopping mechanism of the machine. The means employed can be mechanical, electrical, hydraulic or pneumatic. A control operated by the machine prevents further barrier movement while the barrier is still far enough from the danger area to give protection until the machine has stopped. The control then releases the barrier so that this can move further to provide the required access.

An interlocking device may also be used with a stationary guard, particularly a fixed guard to provide an additional measure of safety.



NOTE: This shows a vertical sliding guard in an open position. Spring-applied bolt A is prevented from moving by the guard and the press ram cylinder is prevented from operating by the negatively operated interlock valve B and the positively operated valve C.



NOTE: This shows the more common type of control guard arrangement in the closed position. Bolt A is engaged preventing the guard from being opened and enabling valve C. Valve B is actuated by the guard allowing the press to downstroke. When the operation is completed, a delay valve or pressure switch can be used to signal the bolt to withdraw thus allowing the guard to spring open.

FIGURE 8.24 CONTROL GUARD FOR A PNEUMATIC OR HYDRAULIC PRESS

8.3 GUARD CONSTRUCTION

8.3.1 General Any guard selected shall not itself present a hazard such as trapping or shear points, rough or sharp edges likely to cause injury.

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

8.3.2 Design requirements Guards shall be made of solid material, mesh or equivalent construction and shall maintain the required minimum safe distance from the danger point or area under deflection.

When a force of 450 N is applied to a square area measuring 50 mm on each side, the guard shall not deflect by a distance greater than 12 mm.

Where a guard is positioned so that a person may climb or rest upon it, the guard shall be capable of sustaining a mass of not less than 75 kg placed in any position upon it, together with a simultaneous force of 220 N applied horizontally at any position. The guard shall maintain the required safe distance from the danger point or area under deflection and shall not deflect by a distance greater than 12 mm.

8.3.3 Material

8.3.3.1 General In many cases, the guard may fulfil a combination of functions, such as prevention of access and containment of hazards. This may apply where the hazards include ejected particles, liquids, dust, fumes, radiation and noise and one or more of these considerations may govern the selection of guard materials. In selecting the material to be used for the construction of a guard, consideration should be given to the guard's—

- (a) ability to withstand the force of ejection of part of the machinery or material being processed, where this is a foreseeable danger;
- (b) ability to provide protection against hazards identified;
- (c) weight and size in relation to the need for removal and replacement for routine maintenance;
- (d) compatibility with the material being processed. This is particularly important in the processing industry where the guard material should not constitute a source of contamination of the product, e.g. food and pharmaceutical industries;
- (e) ability to maintain its physical and mechanical properties after coming into contact with potential contaminants such as cutting fluids used in machining operation or cleaning and sterilizing agents; and
- (f) potential to trap atmospheric contaminants and other materials within the guarded area so that the area within the guard can become a confined space.

8.3.3.2 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 resonate.

8.3.3.3 Metal rod Guards of metal rod are often used in applications where 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 guard. Vertical orientation of rods provides for more effective viewing.

Orientation of the rods parallel with the direction of movement may be advantageous.

8.3.3.4 Perforated and mesh material Guards may 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 which are unlikely to cause overheating. They are unlikely to be suitable where hygiene (see Clause 11.3) or the ejection of material are considerations. The perforation of the mesh or the distance to the danger point should be such that fingers cannot reach the danger point (see Clause 8.4.2).

8.3.3.5 Glass Where an operation is required to be observed and the material is likely to be exposed to high temperatures or abrasive action (see Clause 8.3.3.6(c)), laminated, reinforced or toughened glass may be suitable for guard use.

8.3.3.6 Plastics Transparent plastics sheet material 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, PVC, cellulose acetate and acrylic sheet.

The mechanical properties of most plastics may be adversely affected by contamination such as may 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. 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 polyvinyl chloride (PVC) are the strongest followed by rigid PVC, cellulose acetate and acrylic sheet, in descending order. However, polycarbonate is more notch sensitive than some acrylics and its impact strength may be impaired by contamination with some chemicals which would not affect other plastic materials. Therefore, it may be necessary to increase the thickness of the chosen material in order to achieve an acceptable impact strength.
- (b) Guards can be made from plastic 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 panels ejecting under stress.
- (c) Continuous exposure to high temperature will cause softening and consequently lowering of impact strength.
- (d) Plastics are likely to suffer reduction of their transparency with use due to scratching, although remedial action using polishing compounds may 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.

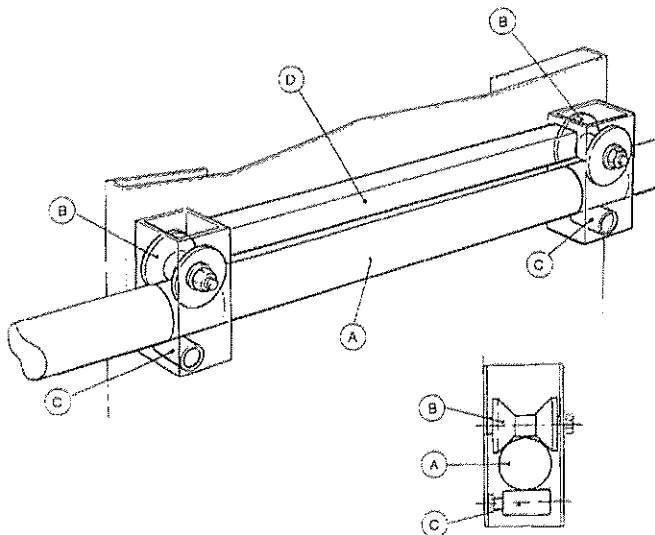
- (e) Most plastics have an ability to hold an electrostatic charge. This can create a risk of electrostatic ignition of flammable materials and can also attract dust. This characteristic can be mitigated by the use of an antistatic preparation.

8.3.3.7 Other materials Timber may sometimes be a suitable material for guard construction and is frequently employed in the woodworking industry to good effect. Where flexibility is required, chain mail, leather, rubber or flexible plastics can be used.

8.3.4 Supports Guards may be fastened to independent supports or to the machinery itself. The number of 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 and similar, provided this clearance does not allow access to the dangerous parts by the body or other items used for cleaning (see paragraph A3.3).

Many incidents have been caused by guard misalignment through wear or failure of supports and tracks resulting in interlocking devices not operating as designed. Roller track systems are superior to surface to surface guiding systems as they generally offer more accurate alignment, reduced frequency of lubrication and lower operating forces. The latter point is of particular significance in manually operated guards. Figure 8.25 shows a typical method of supporting and guiding a horizontal moving guard.



NOTE: The 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 the rollers (B) in contact with the track (A) and the roller housings are connected by an angle section (D).

FIGURE 8.25 SUPPORT FOR A HORIZONTAL MOVING GUARD

8.3.5 Cover plates Removable panels or cover plates may be incorporated into guards to provide easy access or improve visibility. These shall be treated as part of the guarding system and may be considered as either fixed or interlocking guards depending upon the process requirement.

8.4 ANTHROPOMETRIC CONSIDERATIONS

8.4.1 General Guards should be designed and constructed with the object of preventing any part of the body from reaching a danger point or area. They should take account of the physical characteristics of the people involved and in particular, their abilities to reach through openings and over or around barriers or guards (see Section 3).

8.4.2 Opening 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 danger point. This may be achieved by positioning the guard at the required distance or by providing a tunnel which extends outwards from it (see Clause 8.2.1.2).

Where it is necessary for work to be fed through the guard, including the removal of a workpiece or waste, openings shall be sufficient only to allow the passage of material and not create a trap between the material and the guard or allow bodily access to the danger zone. Attention should be paid to the size of any opening when the workpiece or waste container is not in place. The safety distance to any such opening can be found in Appendix A. 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. Such a test should be carried out using both large and small people.

The relationship between the size of the guard opening and the distance of the opening from the danger point is illustrated in Appendix A (see also Figure 8.26). Access through a guard opening can often be prevented by the use of a false table (see Clause 8.2.1.2).

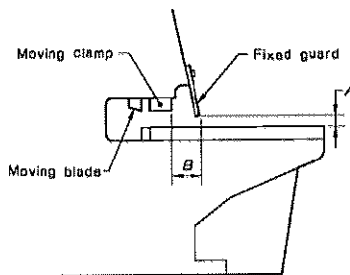


FIGURE 8.26 OPENING IN A FIXED GUARD AT A METAL-CUTTING GUILLOTINE

8.4.3 Barriers Barriers rely on a combination of height and distance to achieve their purpose. A guide figure of 1.8 m high is suggested for perimeter fencing. For specific applications, see Appendix A. The addition of a trip edge to a fixed or interlocking guard (see Clause 9.2.2) increases the protection.

SECTION 9 SAFETY DEVICES

9.1 GENERAL Unlike physical barriers, safety devices are designed to—

- (a) sense the presence of a person or a body part and initiate the stopping of any dangerous motion before access to the dangerous motion or before access to the danger area can be achieved; or
- (b) ensure that a person or body part cannot gain access to a danger area because of the design, placement or junction of machine controls.

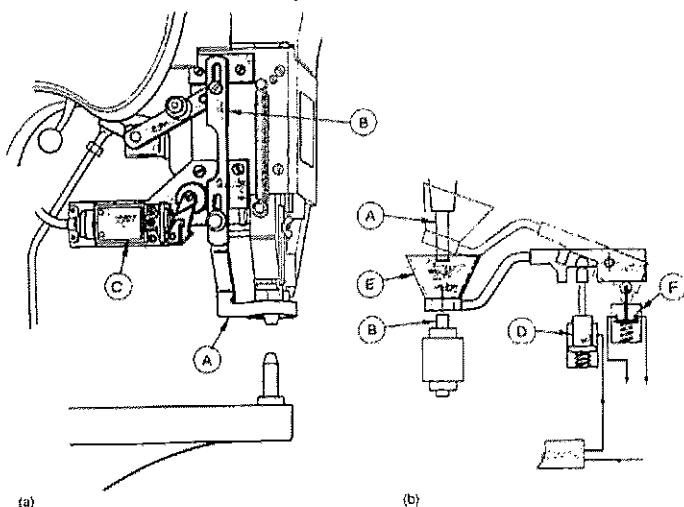
9.2 TRIP DEVICES

9.2.1 General A trip device is a device that causes working machinery to stop or assume a safe condition and prevents injury when a person approaches beyond a safe limit. The device shall keep the machine in a safe condition while the person remains within the danger area unless other means of assuring safety are provided.

Trip devices shall be designed to ensure that an approach to a dangerous part beyond a safe limit causes the device to operate and all dangerous parts to stop before injury can be inflicted. The sensitive trip bar fitted to radial drilling machines (see Figure 9.2) 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 should be controlled within fine limits. A brake may be necessary.

Trip devices shall be designed so that after operation they may be reset either automatically or manually; restarting may be automatic where it is safe to do so, or may be by means of the normal start button. An electrical or electronic trip device should be so designed that its effective operation will not be impaired by any function of the machinery or by extraneous influences.

9.2.2 Mechanical trip device The essential element of a mechanical trip device is a barrier or part of a barrier, e.g. trip edge, which is moved by part of the body as a danger area is approached. This movement of the device operates controls which may be electrical, mechanical, hydraulic or pneumatic. (See Figures 9.1 to 9.6.)



NOTE: 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 in (a) 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. Should the sensing guard be obstructed by a finger, or otherwise fail to reach the pre-set position, the machine will not operate. In some sensing guards electrical control is replaced by either a mechanical linkage or a pneumatic system.

In (b), A shows 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 pre-set 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 9.1 SENSING GUARD FITTED TO A RIVETING MACHINE

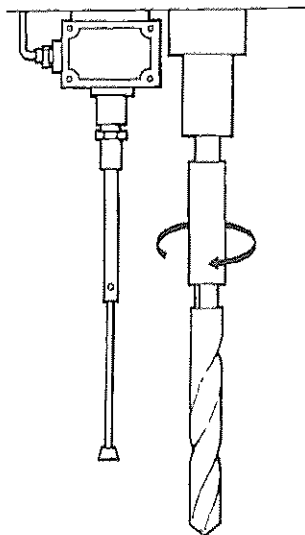


FIGURE 9.2 TRIP DEVICE FOR DRILLING MACHINES

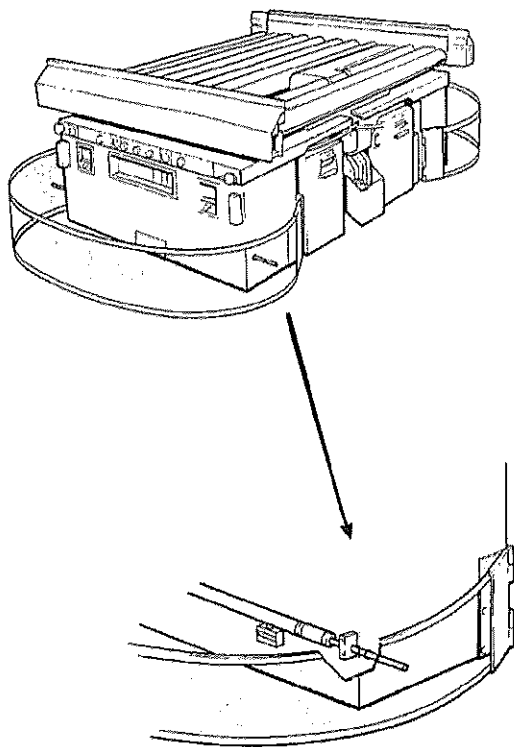
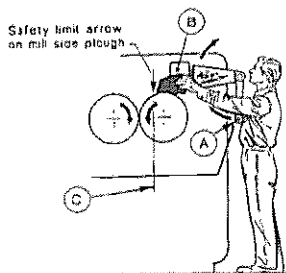
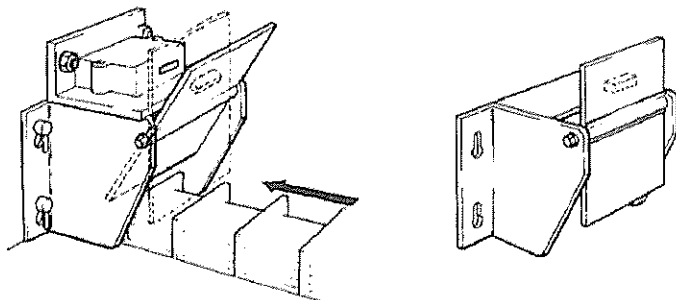


FIGURE 9.3 TRIP DEVICE FITTED TO AN AUTOMATED GUIDED VEHICLE



NOTE: 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 beyond the safety limit (C), which should be marked by an arrow on the mill side plough. The position of the arrow is set taking account of the efficiency of the brake and making allowance for brake wear. After the trip bar (A) has been tripped, the brake should arrest the motion of the rolls before a hand can be drawn into the nip.

FIGURE 9.4 SAFETY TRIP BAR FOR HORIZONTAL TWO-ROLL MILLS USED IN THE RUBBER INDUSTRY



NOTE: Injury is prevented by the operator's hand deflecting the trip guard thus 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. Clearance between the bottom of the guard and the partitions on the conveyor should be kept as small as practicable to prevent operators from reaching through the guard without tripping it.

FIGURE 9.5 TRIP DEVICE WHICH PROTECTS AGAINST THE HAZARDS ASSOCIATED WITH GOODS ON A CONVEYOR PASSING INTO WRAPPING MACHINERY

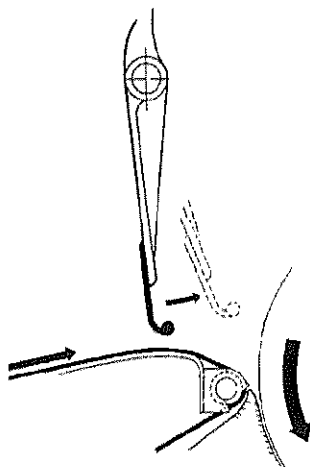


FIGURE 9.6 TRIP DEVICE ON A FLAT WORK IRONING MACHINE (CALENDER) USED IN LAUNDRIES

9.2.3 Electro-sensitive safety systems

9.2.3.1 General Electro-sensitive safety systems are sometimes referred to as intangible barriers and operate either as trip devices on the principle of detecting the approach of persons or objects to dangerous parts, or presence sensing devices where, so long as a person or object is detected, the dangerous parts cannot be set in motion.

The effectiveness of the complete installation will depend not only on the electrical integrity of the electro-sensitive safety system, but also on the electrical and mechanical integrity of the remaining installation, and the location of the electro-sensitive safety system relative to the dangerous parts. Where a high level of integrity is required, the electro-sensitive safety system may have to monitor certain machine functions such as the stopping performance and the performance of the devices controlling the dangerous motions.

9.2.3.2 Photoelectric safety systems (see Figure 9.7) Photoelectric safety systems operate on the principle of the detection of an obstruction in the path taken by a beam or beams of light. The intangible barrier operated by this system may consist of a single beam, a number of beams of light, a curtain of light or any combination of these as necessary to provide the required safeguard.

The curtain of light may be created by a scanning beam or beams, or a number of fixed beams. The light may be visible or invisible, e.g. infrared, and may be continuous or modulated.

9.2.4 Pressure-sensitive systems A pressure-sensitive system contains sensors which operate when a person or object applies pressure to the device. By their nature, pressure-sensitive devices are exposed to potential damage which can result in failure. Where there are electrical connections between the device and the control box, the circuit shall operate at extra-low voltage.

The dimensions of the device shall take account of a person's speed of approach, length of stride, and the overall response time of the safety system. Care shall be taken to ensure that access cannot be gained without actuating the device. Pressure-sensitive devices shall be sensitive over the whole sensing area. Where a number of devices are used together, this shall include the junction between adjoining devices.

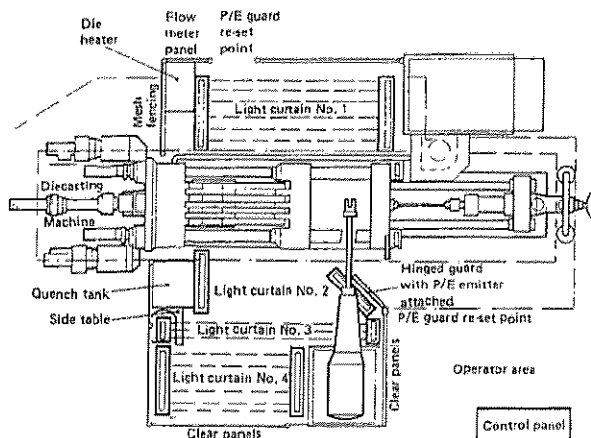


FIGURE 9.7 PHOTOELECTRIC SAFETY SYSTEM AROUND ROBOT SERVED PRESSURE DIE-CASTING MACHINE

9.3 CONTROL DEVICE

9.3.1 General A control device is a safety device which prevents injury by influencing the machine function, minimizing or preventing inadvertent operation or by positioning the controls relative to the danger area.

9.3.2 Controlled movement Controlled movement devices prevent injury to a person by—

- designing the control to minimize inadvertent initiation, e.g. shrouded foot pedals or buttons;
- designing the control so that machine movement is sustained only while the control is held, e.g. a hold-to-run control;

- (c) designing the control so that the function of the machine is controlled, e.g. limited velocity, limited distance or limited force;
- (d) designing the control so that machinery can be rapidly brought to a stop, e.g. an emergency stop; and
- (e) placement of the controls so that the distance from the control to the danger area is such that movement has ceased before access can be achieved.

9.3.3 Two-hand control device

9.3.3.1 General Where guarding is impracticable, two-hand control devices offer a means of protecting the hands of the machine operator (see also Clause 7.3(f)). It may also be used as a hold-to-run control (see Clause 6.3.4.2). Additional guarding such as side and rear guarding should be provided. Except where a physical barrier provides protection, the machine operator's position shall not be adjacent to a passageway.

Where the operator's body does not block access to the front of the machine, consideration to providing return wings or totally enclosing the machine should be given.

A two-hand control device (see Figure 9.8) is a device which requires actuation by both hands in order to initiate and maintain any operation of the machinery while a hazardous condition exists, thus affording a measure of protection only for the person who actuates it and shall be designed in accordance with the following:

- (a) The hand controls shall 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 shall not be possible to set the dangerous parts in motion unless the controls are operated synchronously. Having set the dangerous parts in motion, it shall not be possible to do so again until both controls have been returned to their off position.
- (c) Movement of the dangerous parts shall be arrested immediately or, where appropriate, arrested and reversed if one or both controls are released while there is danger from the movement of these parts.
- (d) The hand controls should be positioned at such a distance from the danger point that on releasing the controls, it is not possible for the operator to reach the danger point before the motion of the dangerous parts has been arrested or where appropriate, arrested and reversed. (See Clause 3.3.3.)

The minimum distance from the nearest hand control to the danger zone shall be determined from the following equation:

$$S = (K \times T) + C$$

where

S = minimum distance from the hand control to the danger point, in millimetres.

K = hand approach velocity, in millimetres per second
= 1600

T = overall system stopping performance, in milliseconds

C = intrusion towards the danger zone prior to actuation of the protective equipment, in millimetres
= 250

If the risk of encroachment of the hands or part of the hands towards the danger zone is eliminated while the controls are being operated, e.g. by shrouding, then C may be reduced to zero, with a minimum allowable distance for S of 100 mm.

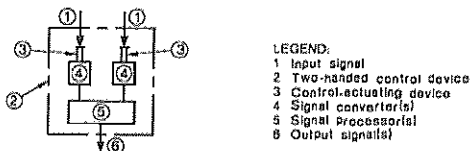


FIGURE 9.8 TWO-HANDED CONTROL DEVICE

Appendix D provides measurement tests for preventing the defeat of two-hand controls.

A two-hand control device will afford protection only to the person who actuates the device. Where several operators work together a two-hand control device for each operator shall be provided.

Where multiple devices are provided, it shall not be possible to initiate or maintain any operation of the machinery until all active devices are simultaneously actuated.

9.3.3.2 Prevention of accidental actuation and of defeat The control-actuating devices of a two-hand control device shall be designed and arranged in such a way that the protective effect of the two-hand control device cannot be easily defeated and that the probability of accidental actuation is minimized in accordance with the risk assessment for the particular application.

The use of one hand alone, possible combinations of one hand and other parts of the body or the use of simple aids which allow defeat shall be considered so that it shall not be possible to reach into the danger zone during a hazardous situation. Accidental actuation by the clothes of the operator shall be considered in the same way.

Clauses 9.3.3.3 to 9.3.3.8 describe some ways in which defeat is possible, together with some precautionary measures for prevention. The methods of defeat that shall be considered will depend upon the design of the two-hand control device, the operating conditions, the method of attachment and positioning of the two-hand control device and the specified safety distance requirements.

The precautionary measures listed may be required singularly or in combination to meet this Standard. The test procedures which shall be applied to the most common types of design are set out in Appendix D. For other designs of two-hand control devices these test procedures may or may not be applicable. In these cases, a hazard analysis and an assessment of risk of the possible use or misuse of the design of a device shall be carried out and appropriate measures shall be taken to comply with this Standard.

9.3.3.3 Prevention of defeat by using one hand Measures to prevent defeat by using one hand shall be provided. Examples of suitable measures are as follows:

- (a) Separation of the control-actuating device (inside dimension) by at least 260 mm.
- (b) By the provision of one or more shields or an elevated area between the control-actuating devices which are designed in such a way that the control-actuating devices are separated by a distance of at least 260 mm around the shields.

9.3.3.4 Prevention of defeat using hand and elbow of the same arm Measures to prevent defeat by using the hand and elbow of the same arm shall be provided. Examples of suitable measures are as follows:

- (a) Separation of the control-actuating devices by between 550 mm and 600 mm inside dimension.

- (b) By the provision of one or more shields or an elevated area between the control-actuating devices which are designed in such a way that the control-actuating devices cannot be touched by the elbow and the tips of the fingers of the same arm at the same time.
- (c) Designing covers in such a way that the control-actuating devices cannot be operated by the elbow.
- (d) Designing control-actuating devices with different types or directions of operation.

9.3.3.5 Prevention of defeat using the forearm or elbow Measures to prevent defeat by using the forearm or elbow shall be provided if the distance of the hands from the hazard as a result of using forearm or elbow is smaller than the required safety distance.

A suitable measure uses covers or collars which are designed so that the control-actuating devices cannot be operated by the forearm or the elbow.

9.3.3.6 Prevention of defeat using one hand and any other part of the body (e.g. knee, hip) Measures to prevent defeat by using other parts of the body in conjunction with one hand shall be provided. Examples of suitable measures are as follows:

- (a) Arrangement of the control-actuating devices on a horizontal or nearly horizontal surface which is at least 1100 mm above the floor or level of access. To prevent actuation by the hip.
- (b) In the case of attachment to a vertical or near vertical surface, by the provision of a protective collar around the control-actuating devices.
- (c) Designing covers and shields in such a way that the control-actuating devices cannot be operated by one hand and any other part of the body.

9.3.3.7 Prevention of defeat by blocking one control-actuating device Measures to prevent defeat by blocking one actuating device shall be provided.

This method of defeat causes a two-hand control device to become a one-hand control and may cause a permanent input signal from the blocked actuating device. This, consequently, may allow the output signal of the two-hand control device to be generated by using only one hand. Suitable measures to prevent this method of defeat are as follows:

- (a) To prevent reinitiation of the output signal for further operation by one hand, it shall be necessary to include the characteristic of reinitiation in the design of the two-hand control device; and
- (b) To prevent the first start by one hand, it shall be necessary to include the characteristic of synchronous operation in the design of the two-hand control device.

9.3.3.8 Accidental actuation The probability of accidental actuation of a two-hand control device shall be minimized.

The measures given in Clauses 9.3.3.3 to 9.3.3.7 will help to minimize accidental actuation. Other suitable measures to prevent accidental actuation are as follows:

- (a) For mechanical control-actuating devices the need for deliberate actuation with respect to the force and the travel required.
- (b) For non-mechanical control-actuating devices (e.g. photoelectric devices, capacitive devices) the need for sensitivity levels which will only allow deliberate actuation.

SECTION 10 INTERLOCKING CONSIDERATIONS

10.1 FUNCTIONS OF AN INTERLOCK An interlock provides the connection between a guard and the control or power medium of the machinery to which the guard is fitted. The interlock and the guard with which it operates shall be designed, installed and adjusted so that—

- (a) until the guard is closed the interlock prevents the machinery from operating by interrupting the power medium; and
- (b) either the guard remains locked closed until the risk of injury from the hazard has passed, or opening the guard causes the hazard to be eliminated before access is possible.

Interruption of the power medium itself may be sufficient to eliminate the hazard before access is possible. Where the hazard cannot be eliminated immediately by power interruption, the interlocking system shall include a guard locking or a machine braking system (or both).

Where whole-body access to a danger area can be gained through an interlocking door, a device which prevents inadvertent closing of the door should be provided. Closing the interlocking door shall not initiate machine start-up.

Care should be taken to ensure that actuation of an interlock installed to protect against one hazard, e.g. stopping a dangerous part of machinery, does not create a different hazard, e.g. the release of dangerous substances into the area surrounding the machinery.

10.2 INTERLOCKING MEDIA The four media most commonly encountered in interlocking are electrical, mechanical, hydraulic and pneumatic. Electrical interlocking, particularly in control systems, is the most common and electrical components are often incorporated in hydraulic and pneumatic circuitry, e.g. solenoid-operated valves. The principles of interlocking apply equally to all media. Each has advantages and disadvantages and the choice of interlocking medium will depend on the type of machinery and the method of actuation of its dangerous parts.

Some interlocking systems have more than one control channel, e.g. dual control systems. It is often advantageous to design these systems so that similar failures in both channels from the same cause (common cause failures) are minimized. One way of achieving this is by using a different control medium for each channel, e.g. one hydraulic and one electrical.

10.3 TYPES OF INTERLOCKING DEVICES Interlocking techniques involve a broad spectrum of technological aspects. As such, interlocking devices can be classified using a great variety of criteria, e.g. the nature of the link between guard and circuit-opening elements, or the technological type (electromechanical, pneumatic or electronic) of the circuit-opening elements.

Table 10.1 establishes the link between the main types of interlocking devices and the Clauses dealing with them.

Examples of a variety of interlocking devices are given in Appendix E.

TABLE 10.1
TECHNOLOGICAL FORMS OF INTERLOCKING DEVICES

Interlocking devices implementing:	Provision in clauses
<ul style="list-style-type: none"> • mechanically actuated detectors <ul style="list-style-type: none"> • Cam-operated detectors • Tongue-operated detectors • captive-key systems • trapped-key systems 	10.6 to 10.9; 10.12.2; 10.14 10.12.2.1 10.12.2.2 10.19.4.1 10.19.4.2
<ul style="list-style-type: none"> • plug and socket systems 	10.12.4
<ul style="list-style-type: none"> • Non-mechanically actuated detectors <ul style="list-style-type: none"> • magnetically actuated switches • electronic proximity switches 	10.12.3; 10.15 10.12.3; 10.15

10.4 INTERLOCKING PRINCIPLES

10.4.1 Control interlocking The stop command from the interlocking device is introduced into the control system so that interruption of the energy supply to the machine actuators, or mechanical disconnection of moving parts from the machine actuators, is triggered by the control system (indirect interruption).

10.4.2 Power interlocking The stop command from the interlocking device directly interrupts the energy supply to machine actuators or disconnects moving parts from the machine actuators. 'Directly' means that, unlike control interlocking (see Clause 10.4.1), the control system does not play any intermediate role in the interlocking function.

10.5 TYPICAL FORMS OF INTERLOCKING DEVICES

10.5.1 Interlocking device (without guard locking) It is always possible to open the guard. As soon as the guard is no longer fully closed, the interlocking device generates a stop command. As it is possible to start opening the guard during operation of the machine (or of the hazardous machine elements), the function is that of an interlocking device.

10.5.2 Interlocking device with guard locking The guard is held closed by a guard-locking device. There are two types of devices, as follows:

- (a) Devices where unlocking the guard can be initiated at any time by the operator (unconditional unlocking).
- (b) Devices where unlocking the guard is possible only if a condition is fulfilled, thus ensuring that the hazard has disappeared (conditional unlocking).

The guard-locking device can be an integral part of an interlocking device, or a separate unit. In a guard-locking device, the part which is intended to lock or unlock the guard can be any of the following:

- (i) Manually applied, power released.
- (ii) Spring applied, spring released (see Figure 10.2a).
- (iii) Power applied, spring released (see Figure 10.2b).
- (iv) Power applied, power released (see Figure 10.2c).

10.6 ACTUATION MODES OF MECHANICALLY ACTUATED POSITION DETECTORS When a single detector is used to generate a stop command, it shall be actuated in the positive mode (see Figure 10.1). Non-positive mode actuation is only allowed in conjunction with a detector with positive mode actuating, notably to avoid common cause failures (see Clause 10.9.2). A simple design of actuator is recommended, since this may reduce the probability of failure.

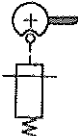
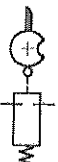

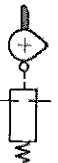
Mode of actuation	Guard closed	Guard open	Working mode
Positive mode			The detector stem (actuator) is held depressed by a cam as long as the guard is open.
Non-positive mode			The detector stem (actuator) is held depressed by a cam as long as the guard is closed. When the guard is opened, the detector changes its state as the result of the action of a return spring.

FIGURE 10.1 ACTUATION OF POSITION DETECTORS IN THE POSITIVE MODE AND IN THE NON-POSITIVE MODE

10.7 ARRANGEMENT AND FASTENING OF POSITION DETECTORS Position detectors shall be arranged so that they are sufficiently protected against a change of their position. In order to meet this requirement—

- the fasteners of the position detectors shall be reliable and require a tool;
- the use of slots shall be limited in initial adjustment;
- provisions shall be made for positive location after adjustment (e.g. by means of pins or dowels);
- replacement of the detectors shall be possible without any need for an adjustment.
- self-loosening or easy defeat of the detector and of its actuator shall be prevented;
- the support for position detectors shall be sufficiently rigid to maintain correct operation of the position detector;

- (g) the movement produced by mechanical actuation shall remain within the specified operating range of the position detector to ensure correct operation or prevent overtravel;
- (h) displacement of the guard before the position detector changes its state shall not be sufficient to impair the protective effect of the guard;
- (i) the position detectors shall not be used as mechanical stops;
- (j) the position detectors shall be located and, if necessary, protected so that damage from foreseeable external causes is avoided; and
- (k) access to position detectors for maintenance and checking or correct operation shall be ensured.

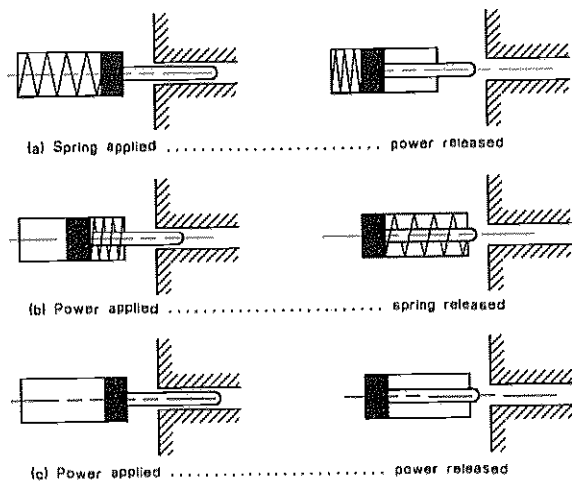


FIGURE 10.2 POWER ACTUATED LOCKING DEVICE OPERATING MODES

10.8 ARRANGEMENT AND FASTENING OF CAMS Rotary and linear cams for actuating mechanical position detectors shall be designed so that—

- (a) they are positively located, and fixed by fasteners requiring a tool;
- (b) their self-loosening is prevented;
- (c) they can only be mounted in a correct position; and
- (d) they do not damage the position detector or impair its durability.

NOTE: These provisions exclude friction assemblies.

10.9 REDUCING THE POSSIBILITY OF COMMON CAUSE FAILURES

10.9.1 General When switching elements have been made redundant, common cause failures shall be avoided, e.g. by use of the measures described in Clauses 10.9.2 and 10.9.3.

10.9.2 Positive and non-positive mode association of mechanically actuated position detectors Typical causes for failure of mechanically actuated position detectors are—

- (a) excessive wear of the actuator (e.g. plunger or roller) or of the cam attached to the guard: misalignment between cam and actuator; and
- (b) jamming of the actuator (plunger) making actuation by the spring impossible.

Detectors actuated in the positive mode, as D_1 , (see Figure 10.3) fail to danger in case (a), but not in case (b).

Detectors actuated in the non-positive mode, as D_2 , (see Figure 10.3) fail to danger in case (b) but not in case (a).

In the event of a failure of either D_1 or D_2 , breaking of the circuit is ensured by the other detector.

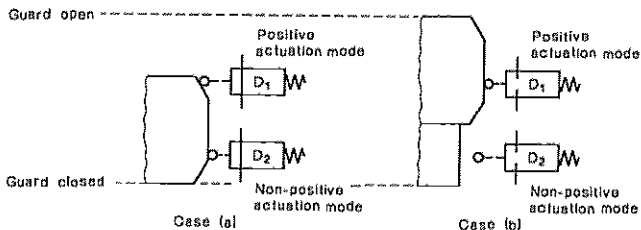


FIGURE 10.3 AVOIDING COMMON-CAUSE FAILURE OF TWO MECHANICALLY ACTUATED POSITION DETECTORS BY USING ASSOCIATED POSITIVE AND NON-POSITIVE MODE ACTUATION

10.9.3 Cross-monitoring of position detectors A higher level of system integrity is assured by cross-monitoring the two position detectors as shown in Figure 10.4. Cross-monitoring minimizes the risk associated with the failure of one detector when a pair of detectors are connected in positive and non-positive mode. (See Clause 10.9.2). The risk is that in the event of one detector failing, the failure is not immediately apparent to the operator and safety will depend on the correct functioning of the remaining detector.

10.9.4 Power medium diversity In order to minimize the possibility of common-cause failure, two independent interlocking devices, each of which interrupts the flow of a different power medium, may be associated with a guard.

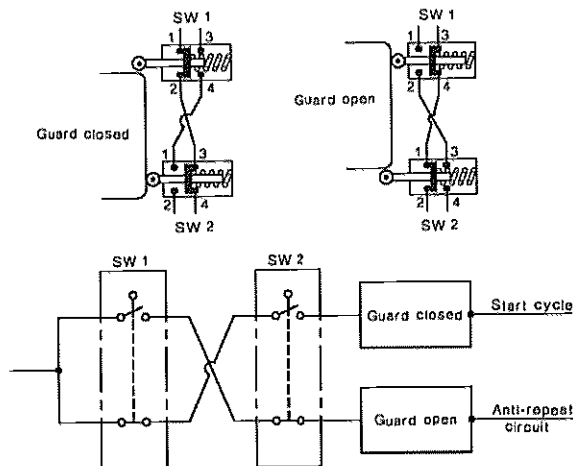


FIGURE 10.4 CROSS-MONITORING OF POSITION DETECTORS

10.10 GUARD LOCKING DEVICE The guard lock shall operate by the engagement of two rigid parts (positive location).

The guard lock shall be 'spring applied, power released'. Other systems may be used if, in a specific application, they provide an equivalent level of safety.

For 'spring applied, power released' guard locks, a manual unlocking device requiring operation by a tool shall be provided.

The position of the guard lock shall be monitored (e.g. by a detector actuated in the positive mode), such that the machine cannot be started until the guard lock is in the fully engaged position.

The guard lock shall be able to withstand the forces which are to be expected during normal operation of the guard. The force which the guard lock is able to withstand without damage affecting further use shall be indicated either on the guard locking device itself or in the manufacturer's instructions supplied with the device.

NOTE: Guard locking devices can be used to prevent an enclosure around an automatic unit being opened before the machine/process has reached a definite state, thus preventing loss of information or material damage.

10.11 DELAY DEVICES When a delay device, e.g. a timer, is used, a failure in this device shall not decrease the delay.

10.12 DESIGN TO MINIMIZE DEFEAT POSSIBILITIES

10.12.1 General Interlocking devices shall be designed and instructions for their installation and maintenance shall be given so that they cannot be defeated in a simple manner, i.e. achieved manually or with a readily available object. Readily available objects may be—

- (a) screws, needles, sheet-metal pieces; or
- (b) objects in daily use such as keys, coins or tools required during the intended use of the machine and similar.

Provisions by which defeat may be made more difficult include—

- (i) provisions expressed in Clause 10.7;
- (ii) the use of interlocking devices or systems which are coded, e.g. mechanically, electrically, magnetically or optically; and
- (iii) physical obstruction or shielding of the interlocking device while the guard is open.

Where interlocking systems rely on special actuators or keys (coded or not), advice should be given in the instructions for use concerning risks associated with the availability of spare actuators or keys and master keys.

10.12.2 Design to minimize defeat of mechanical actuated position detectors

10.12.2.1 Cam-operated position detectors When a single detector is used, it shall be actuated in the positive mode (see Clause 10.6) since, among other characteristics, this mode of actuation prevents the detector from being defeated in a simple manner.

NOTE: A higher level of protection against defeat can be achieved, e.g. by enclosing the cam and detector.

10.12.2.2 Tongue-operated switches As the integrity of the switch relies heavily upon the design of the tongue and the mechanism, the switch shall incorporate a system or systems to render it difficult to defeat by simple tools such as pliers, screwdrivers, wire or similar.

A higher level of protection against defeat can be achieved by either using covered mounting to prevent introduction of spare actuators (see Figure 10.5), or by permanent assembly (e.g. by welding, riveting, 'one-way' screws) of the tongue with the guard to render dismantling more difficult.

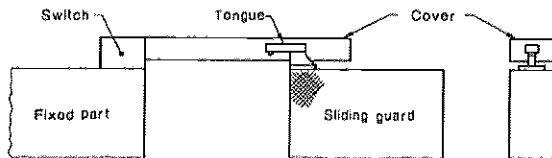
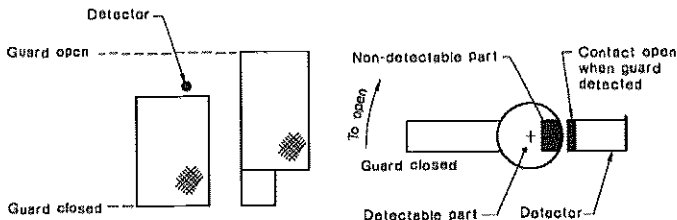


FIGURE 10.5 EXAMPLE OF PROTECTION AGAINST DEFEATING A TONGUE-OPERATED SWITCH

10.12.3 Design to minimize defeat of proximity and magnetic switches Proximity switches which rely solely on the presence or absence of detectable material or of a magnet for their actuation can easily be defeated. Therefore, their method of mounting shall give protection against defeat.

Where there is a risk of a substitute actuator being used to defeat the system, an obstruction should be incorporated into the mechanical arrangement to prevent the substitute actuator being aligned with the sensing head (see Figure 10.6).



NOTE: Defeating the detector is made difficult by the presence of the guard in front of it.

FIGURE 10.6 EXAMPLES OF PROTECTION AGAINST DEFEAT OF A PROXIMITY SWITCH OR MAGNETIC SWITCH

10.12.4 Design to minimize the possibility of defeating plug and socket interlocking devices Protection against defeat can be achieved by—

- locating the socket such that access to it is prevented when the guard is open;
- using a multi-pin plug and socket system the wiring of which being hidden, makes it difficult to re-establish the continuity of the circuit; or
- using a plug and a socket system specifically designed for every particular application.

10.13 ENVIRONMENTAL CONSIDERATIONS The selection of an interlocking device or its components shall take into consideration the environment (e.g. temperature) in which it is intended to be used.

10.14 INTERLOCKING DEVICES INCORPORATING MECHANICALLY ACTUATED POSITION SWITCHES

10.14.1 Interlocking devices incorporating one single mechanically actuated position switch The position switch shall be actuated in the positive mode and the break contact of the position switch shall be of the 'positive opening operation' type.

10.14.2 Interlocking devices incorporating two mechanically actuated position switches The position detectors should operate in opposite modes, that is one with a normally closed contact (break contact), actuated by the guard in the positive mode and the other with a normally open contact (make contact), actuated by the guard in the non-positive mode.

NOTE: This is a common practice. It does not exclude, when justified, the use of two switches actuated in the positive mode.

10.15 INTERLOCKING DEVICES INCORPORATING NON-MECHANICALLY ACTUATED POSITION SWITCHES (PROXIMITY SWITCHES AND MAGNETIC SWITCHES)

10.15.1 General An interlocking device incorporating non-mechanically actuated position switches can be used, as shown in Figure 10.6 and in Appendix E, to overcome problems arising from the use of mechanically operated switches when a guard can be removed completely from a machine or when the environmental conditions require a sealed switch (or sealed switches).

10.15.2 Equivalence with mechanically actuated position switches When non-mechanically actuated position switches are used, the level of safety achieved shall not be less than that obtainable with mechanically actuated position switches.

Equivalent safety may be achieved for instance by minimizing the possibility of defeat or by using the techniques such as duplication and automatic monitoring, as well as diversity of design or technology to avoid common-cause failure.

10.15.3 Immunity from disturbance Proximity switches and magnetic switches for interlocking applications shall be selected and used so that foreseeable external fields do not impair their function.

10.15.4 Mutual influencing Proximity switches shall be mounted so that malfunction caused by mutual influences is prevented.

10.15.5 Electrical operating conditions When proximity and magnetic switches are used in interlocking devices, necessary precautions shall be taken to prevent malfunction caused by voltage fluctuations and transient overvoltage.

10.15.6 Specific provision for magnetic switches Magnetic switches used without additional measures, such as overcurrent protection or redundancy and automatic monitoring, are generally not suitable for interlocking duties principally because they can fail to danger. Malfunction by vibration shall be prevented.

10.16 SELECTION OF INTERLOCKING DEVICES

10.16.1 General In selecting an interlocking device for a machine, it is necessary to consider all phases of the interlocking device life cycle and at least the following criteria:

- (a) The conditions of use and the intended use of the machine (see Clause 10.16.2).
- (b) The hazards present at the machine (see Clause 10.16.3).
- (c) Severity of the possible injury (see Clause 10.16.3).
- (d) Probability of failure of the interlocking device (see Clause 10.16.3).
- (e) Stopping time and access time considerations (see Clause 10.16.4).
- (f) Frequency of access (see Clauses 10.16.5 and 10.16.3).
- (g) Duration of person exposure to the hazard(s) (see Clause 10.16.3).
- (h) Performance consideration (see Clause 10.16.6).

10.16.2 Conditions of use and intended use All types of interlocking device types shall be considered to ensure that the type of device selected is suitable for the conditions of use (e.g. environment or hygiene) and the intended use of the machine.

10.16.3 Risk assessment In order to select the most appropriate interlocking device for a specific machine in specific conditions of use, the designer must carry out the risk assessment process, taking into account different types of interlocking devices until adequate safety is achieved. The probable effects of a failure to danger in a single channel for various types of control system interlocking are given in Table 10.2.

The risk to be assessed is that risk which would occur if the safety function of the interlocking device was not performed.

TABLE 10.2
PROBABLE EFFECT OF A FAILURE TO DANGER

Interlock category number	Type of system	Probable effect of a failure to danger in a single channel	Routine maintenance required to maintain reliability and prevent common cause failure	Action (in addition to routine maintenance) needed to maintain integrity
1	Single-control system interlocking without indication of failure	Machinery will continue to operate normally. Guarding system is ineffective	To be carried out in accordance with manufacturer's recommendations and AS 2671 or AS 2788 as appropriate	Check functioning of guarding system frequently to ensure its effectiveness and detect incipient failure. If fault detected, take machinery out of service and take necessary remedial action
2	Single-control system interlocking provided with indication of failure	Machinery will continue to operate normally. Guarding system is ineffective	To be carried out in accordance with manufacturer's recommendations and AS 2671 or AS 2788 as appropriate	Note indication of failure. Take machinery out of service. Take necessary remedial action
3	Dual-control system interlocking without either cross-monitoring, or indication of failure	Machinery will continue to operate normally. Guarding system remains effective only on one channel	To be carried out in accordance with manufacturer's recommendations and AS 2671 or AS 2788 as appropriate	Check functioning of each element of guarding system frequently. Take necessary remedial action
4	Dual-control system interlocking without cross-monitoring but provided with indication of failure	Machinery will continue to operate normally. Guarding system remains effective only on one channel	To be carried out in accordance with manufacturer's recommendations and AS 2671 or AS 2788 as appropriate	Note indication of failure. Take necessary remedial action
5	Dual-control system interlocking with cross-monitoring. Monitoring function not self-checked	(a) <i>Failure in interlocking circuit</i> Further operation of machinery prevented at or before end of cycle of operation in which failure occurred. Guarding system remains effective	To be carried out in accordance with manufacturer's recommendations and AS 2671 or AS 2788 as appropriate	None
		(b) <i>Failure in monitoring circuit</i> Guarding system remains effective but monitoring is ineffective. Subsequent failure of guarding system will be undetected	To be carried out in accordance with manufacturer's recommendations and AS 2671 or AS 2788 as appropriate	Regular checks to ensure effectiveness of monitoring system
6	Dual-control system interlocking with cross-monitoring. Monitoring function self-checked	Further operation of machinery prevented at or before end of cycle of operation in which failure occurred Guarding system remains effective	To be carried out by trained personnel at intervals recommended by the manufacturer	None

10.16.4 Stopping time and access time An interlocking device with guard locking shall be used when the stopping time is greater than the time taken by a person to reach the danger zone (access time).

10.16.5 Frequency of access

10.16.5.1 Frequent access required For applications requiring frequent access, the interlocking device shall be chosen to provide the least possible hindrance to the operation of the guard.

NOTE: It is necessary that a clear distinction be made between—

- (a) the concept of frequent access required by the normal operation of the machine, e.g. once per cycle to feed raw products to the machine and remove finished products; and
- (b) the concept of occasional access, e.g. to carry out adjustment or maintenance interventions or for random corrective actions in danger zones.

Each of these concepts is associated with a large difference in the frequency of human intervention in the danger zone, e.g. for example one hundred times per hour in the case of one access per cycle, and several times per day in the case of occasional access for adjustment or maintenance during the course of an automatic production process.

10.16.5.2 Automatic monitoring used For applications using interlocking devices with automatic monitoring, the monitoring may depend on a change of state of the device at every access. In this situation, if there is only infrequent access these devices should be used with additional measures such as conditional guard unlocking (see Figure 10.2), as there is an increased possibility that an undetected fault can occur between checking cycles.

10.16.6 Performance consideration Control interlocking devices are a safety-related part of the control system of a machine. Therefore, it is essential that a control interlocking device is compatible with the machine control system to ensure that the required safety performance is achieved.

If power interlocking is used, the components shall have a suitable resistance to breakage, taking into account all foreseeable situations (e.g. overload).

10.17 DESIGN OF SAFETY RELATED PARTS OF CONTROL SYSTEMS

10.17.1 The safety related parts of control systems These shall be in accordance with the requirements of one or more of the five categories, (See Clause 10.17.2 and Table 10.3). The categories state the required behaviour of safety related parts of a control system in respect of its resistance to faults.

Category B is the basic category. When a fault occurs, the safety function may not be performed. In Category 1 improved resistance to faults is achieved predominantly by selection and application of components. In Categories 2, 3 and 4, improved performance in respect to a specified safety function is achieved predominantly by improving the structure of the safety related part of the control system. In Category 2 this is provided by periodically checking that the specified safety function is being performed. In Categories 3 and 4 this is provided by ensuring that the single fault will not lead to the loss of the safety function. Whenever practicable in Category 3, and in Category 4, such faults will be detected and resistance to their accumulation will be specified.

Direct comparisons of capability to resist faults between categories, can only be made if one parameter at a time is changed. Higher categories can only be interpreted as providing a greater resistance to faults in comparable circumstances, e.g. when using similar technology, components of comparable reliability, similar maintenance regimes and in comparable applications.

When considering the causes of failures in some components it is possible to exclude certain faults.

TABLE 10.3
CATEGORIES OF SAFETY RELATED PARTS OF CONTROL SYSTEMS

Category	Summary of requirements	System behaviour*	Main principle to achieve safety
B (see Clause 10.17.2.1)	Safety related parts of machine control systems or their protective equipment, as well as their components, shall be designed, constructed, selected, assembled and combined in accordance with relevant Standards so that they can withstand the expected influences.	When a fault occurs it can lead to the loss of the safety function.	By selection of components
1 (see Clause 10.17.2.2)	Requirements of B shall apply. Use well-tried safety components and safety principles.	As described for category B, but with higher safety related reliability of the safety function.	
2 (see Clause 10.17.2.3)	Requirements of B and the use of well-tried safety principles shall apply. Safety function(s) shall be checked at suitable intervals by the machine control system. NOTE: What is suitable depends on the application and type of machine.	The occurrence of a fault can lead to the loss of the safety function between the checking intervals. The loss of safety function is detected by the check.	
3 (see Clause 10.17.2.4)	Requirements of B and the use of well-tried safety principles shall apply. Control systems shall be designed, so that— (a) a single fault in the control does not lead to the loss of the safety function(s), and (b) whenever reasonably practicable the single fault is detected.	When the single fault occurs the safety function is always performed. Some but not all faults will be detected. Accumulation of undetected faults can lead to the loss of the safety function.	By structure
4 (see Clause 10.17.2.5)	Requirements of B and the use of well-tried safety principles shall apply. A control system shall be designed, so that— (a) a single fault in the control does not lead to a loss of safety function(s), and (b) the single fault is detected at or before the next demand upon the safety function. If this is not possible, then an accumulation of faults shall not lead to a loss of safety function.	When the faults occur the safety function is always performed. The faults will be detected in time to prevent the loss of the safety functions.	By structure

* The risk assessment will indicate whether the total or partial loss of the safety function(s) arising from faults is acceptable.

10.17.2 Category specification

10.17.2.1 Category B The safety related parts of control systems shall, as a minimum, be designed, constructed, selected, assembled and combined, using basic safety principles for the specific application so that they can withstand —

- (a) the expected operating stresses (e.g. the durability and reliability with respect to switching capacity and frequency);
- (b) the influence of the processed material; and
- (c) other relevant external influences (e.g. mechanical vibrations, external fields, power supply interruptions or disturbances).

10.17.2.2 Category I The requirements of Category B and of this Clause shall apply.

Safety related parts of control systems complying with Category I shall be designed and constructed using well-trying components and principles.

A well-trying component for a safety related application is a component which has been widely used in the past with successful results in similar applications, or made and verified using principles which demonstrate its suitability and reliability for safety related applications.

In some well-trying components certain assessed faults can also be excluded because the fault rate is known to be very low.

The decision to accept a particular component as a well-trying one can depend on the application.

Well-trying safety principles include—

- (a) the avoidance of certain faults (e.g. avoidance of short circuit by separation);
- (b) reducing the probability of faults (e.g. over-dimensioning or underrating of components);
- (c) orientating the mode of a fault (e.g. by ensuring an open circuit when it is vital to remove power in the event of a fault);
- (d) detecting faults very early (e.g. earth fault detection); and
- (e) restricting the consequences of a fault.

Newly developed components and principles may be considered as equivalent to 'well-trying' if they fulfil the above conditions.

NOTES:

- 1 On the level of single electronic components alone, it is not normally possible to realise Category I.
- 2 The probability of failure in Category I is lower than in Category B. Consequently the loss of the safety function is less likely.
- 3 When a fault occurs it can lead to the loss of the safety function.

10.17.2.3 Category 2 The requirement of Category B, the use of well-trying safety principles and the requirements in this Clause shall apply.

The safety function of safety related parts of the control systems complying with Category 2 shall be checked at suitable intervals by the machine control system. The check of the safety function(s) shall be performed at the machine start-up, prior to the initiation of any hazardous situation and periodically during operation if the risk assessment and the kind of operation shows that it is necessary.

The initiation of this check may be automatic or manual. Any check of the safety function shall either—

- (a) allow operation if no faults have been detected; or

- (b) generate an output which initiates appropriate control action if a fault is detected. Whenever possible this output shall initiate a safe state. When it is not possible to initiate a safe state (e.g. welding of contacts in the final switching device) the output shall provide a warning of the hazard.

The check itself shall not lead to a hazardous situation.

After the detection of a fault, a safe state shall be maintained until the fault is cleared.

The checking equipment may be integral with, or separate from, the safety related part(s) providing the safety function.

NOTES:

- 1 In some cases Category 2 is not applicable because the checking of the safety function can not be applied to all components, e.g. pressure switch or temperature sensor.
- 2 In general Category 2 can be realised with electronic techniques, e.g. in protective equipment and particular control systems.
- 3 This allows a fault to occur, which can lead to the loss of the safety function between the checking intervals, however the loss of safety functions is detected by the next check.

10.17.2.4 Category 3 The requirements of Category B, the use of well-tried safety principles and the requirements of this Clause shall apply.

Safety related parts of control systems complying with Category 3 shall be designed so that a single fault in any of these parts does not lead to the loss of the safety functions. Common mode failures shall be taken into account. Whenever reasonably practicable the single fault shall be detected at or before the next demand upon the safety function.

NOTES:

- 1 This requirement of single fault detection does not mean that all faults will be detected. Consequently, the accumulation of undetected faults can lead to an unintended output and a hazardous situation at the machine. Typical examples of practicable measures for fault detection are connected movement of relay contacts or monitoring of redundant electrical outputs.
- 2 This system behaviour allows that—
 - (a) when a single fault occurs the safety function is always performed;
 - (b) some but not all faults will be detected;
 - (c) accumulation of undetected faults can lead to the loss of the safety function.

10.17.2.5 Category 4 The requirements of Category B, the use of well-tried safety principles and the requirements of this Clause shall apply.

Safety related parts of control systems complying with Category 4 shall be designed so that—

- (a) a single fault in any of these safety related parts does not lead to a loss of the safety functions; and
- (b) the single fault is detected at or before the next demand upon the safety functions, e.g. immediately a machine operating cycle is switched on. If this detection is not possible, then an accumulation of faults shall not lead to a loss of safety functions.

If the detection of certain faults is not possible during the first inspection after the occurrence of the fault, the occurrence of further faults shall be assumed. In this situation the accumulation of faults shall not lead to the loss of the safety functions. Fault review may be stopped when the probability of occurrence of further faults is considered to be sufficiently low. In this case the number of faults in combination which need to be taken into consideration will depend upon the technology, structure and application, but shall be sufficient to meet the detection criteria.

This fault review may be limited to two faults in combination, when—

- (i) the fault rates of the components are low;
- (ii) the faults in combination are largely independent of each other; and
- (iii) the faults have to appear in a certain order to interrupt the safety function.

If further faults occur as a result of the first single fault the first and all consequent faults shall be considered as a single fault. Common mode failures shall be taken into account, e.g. by using diversity, or special testing procedures.

NOTES:

- 1 In practice, the number of faults which need to be considered will vary considerably, e.g. in the case of complex microprocessor circuits, a large number of faults can exist but in a electro-hydraulic circuit, the consideration of three (or even two) faults can be sufficient.
- 2 In the case of the complex circuit structures (e.g. microprocessors, complete redundancies) the review of faults is generally carried out at the structural level, i.e. based on assembly groups.
- 3 This allows that even under fault conditions the safety function is always performed and the faults will be detected in time to prevent the loss of the safety function.

10.17.3 Selection and combination of safety related parts of different categories

10.17.3.1 Selection of categories Fault behaviour categories shall be selected for all parts of the safety related control system which perform these safety functions to achieve the intended risk reduction. If different categories are selected for the safety related parts of the control system, these parts shall still maintain the intended system behaviour in case of fault(s). Guidance for the selection of categories is given in Appendix F, while Appendix G provides guidance on control system and interlock system selection.

The selection of a category for a particular safety related part of the control system depends mainly upon—

- (a) the reduction in risk to be achieved by the safety function to which the part contributes;
- (b) the probability of occurrence of a fault in that part;
- (c) the risk arising in the case of a fault in that part; and
- (d) the possibilities of avoiding a fault in that part.

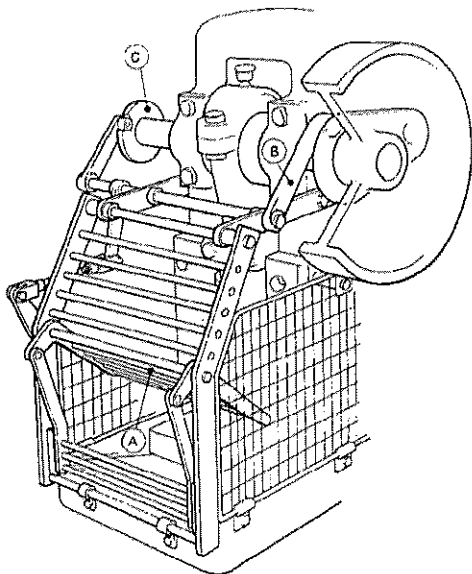
10.17.3.2 Combination of safety related parts One or more of the safety related parts may be used alone or in combination to achieve the required output signals. One safety function may be processed by one or more parts (alone or in combination). Also several safety functions may be processed by one part.

When subparts of different categories carry out a safety function, the resulting category can only be established by a new overall analysis of the fault behaviour of the system, taking into account the structure. This analysis can be simplified if the results of subparts' analysis are available.

10.18 MECHANICAL CONSIDERATIONS

10.18.1 Interlocking devices Mechanical devices for connecting guard movement with the machine power or control system can take various forms but will generally perform the same function. They will usually be 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 10.7 shows one such arrangement. A number of different ways of mechanically interlocking two components is shown in Figure 10.8.

In each of the methods illustrated, there are two components, each of which is responsible for a particular function. One of these is usually the movement of the guard; the other may be, e.g. 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.



NOTE: The guard consists of an enclosure with a movable gate (A), which prevents access of any part of the body to the danger area from any direction. The gate is interlocked by a 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 a guard control (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. A safe sequence of operation is thus ensured.

FIGURE 10.7 INTERLOCKING GUARD FOR POSITIVE CLUTCH POWER PRESS

10.18.2 Clutches and brakes

10.18.2.1 Clutches Clutches are mechanical engagement and disengagement devices and in mechanical interlocking systems are the devices which interrupt the transmission of mechanical power. The basic design recommendations are given in Clause 6.5.

10.18.2.2 Brakes Friction brakes operate by applying mechanical forces and may be actuated by linkages or by other control media. The basic design recommendations are given in Clause 6.6.2.

10.18.3 Overall system design Transmission of forces and movements in a mechanical interlocking system rely on the integrity of the individual components and their mechanical construction and assembly.

When assembling major components of a primary interlock on to shafts, these should be secured positively, e.g. welded, keyed or pinned.

Methods relying on friction alone should not be used.

Certain components are provided with adjustment to enable them to be correctly installed. These adjustable components should then be fixed to prevent improper setting thereafter.

Provision should be made for regular maintenance and lubrication where necessary.

10.18.4 Mechanical 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 systems design possibilities, e.g. additional clutches, brakes or linkages. An approximation to power interlocking methods may be achieved when the link between the guard and the power interruption devices is direct.

The basic elements of single-control system interlocking are—

- the actuating device operated by the guard;
- interposed mechanical linkages, if any; and
- the clutch or brake controlling the drive.

Reducing the number of interposed linkages reduces the probability of the system failing to danger.

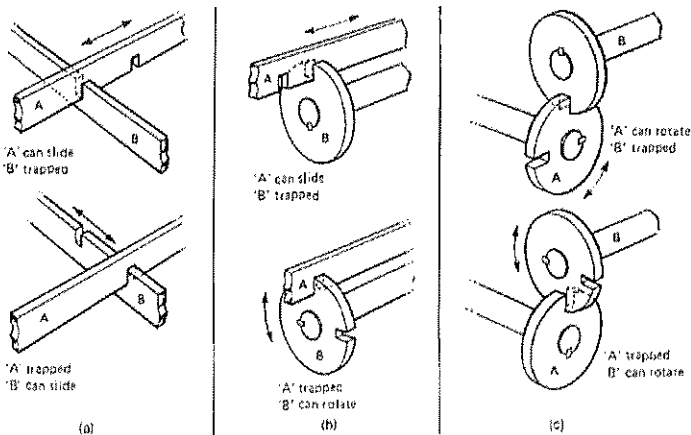


FIGURE 10.8 MECHANICAL INTERLOCKING

10.19 HYDRAULIC AND PNEUMATIC CONSIDERATIONS

10.19.1 General

10.19.1.1 Operating parameters When valves and other components are selected for machinery safeguarding applications, care shall be taken to ensure that their operating parameters will not be exceeded during use. The parameters to be considered include operating temperature range, operating pressure range and fluid properties.

10.19.1.2 Cam-operated valves A cam-operated valve can be actuated in either the positive or negative mode. When actuated positively, 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 by the action of the cam and the output is exhausted or returned to the tank for pneumatic or hydraulic systems respectively. When activated negatively, 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 with the valve cutting off the supply.

In single-control system interlocking methods, the valve should always be installed in the positive mode, except where two valves are used to improve the mechanical integrity to ensure that the valve flow paths are opened by the operating of the cam and to prevent the valve from being deliberately defeated. In addition, valves actuated in the positive mode should have sufficient pretravel and overtravel 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 overtravel 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, e.g. captive-key control or trapped-key control.

10.19.1.3 Shotbolt In addition to specially designed safeguarding devices with integral bolts, pneumatically or hydraulically operated bolts may be used in conjunction with conventional interlocking devices to retain guards in position while a machine is operated and during run down. Where shotbolts of this nature are used, they should be designed to minimize failure to danger, i.e. power retracted, spring extended.

The system integrity may be further improved 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. The guard can be designed so that in all positions other than closed the bolt movement is scotched.

10.19.1.4 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 friction or seizure. This is the basic reason why single-control system interlocking is unacceptable in situations requiring a very high integrity.

Signal-operated valves used in control systems should be selected on the basis of ensuring 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.

10.19.1.5 Interconnections All piping and hoses 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, further effectively protected and securely mounted.

Pipework fittings should be selected to ensure their integrity does not compromise the overall integrity of the interlocking system. This may involve the use of welded or flanged connections.

10.19.1.6 Single-control system interlocking (see Figure 10.9) The basic elements of single-control system interlocking are—

- the interlocking valve or position switch operated by the guard;
- interposed control valves, electromechanical relays or solid-state switching devices if any; and
- an hydraulic or pneumatic-operated solenoid-operated or solenoid-actuated hydraulic or pneumatic-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, hence interposing devices should be avoided, if possible.

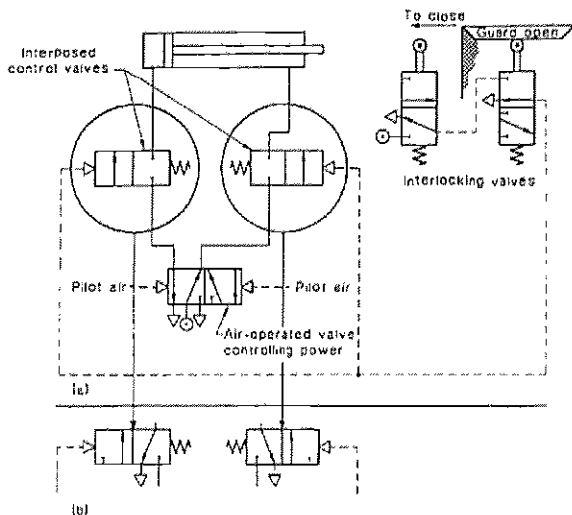
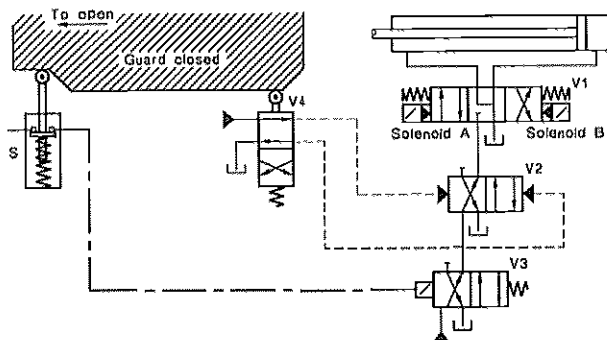


FIGURE 10.9 SINGLE CONTROL SYSTEM INTERLOCKING

10.19.1.7 Dual-control system interlocking (see Figure 10.10) The basic elements are similar to those employed in single-control system interlocking. To minimize the possibility of common cause failures, two channels are used and kept separate except for necessary interconnections for cross-monitoring (where provided) and connection to the supply.



NOTE: 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 V to be energized and hydraulic valve V pilots interlock valve B2 so that pump pressure is available at the machine control valve V.

In most cases the hydraulic interlock will be the most reliable because the solenoid provides a comparatively weak link in the electrical interlocking channel. However, there may be circumstances where it will be preferable to reverse the modes of the electrical interlocking switch and valve.

It would be noted that 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 will then self-centre, interrupting the hydraulic supply and thus carrying out the same function as valve V3.

This diagram illustrates the principles only and does not provide all the information needed to construct a working system.

FIGURE 10.10 DUAL-CONTROL SYSTEM INTERLOCKING WITHOUT CROSS-MONITORING

10.19.2 Hydraulic interlocking systems

10.19.2.1 General Where hydraulically operated equipment is used, two conditions which require particular attention are intensification and stored energy. Protection against intensification in any part of the system should be provided.

Energy may be stored in many parts of the system, including—

- energy transmitted from a supporting mass;
- energy stored in an accumulator;
- energy stored in an hydraulic cylinder under pressure; and
- energy stored in high volume pipework.

Any interlocking system should be designed to protect against the risk of injury from stored energy sources.

10.19.2.2 Hydraulic downstroking platens Where scotches are used to support the platen of a downstroking machine at the top of its stroke and the scotches are used in conjunction with interlocking guards, the scotches should remain in place until the guard is fully closed. The guards should then remain locked and closed until the dangerous motion has been completed and the scotches are in place. Additional information about protection against unintended gravity fall is given in Clause 6.15.2.

Controlled gravity descent is a frequently used design feature to facilitate rapid closure of the platen to the workpiece. Where controlled gravity descent is used, all of the fluid in the platen supporting cylinders should pass through the main control valve. Where it is not practicable to pass the oil through the main control valve, the oil may pass via an auxiliary valve provided that the operation of the auxiliary valve is totally dependent upon the supply of pilot oil from the main control valve.

10.19.2.3 Hydraulic upstroke platens Where upstroking platens are used, the platen has to be raised against the force of gravity. On large presses, large volumes of fluid have to be supplied to the press cylinders. Where the fluid is fed directly to the cylinder, e.g. by non-return valves, the platen may make an unintentional stroke because of back pressure in the system. All the fluid capable of causing the platen to make an unintentional stroke should pass through the main control valve. Where it is not practicable to pass the fluid through the main control valve, it may pass through an auxiliary valve provided that the operation of the auxiliary valve is totally dependent upon the supply of pilot fluid from the main control valve.

10.19.3 Pneumatic system design

10.19.3.1 General Because the power medium is compressible and normally vented to atmosphere, pneumatic safety circuit design is not as straightforward as for other power media. Where possible, the power supply should be interrupted by the guard-operated interlock device, and any residual system pressure exhausted to atmosphere. In this condition cylinders will be pre-exhausted, and alternative arrangements in the system design will be necessary where cylinders are under constant load, e.g. for clamps, supports or elevators. These alternatives may include single acting cylinders or spring-applied mechanical scotches.

10.19.3.2 Reinstatement of supply When reinstating the supply to a pre-exhausted cylinder, precautions to prevent undesirable rapid acceleration may be necessary. This condition may be overcome by introducing a means of restricting the flow rate to the cylinder until a predetermined pressure has been attained.

10.19.3.3 Arresting and holding cylinder movement Where, for safety reasons, it is required 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 10.9. However, a hazard could arise if connections to the cylinder are broken, overriding the locked position. Air exhausting through the broken connection could allow air under pressure on the opposite side of the piston to expand, thereby causing movement which 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 10.9. 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.

10.19.3.4 Arresting cylinder movement 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 10.11 or an equalizing valve. Both these techniques allow manual repositioning of the cylinder with the guard open without disconnecting pipes but are unsuitable for clamping or supporting applications.

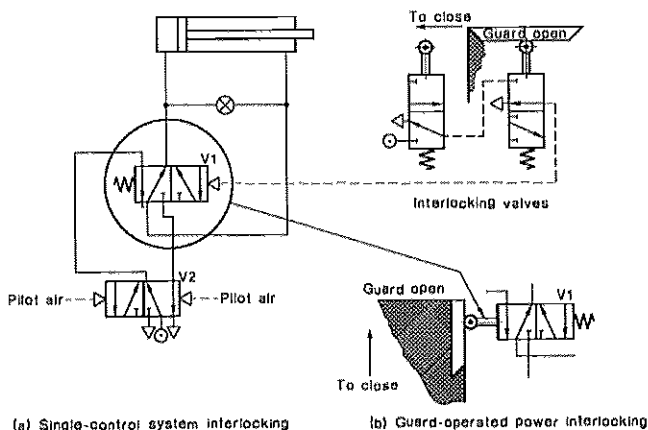


FIGURE 10.11 USE OF EQUALIZING VALVE

10.19.3.5 Power supply failure Where it is necessary to ensure that cylinders adopt a safe position in the event of power supply failure, single acting cylinders may be used. Alternatively, a reservoir having sufficient capacity to ensure that cylinders do not stall in an unsafe position may be used.

10.19.3.6 Security of interlocking systems When designing a pneumatic circuit which incorporates valves, the intent must be to ensure the security of the system. The following points should be considered:

- When the circuit incorporates devices which could be adversely affected by excessive pressure, e.g. diaphragm valves, suitable protection should be provided by fitting pressure relief valves.
- 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 valve, 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.
- When three-position valves are used in safety 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.

10.19.4 Pneumatic interlocking systems

10.19.4.1 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.

10.19.4.2 Trapped-key control system (key exchange) In a trapped-key control system, the guard lock and valve, which also incorporates a lock, are separate, as opposed to being 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 require to be interlocked, the use of a key exchange unit enable their interlocking with one or more valves. A delay can also be incorporated in the key exchange unit as in the equivalent electrical device.

10.20 ELECTRICAL CONSIDERATIONS

10.20.1 General All electrical control systems can fail in ways which could create dangerous situations. Particular attention should be given to minimizing the probability of this occurring. Devices should only be selected from those where the performance, as stated by the manufacturer, is suitable for the specific safety application. Attention should be paid to the resistance of the devices to the environmental conditions under which they must operate, including—

- (a) the index of protection (IP) offered;
- (b) corrosion resistance;
- (c) vibration resistance; and
- (d) resistance to electromagnetic interference

The life evaluation and reliability of the devices should also be considered.

10.20.2 Overall system design So that a control system circuit incorporating electromechanical/electromagnetic components achieves the basic concepts, the following points should be observed;

- (a) Relay and contactor contacts in the safety circuit should open on de-energization of their coils.
- (b) Where the supply to the safety circuit is taken from the secondary winding of an isolating transformer, one side of the circuit should be connected to earth side of the circuit and the other side of the circuit should be suitably fused (see Figure 10.12).

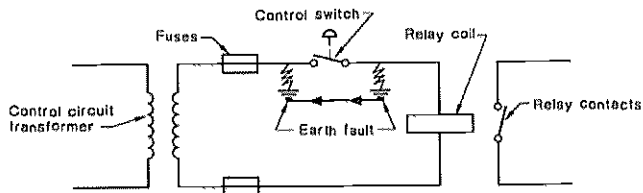
Alternatively, equally effective means should be adopted to prevent malfunction due to cross-connection faults.

See Clause 10.20.4 for information on systems incorporation solid-state components.

10.20.3 Electrical interlocking methods

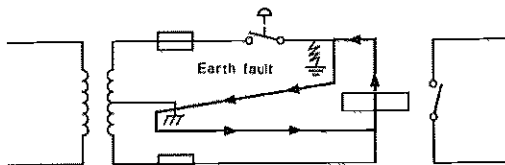
10.20.3.1 Single-control system interlocking (see Figure 10.13) The basic elements of single-control system interlocking are—

- (a) the interlocking switch operated by the guard;
- (b) interposed electromechanical relays or solid-state switching devices, if any; and
- (c) the electromagnetic contactor (or solid-state equivalent, e.g. thyristor or triac) or a pneumatic or hydraulic solenoid valve controlling power to the drive.



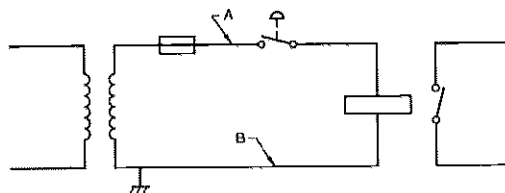
On an ungrounded control circuit, two earth faults can bypass the control switch. This can lead to unintended starting and inability to stop the machine.

(a) Fails to danger



On a mid-point earthed control circuit, one earth fault can leave 50% voltage on the relay coil. The relay may hold on resulting in inability to stop the machine.

(b) Fails to danger



Earth faults on the switch line A cause the fuse to blow and the circuit fails to safety in these circumstances. As coil line B is deliberately earthed, earth faults on that line are immaterial.

(c) Fails to safety

FIGURE 10.12 PREVENTION OF EARTH FAULT CIRCUIT

10.20.3.2 Dual-control system interlocking The basic elements are similar to those employed in single-control system interlocking. To minimize the possibility of common cause failures, two channels are used and kept separate except for 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 or entirely electrical. In both channels, the output of the power controlling devices should be connected so that either can stop dangerous movement of the machinery irrespective of the condition of the other. The integrity of dual-control systems interlocking can be improved by monitoring (see Table 10.2 and Figure 10.14).

Specific installations should be designed, then analysed and tested to ensure that the required standard of integrity is achieved.

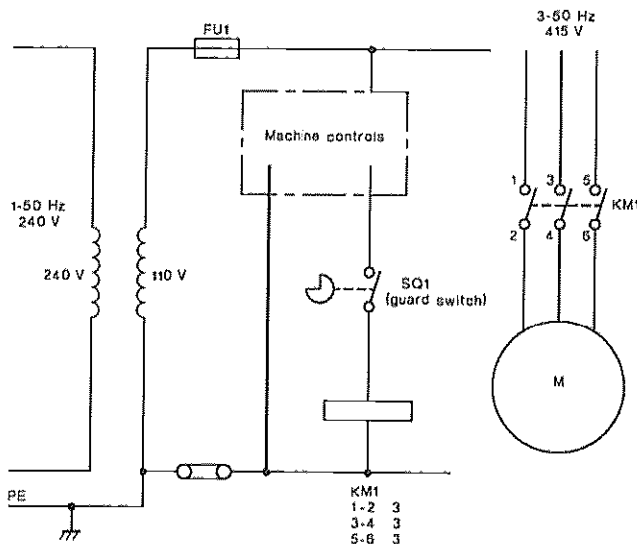
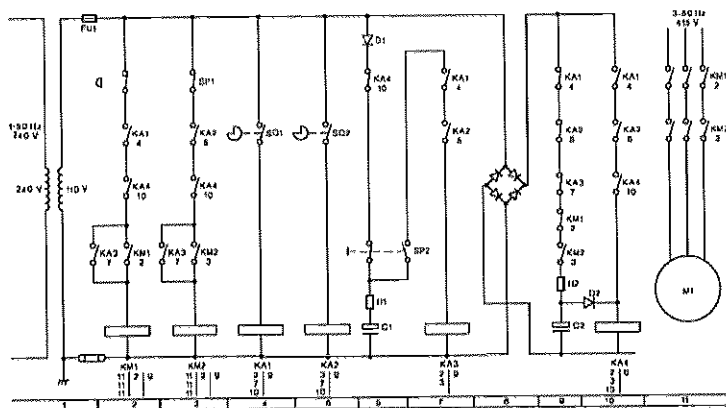


FIGURE 10.13 EXAMPLES OF SINGLE-CONTROL SYSTEM INTERLOCKING

10.20.3.3 Power interlocking Power interlocking is achieved by direct actuation of a switch in series with the power supply to the prime mover. The actuation may be by means of a cam or linkage (guard operated), captive-key, trapped-key or similar mechanical arrangement to prevent the release of the guard until the power is isolated (guard inhibited).

Power interlocking is superior to single-control system interlocking provided the switch and the mechanical interface arrangement between the guard and the switch are of high integrity. The arrangement should ensure as far as possible, that the guard cannot be opened if, for any reason, the switch contacts stay in the 'on' position.

Usually, it will only be possible to apply power interlocking when the requirement to open the guard is infrequent or the motor is of low power.



NOTE: This circuit enforces the opening and closing of the guard and hence the guard switches to provide a pre-start check after switching on the supply.

The circuit operation is as follows:

- If guard switches SQ1 and SQ2 are closed at switch-on, relays KA1 and KA2 will energize, preventing relay KA4 from energizing via diode D2. Opening the guard and hence the guard switches SQ1 and SQ2, will de-energize KA1 and KA2 and allow relay KA4 to energize via the rectifier bridge the normally closed contacts KA1, KA2, KA3, KM1, KM2, R2 and diode D2. C2 will also charge and capacitor C1 already has been electrically charged via diode D1, contact KA4, the start button SP2 and resistor R1. When guard switches SQ1 and SQ2 are re-closed, relays KA1 and KA2 energize and relay KA4 remains energized via the normally open contacts KA1, KA2 and KA4. When the start push button SP2 is operated, capacitor C1 momentarily energizes relay KA3 via the contacts SP2, KA1 and KA2. Contactors KM1 and KM2 energize via the contacts SP1, KA1, KA4, KA3 and SP1, KA2, KA4, KA3 respectively. The contacts KM1 and KM2 close, maintaining the contactors KM1 and KM2 energized thus starting the motor and removing the need for relay KA3.
- Opening the guard should open both guard switches SQ1 and SQ2 which will de-energize relays KA1 and KA2. Contacts on these relays in turn de-energize contactors KM1 and KM2 and recharge capacitor C2. Relay KA4 momentarily de-energizes allowing capacitor C1 to be re-charged.

This diagram illustrates the principles only and does not provide all the information needed to construct a working system.

FIGURE 10.14 DUAL-CONTROL SYSTEM INTERLOCKING WITH MONITORING WITH PUSH BUTTON START CONTROL

10.20.4 Systems incorporating solid-state devices or components

10.20.4.1 General Individual solid-state devices and components are usually extremely reliable although it is possible that the overall reliability of a system may be reduced because of the high number of components sometimes used.

Solid-state devices have high switching speeds and low signal voltage and current requirements, and can therefore respond to electrical interference which would not affect electromagnetic and electromechanical devices. It is therefore essential that any system for machinery safeguarding, incorporating solid-state devices should not be adversely affected by, any mains-borne or radiated interference which can occur in the environment for which it is intended. Manufacturers and users should assess the level of interference and ensure that the system is either not adversely affected by or protected against, that interference.

Much can be done to guard against malfunction from external interference by careful design of the system and the use of redundancy techniques. However, particular account should be taken of common cause failure.

10.20.4.2 Input and fixed logic stages In electronic stages, it is often possible to improve the integrity of a single-channel system by employing pulse or modulation techniques with internal checking, instead of by increasing the number of channels. In stages where these techniques cannot be employed, duplication and monitoring techniques will still be needed. The overall integrity required should be assessed.

Where integrated circuits form part of a multi-channel system, any one integrated circuit chip should only be used for one signal-processing channel.

10.20.4.3 Programmable logic stage Programmable logic stage involves solid-state devices which are capable of processing input signals according to a pre-arranged instruction (or program) normally to produce electrical outputs. The same integrity considerations apply as for fixed logic stages.

The start circuit for a programmable controller should be externally controlled to minimize risks of a logic state failure forcing an output signal to the start circuit.

10.20.4.4 Digital programmable electronic systems (PES) Considerations for programmable systems generally are given in Clause 6.22.

10.20.4.5 Interlocking programmable machinery Where the machinery is controlled by a programmable system, the options open to the designer of interlocking systems include—

- (a) conventional hardwired 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 hardwired and a programmable system where the programmable system is 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 Clause 6.22.

10.20.5 Interconnections All wiring between control switches, relays and contactors should be insulated and, where necessary, should also be efficiently protected and securely mounted.

Secure terminations, adequate clearance and creepage distances, suitable barriers between terminals and identification of circuits should be provided. See Clause 10.20.4 for information about systems incorporating solid-state components.

SECTION 11 WORKING ENVIRONMENT CONSIDERATIONS

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

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

11.3 HYGIENE AND GUARD DESIGN Machinery used in certain industries, notably for the processing of food and pharmaceuticals, should be so designed that it is not only safe to use but can be readily cleaned. Where guarding is added at a later stage, it should allow adequate facilities for the cleaning of both the machine and the guard.

Where practicable, guards which require to be opened for cleaning should be completely detachable in order to eliminate the need for inaccessible hinge pins which can be difficult to clean. Where it is necessary to provide a safeguard which is not detachable, e.g. a trip device, the number of hinges should be kept to a minimum and located as far as possible from the material being processed.

Guarding may 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 the fingers to the dangerous parts while they are in motion (see Appendix A).

Materials used for safeguards should be non-toxic, non-absorbent, shatterproof, readily cleanable and unaffected by the material being processed or by the cleaning or sterilizing agent in use. 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.

11.4 COOLANT AND SWarf Machinery should be designed as far as is practicable to contain coolant or swarf (or both), so as not to expose persons to additional hazards.

11.5 GASES, MIST, FUMES, VAPOUR AND DUST Where machinery gives rise to hazardous or objectionable levels of gases, mist, fumes, vapours or dust, containment or suitable extraction equipment should be provided.

The levels of exposure to mist, fumes, vapour and dust shall comply with the Worksafe Australia publication, *Exposure standards for atmospheric contaminants in the occupational environment*.

11.6 NOISE Although specific guidance on the subject of noise is outside the scope of this Standard, consideration should be given to noise reduction when designing safety 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 because of poor design or fixing.

11.7 LIGHTING When considering the lighting in relation to machinery, the following aspects may affect the safety of the people involved:

- (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.
 - (e) The stroboscopic effect from moving machinery.
- Guidance on local lighting is given in Clause 6.18.

SECTION 12 INSTALLATION CONSIDERATIONS

12.1 GENERAL Machinery shall be installed and commissioned in accordance with the design specifications and the manual supplied (see Clause 15.5). Where a deviation appears necessary, approval by the designer should be sought.

12.2 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 wide enough to provide access for the transport of tools and materials as well as personnel. Wherever possible, pedestrians should be separated from vehicles and provision may be needed for special purpose transport such as automated guided vehicles. Gangways and other areas to be kept free of obstructions and should be clearly defined, e.g. by floor markings. When required, hazardous areas should be separately identified by 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.

12.3 MOVING PARTS OF MACHINERY Where a person may pass between a traversing part of a machine and any fixed structure including parts of the machine, the minimum clearance between the traversing and fixed parts shall be not less than 500 mm. Extra space may be required for large tools and components or for any handling equipment needed (or both).

12.4 SERVICES

12.4.1 Cables and pipes Service pipes and cables should be placed either below ground, clear of the machinery foundations and provided with covers of adequate strength, or at such a height as to have clear headroom; the traversing of gangways should be avoided if possible.

Service pipes and cable conduits should be colour coded in accordance with AS 1345.

12.4.2 Access to machinery for maintenance To facilitate cleaning and maintenance work without causing interference to adjacent machinery, platforms, safe means of access and lifting appliance suspension points should be built-in, where practicable. In such circumstances, it may be necessary to safeguard moving parts which would otherwise be out of reach. Under certain circumstances, e.g. where a position is normally inaccessible, a safe system of work may be a suitable alternative to guarding. For example, to gain access to an inaccessible danger point, the power may be locked out and an elevated work platform or similar equipment used to gain access.

12.5 COMMISSIONING During the commissioning phase and on more complex machinery during the installation phase, it may be necessary to start and run parts of the machinery prior to proceeding to the next stage.

During this phase where final safeguarding may not be in place or operational, fencing and barricading should be provided, accompanied by appropriate signs, so that only those personnel who are responsible for the installation and commissioning may approach the machinery.

In these cases safe working practices are important and guidance may be found in Section 15.

In a similar way to the importance of consultation prior to or at the design stage (see Clause 2.5), every endeavour should be made to consult those personnel who will use and maintain new machinery or machinery which has been modified or relocated, prior to its use. Wherever possible this should include the designer, installer and commissioner of the machines.

In this way safety related issues which may not have been foreseeable at the earlier stages can be corrected prior to the use of machinery.

A record of such inspection should be kept as a reference, for the life of the machinery.

SECTION 13 MAINTENANCE

13.1 GENERAL All required inspection and maintenance procedures should be carried out in the manner and at the frequency indicated in the manufacturer's instructions. Manuals should be supplied (see Clause 15.5).

Where instructions and manuals are not supplied, sound engineering principles should be used or alternatively, the advice of consultative bodies should be sought.

The safe performance of maintenance operations relies heavily on the practices used, and guidelines for safe working practices are given in Section 15.

13.2 SERVICE LIFE When determining the useful life of vital components within a safeguard, e.g. switches, relays or valves, reference shall be made to the designer's or supplier's specifications to ensure that the required level of safety is maintained by not exceeding their recommendations.

13.3 INSPECTION OF SAFEGUARDS

13.3.1 General Inspection and maintenance shall be carried out by trained and experienced personnel. The depth and scope of training will depend upon the complexity of the machinery and the risk arising from its use.

13.3.2 Inspection during production Some safeguards may be tested as part of a normal production procedure. The frequency of testing will depend upon the type of safeguard and its operational characteristics.

Some safeguards incorporate a self-testing facility which may be automatically invoked at pre-set intervals.

13.3.3 Inspection during routine maintenance An inspection of all safeguards shall form a part of any planned preventative maintenance schedule.

Where no preventative maintenance is used, a regular inspection of all safeguards shall be made.

In either case, the frequency and extent of inspections shall be in accordance with those recommended by the designer or supplier of the safeguard, consistent with the complexity of the machine and the risk arising from its use.

13.4 REPLACEMENT OF SAFEGUARDS Upon completion of any maintenance task on machinery or process plant, a check shall be made to ensure that any safeguard installed has been restored to a fully operational state before signing off the machine for production use.

13.5 GENERAL MAINTENANCE Care is necessary when maintenance work is carried out on machine control and operational functions. Many control functions have a significant effect on safety, e.g. workholding devices and programmable systems.

13.6 CONFINED SPACES Machine guards constructed from solid or unventilated material can trap materials which are hazardous and can result in the guard becoming a confined space. Where entry to a confined space is required, such an entry shall comply with the requirements of AS 2865.

SECTION 14 ISOLATION AND ENERGY DISSIPATION

14.1 GENERAL The guidance set out in this Section refers specifically to entry or access to danger zones during maintenance operations, e.g. repair or major set-up, and should not be confused with operational access. Safe entry provisions for operational access are described in Sections 7, 9 and 10.

Keeping a machine in a stopped condition during all types and conditions of entry to danger zones constitutes one of the most important conditions of the safe use of machinery and hence one of the major aims of the machine designer.

In the past, the concepts of 'operating machine' and 'stopped machine' were unambiguous: a machine was—

- (a) operating when its movable elements, or some of them, were moving; or
- (b) stopped (or at a standstill) when its movable elements were at rest.

Transition from the stopped condition to the operating condition normally did not occur without an actuator (control) being actuated. The simplicity of control systems normally made any unintended or unexpected start-up improbable.

Machine automation has moved towards a more indirect link between operating or motion on one hand and stopped condition or rest on the other hand. Thus, a machine having its movable elements at rest shall be considered as operating if at least one element can be automatically started.

Machine automation has also multiplied the causes of unexpected start-up. Moreover, hazards other than those generated by movable elements often have to be taken into account.

A risk assessment relating to a given entry or access to the danger zone of a stopped machine shall take into account the probability of an unexpected start-up of the hazard-generating elements occurring during this entry or access.

In principle, where the work to be carried out requires placing any part of the body in such a position that unexpected movement, release of stored energy, energizing of electrical systems or the flow of gases or fluids could result in injury, means shall be provided for isolating the machine from the power supplied, dissipating or restraining stored energy or otherwise preventing unexpected machine start-up.

14.2 MACHINE START-UP

14.2.1 General A machine start-up can be described as a change from rest to motion of a machine or of one of its parts. This includes functions other than motion, e.g. the start-up of a laser beam.

14.2.2 Unintended (or unexpected) start-up An unintended start-up is any start-up caused by—

- (a) a start command which is the result of a malfunction from failure in (or external influence on) the control system;
- (b) a start command generated by inappropriate human action on a start control or on another part of a control system (e.g. on a critical sensor), or on other parts of the machine (on a power control element); or
- (c) external/internal influence, e.g. gravity, wind or self-ignition on other parts of the machine.

14.2.3 Intended (or expected) start-up Intended start-up is any expected start-up in response to the manual actuation of a machine cycle start control or the resumption of a machine cycle in response to a physical actuation of a reset control. An intended start-up is subject to certain conditions being fulfilled, e.g. interlocked guards closed, and is usually associated with initial cycle start or a cycle start following operational access. Prevention of an unintended start-up using various interlocking methods is covered in Sections 7 and 10.

14.3 ISOLATION AND ENERGY DISSIPATION Isolation and energy dissipation consist of the four following inseparable actions:

- (a) Isolating (disconnecting, separating) the machine (or a defined part of the machine) from all power supplies.
- (b) Locking (or otherwise securing) all the isolating units in the 'isolating' position.
- (c) Dissipating, restraining or containing any stored energy which may give rise to a hazard.

NOTE: Energy may be stored in—

- (a) mechanical parts continuing to move through momentum;
- (b) mechanical parts liable to move by gravity;
- (c) capacitors, accumulators;
- (d) pressurized fluid; or
- (e) springs.

- (d) Verifying by a safe working procedure the effect of the measures taken previously.

14.4 MEANS INTENDED FOR ISOLATION AND ENERGY DISSIPATION

14.4.1 General Machinery shall be fitted with a device to enable it to be isolated from all power supplies and stored energy to be dissipated.

14.4.2 Means for isolation from power supplies

14.4.2.1 Isolation Isolation from any power supply shall be either an interruption of continuity in the power supply circuits or a reliable physical barrier (e.g. manually operated shut-off valve(s) in the power supply circuits).

14.4.2.2 Plug and socket Plug and socket systems (for electrical supply) or their pneumatic, hydraulic or mechanical equivalents are examples of isolating devices with which it is possible to achieve a visible and reliable discontinuity in the power supply circuits. However, because of the ease with which these systems can be reconnected, their use is only recommended where other methods prove to be impracticable.

14.4.2.3 Other isolating devices Isolation devices other than plug and socket systems shall ensure—

- (a) a reliable isolation (interruption of continuity or physical barrier(s) in the supply circuit);
- (b) a reliable mechanical link between the manual control and the isolating element(s); or
- (c) a clear and easily understood identification of the state of the isolation device which corresponds to each position of its manual control (actuator).

14.4.2.4 Relationship between isolating devices The relationship between each isolating device and the machine (or part of it) which is to be isolated, shall be clear and easily understood.

14.4.2.5 Additional precautions When certain circuits have to remain connected to their power supply, e.g. to hold parts, protect information or light interiors, special steps shall be taken to ensure operator safety. Such steps may be enclosures which can be opened only with a key or a special tool, warning labels or warning lights.

14.4.3 Locking means

14.4.3.1 General Except where reconnection cannot endanger the person on the machine and a plug/socket combination or its pneumatic or hydraulic equivalent is used as an isolation means, the isolation means shall be capable of being locked or otherwise secured in the 'isolated' position.

14.4.3.2 Padlocking The isolation device may be designed so that one or more padlocks can be fitted or alternatively the device may be used with a multi-padlock hasp (see Figure 14.1). Each person should apply an individual padlock (see Figure 14.2) or key to each relevant control.

The placement of a lock should be accompanied by a danger tag which identifies the employee who placed the lock and the reason for its placement.

14.4.3.3 Removal of padlocks A padlock should only be removed by the person who fitted it at either the completion of the overall task or upon completion of that person's part of the overall task.

Where a task is unfinished, and the machinery is left in an inoperable state for a prolonged period, e.g. over a weekend, it is permitted that personal padlocks be removed from the isolator, provided that an additional padlock supplied by management is fitted prior to their removal.

Where a job is likely to take several weeks to complete, a management-supplied padlock may be left on the isolators for the duration of the task.

A padlock may only be removed by a person other than the person who fitted it when it is known that the owner of the padlock is not available, i.e. not on the worksite. Under these conditions the padlocks may be removed by the senior person responsible for managing the work after verifying that no person would be placed at risk as a result of its removal and after an inspection of the machinery to ensure no damage to the machine will occur.

14.4.3.4 Trapped key A trapped key interlocking device incorporating a key exchange device which releases a second or multiple keys which can be removed by a person or persons entering the danger zone. This prevents the first (master) key from being removed and used to switch on the power until the secondary keys have been returned.

14.4.4 Energy dissipation or restraint (containment) means

14.4.4.1 General Means shall be incorporated into the machine to dissipate residual energy stored in any part of the machine and which may give rise to a hazard.

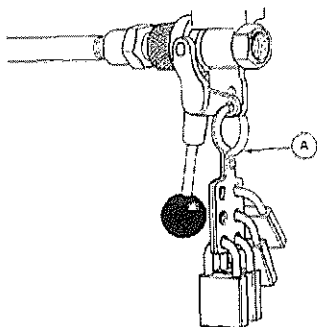
Such means include brakes intended to absorb kinetic energy of moving parts, and resistors and relevant circuitry to discharge electric capacitors, valves or similar devices to depressurize accumulators.

Where dissipation of all residual stored energy would excessively reduce the ability of the machine to be used, additional means shall be incorporated to reliably restrain or contain the stored energy.

The means for energy dissipation or restraint (containment) should be designed so that dissipation/restraint (containment) results from the isolation of the machine (or part of it).

The energy dissipation process shall not give rise to any hazardous situation.

The necessary procedures for energy dissipation or restraint (containment) shall be described in the instruction handbook of the machine or on warnings on the machine itself.



Valve locked in OFF position
with padlocks of four employees

NOTE: Before the hasp (A) can be released and the valve handle operated, all four padlocks, one per employee who would otherwise be at risk, have to be removed.

FIGURE 14.1 MULTI-PADLOCK HASP

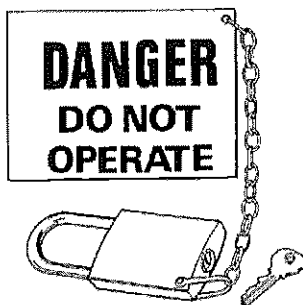


FIGURE 14.2 EXAMPLE OF PADLOCK

14.4.4.2 Mechanical elements When mechanical elements can give rise to a hazardous situation by virtue of their weight and position, e.g. unbalanced or raised or in any situation from which they can move under the effect of gravity or as a result of the action of the spring load, means shall be provided to bring them to the lowest energy state (lowest position or spring released) by means of the usual machine manual controls or by means of devices designed and identified (marked) for the specific function.

When the mechanical elements cannot be brought into an intrinsically safe state, they shall be mechanically secured by means such as brakes or mechanical restraint devices.

14.4.4.3 Locking or securing means The means for energy restraint (containment) shall whenever necessary be capable of being locked or otherwise secured.

14.4.5 Provisions for verification and testing

14.4.5.1 General The machine and isolation and energy dissipation or restraint means shall be designed so that verifying and, if necessary, testing of the effectiveness of the isolation and energy dissipation or restraint procedures can be performed easily and reliably.

Provisions to verify and test the isolation, energy dissipation and restraint means shall not impair the effectiveness of those means.

14.4.5.2 Provisions aimed at facilitating verification of isolation Isolation from any power supply shall either be visible (visible interruption of continuity in the power supply circuits) or readily identifiable by the position of the manual control (actuator) of the isolating device.

See also Clause 14.4.2.3 relating to the mechanical link between the isolating element(s) and the manual control.

14.4.5.3 Provisions in view of facilitating verification and testing of energy dissipation or restraint Built-in devices (such as pressure gauges) or test points shall be provided for verifying the absence of energy in parts of a machine where interventions are foreseen.

Information provided for users of machines (see Clause 15.5) should provide guidance on—

- (a) energy dissipation or restraint which has to be verified before intervening in a danger zone; and
- (b) where and how to carry out the verification or testing easily, reliably and safely.

Labels shall be affixed on assemblies, giving warning of hazardous stored energy (e.g. springs remaining compressed) where assemblies can be removed or dismantled during maintenance or other activities.

SECTION 15 SAFework PROCEDURES

15.1 GENERAL Machinery safety depends on a combination of hazard and risk minimization measures, safeguards and safework practices. In every case the total safeguarding strategy requires an integrated approach from the designer, the manufacturer, the supplier, the installer and ultimately, the employer or user, and should take account of activities which will occur during all phases of machine life.

Ultimately however, it is the employer or the end user who are exposed to any residual hazards after the installation and commissioning phase is complete. These residual hazards are—

- (a) those unable to be eliminated by design, for which safeguards have been provided to minimize risk; and
- (b) those unable to be safeguarded, for which safework procedures have been defined.

It is the responsibility of the employer or the end user to implement the safework procedures specified by the designer, or to develop those which meet the needs of the workplace. The overriding concern at all times being the need to eliminate or minimize the risk of injury to exposed persons.

The following briefly summarizes those sections of the Standard in which employer and user responsibilities are introduced and demonstrates the vital role that these play in an overall safeguarding strategy.

Section 2 sets out the principal aim of the Standard, i.e. to eliminate hazards and control or minimize risk by design through the selection of appropriate safeguards and the use of safework practices as complementary measures. The risk assessment phase (see Section 5), introduces another critical issue; the assessment of risk should not be restricted only to that relating to the intended use of machinery, but also to that associated with its foreseeable use or misuse.

Section 7 shows the relationship between safeguards and safe working practices within the overall safeguarding framework. Safework practices should be documented during the machine design phase, as aids for safeworking, e.g. jigs, manual handling aids or work holding devices may need to be integrated with the machine design. At the same time training needs, maintenance requirements and cleaning practices should be established.

Elimination of hazards and the design of completely adequate safeguards to protect people during all phases of machine life may not always be possible. Where a machine can be safeguarded to allow for operational access, mechanical hazards will generally be avoided but may still require safework practices for setting or correcting machine malfunctions. Maintenance access requires adherence to machine isolation and other safework practices such as a 'permit-to-work' system. Some machinery cannot be totally safeguarded during all phases of its normal operation, e.g. a manually fed bench saw, and for this type of operation safework practices are mandatory.

All the design work, apart from elimination of a hazard by design, is frustrated if employers fail to exercise the strongest control and supervision over the workplace, and users disregard safework procedures. Critical employer and user responsibilities are as follows:

- (i) Instruction and training, including—
 - (A) new employee induction or new equipment introduction;
 - (B) ongoing current employee instruction and refresher training; and
 - (C) contractors.

- (ii) Implementation and development of safework procedures, including—
 - (A) systems of work and work practices;
 - (B) workplace inspections and audits;
 - (C) permit-to-work systems and maintenance isolation; and
 - (D) emergencies.
- (iii) Personal protective equipment, including—
 - (A) selection and purchase; and
 - (B) wearing and maintenance.

Section 15 also includes a summary for the provision of information. Although a responsibility of the designer, this is a vital element for the development of safework procedures by the employer or user.

15.2 INSTRUCTION AND TRAINING

15.2.1 General Supervisors and users alike should be formally trained in the knowledge and application of safework procedures and practices. This is particularly applicable to young or inexperienced persons including skilled persons not familiar with the workplace and is particularly important for those phases of machine life where risk is higher, e.g. due to the removal of safeguards. Safety training should, where possible, form part of an integral program covering all aspects of the work to be undertaken. All formal training should be documented so that a permanent record exists of the date and topics covered for each person. Regular refresher training should also be carried out to ensure that standards of performance are maintained. Refresher training is an excellent opportunity to review existing procedures and practices for their suitability in the light of current or changing circumstances.

Suppliers of machinery should advise the users of all training courses offered on the operation and maintenance of the machinery.

15.2.2 Training topics

15.2.2.1 Supervisors and machinery operators Supervisors and machinery operators shall be instructed and trained in at least the following:

- (a) Machinery safety procedures, including emergency procedures.
- (b) The correct and safe way of operating machinery, including the freeing of jammed material and the correction of machine malfunctions.
- (c) Knowledge and understanding of the hazards they face at the workplace.
- (d) Understanding the purpose and function of the safeguards which protect them, e.g. where guards are used but which may not afford completely effective safeguarding such as on some woodworking and milling machines.
- (e) Reporting faults immediately, including guard defects.
- (f) Selection, use and care of protective clothing and equipment relevant to the workplace.
- (g) Need for good housekeeping.
- (h) Statutory requirements.

15.2.2.2 Designers of machinery and guards Designers of machinery and guards should be trained in the basic principles outlined in Clause 2.1.

15.2.2.3 Plant engineers and maintenance staff (including contractors) Plant engineers and maintenance staff shall be trained in at least the following:

- (a) Principles of safeguarding machinery.
- (b) Electrical and mechanical safety.
- (c) Precautions during maintenance work, including safe systems of work and, where necessary, permit-to-work and lock-off systems, e.g. padlock, captive-key or interlock key exchange and emergency procedures.
- (d) Wearing and care of protective clothing and equipment.
- (e) Maintaining any specialized equipment under their control.

15.3 SAFework PROCEDURES

15.3.1 General Where safety from hazards associated with machinery is dependent upon people carrying out safe working procedures, it is essential that an appropriate degree of managerial or supervisory control is exercised. Similarly, it is vital that users of machinery adhere to safework procedures and practices and not take shortcuts or ignore them. Where specified procedures or practices appear to have shortcomings, these should be reported to supervisors, and revised as soon as practicable.

Where the risk is minimal, verbal instructions may be adequate, but as the risk increases it is essential to develop written procedures and practices. It is recommended that all procedures and practices for the safe use of machinery are documented. This helps to avoid the inevitable deterioration over time which occurs when safework practices are passed by word-of-mouth from one user to another and also provides essential source material for training and supervision.

Safework practices are generally a subset of safework procedures. They describe the manner in which a specific task is performed, whereas safework procedures describe the system of work or the manner in which a range of tasks interrelate between different users or persons with different responsibilities. In small workplaces, a series of safework practices may suffice, but as the complexity of the workplace increases overall procedures are necessary to effectively integrate all activities.

For example, the safework practice for operating a bench saw may specify such requirements as the setting of the guard and riving knife, the use of a push stick, where to stand when operating the saw, personal protection equipment to be worn and avoidance of loose clothing. A safework procedure covering the general area in the same workplace may include—

- (a) inspection and storage of raw timber by the storeman;
- (b) handling of raw timber by the storeman;
- (c) operating the saw; and
- (d) stacking and dispatching the sawn product.

Each of these procedural tasks may have detailed work practices, e.g. the operating practice for the saw detailed above.

15.3.2 Safework practices

15.3.2.1 General As previously mentioned, there are many situations in which machinery cannot be totally safeguarded. Similarly, there are situations where there is a need for reliance on employees exercising personal responsibility for the way in which a task is carried out. Some indication of the scope of these responsibilities is given below.

15.3.2.2 Safe access Firm footholds (and handholds where necessary) should be provided. They should be free of obstruction and any material likely to cause slipping.

Where these have not been provided, a ladder or other temporary structure should be used. A high standard of housekeeping should be exercised at all times to eliminate the possibility of slips, trips and falls.

15.3.2.3 Entanglement Where the hazards include entanglement and drawing-in, loose clothing, neckties, gloves, rings and other jewellery, long hair (unless tied back or covered), fabric first aid dressings and bandages and any other material likely to be caught up should be avoided. For any close approach, close-fitting overalls with close-fitting cuffs and no external pockets should be provided. It should be borne in mind that even when guarded against contact, entanglement hazards may be within reach of adjacent loose or stray material.

Material in the machine, e.g. material being processed or byproducts may also present an entanglement hazard.

15.3.2.4 Flying objects Where the hazards include impact or penetration by flying objects, including small particles and dust, appropriate eye protection should be worn (see AS/NZS 1337), as well as protective clothing.

15.3.2.5 Kickback 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 the following:

- (a) Provision of backstops on vertical spindle moulding work.
- (b) Ensuring circular saw blades are adjusted to protrude through the material being cut, and that riving knives are of the correct thickness.
- (c) Ensuring work rests are adjusted close to abrasive wheels or tool rests are correctly adjusted (see Clause 6.2.2).
- (d) 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 should be labelled with the minimum blade diameter.
- (e) Wherever possible, position the body outside the line of possible kickback.

15.3.2.6 Bursting Precautions against impact injuries due to bursting generally involve ensuring that relevant rotating equipment and any abrasive wheels used with it are clearly marked with their speeds.

15.3.2.7 Mechanical hazards There are also practices relating to approach to mechanical hazards which are relevant to most of the types listed in Clause 4.2. These include the following:

- (a) Limiting closeness of approach, e.g. in work near overhead travelling cranes, in taking off work from the rear of a saw table and in avoiding certain areas of a machine's traverse.
- (b) Provision and use of manual handling devices, e.g. tongs for forging work, push sticks for circular saws and spindle moulders or push blocks for planing machines.
- (c) Provision of jigs and holders for workpieces, e.g. for vertical spindle moulding or for cutting irregular material on circular saws.

It should be noted that there is a logical progression from tongs, push sticks and similar through jigs and holders, through more sophisticated clamping devices and manually operated travelling tables to power-driven feeds and automatic feeding arrangements in general.

15.3.2.8 Emergency stop controls Emergency stop controls shall be readily accessible.

15.3.3 Workplace inspections and audits

15.3.3.1 General Workplace inspections and audits are essential elements in any management strategy to ensure that selected safeguard and safework procedures are maintained.

15.3.3.2 Inspection The carrying out of workplace inspections is an important aspect of day-to-day management of the safe use of machinery. Inspection may be carried out by a range of personnel in the workplace to suit varying needs. Management may carry out inspections to demonstrate its commitment to the maintenance of a safe and healthy workplace and as a means of maintaining an ongoing liaison with the shopfloor. Inspections are valuable supervisory tools, providing an excellent opportunity for on-the-job training where non compliance is observed or positive feedback to those employees complying with safework practices. Daily inspections by machinery users covering such areas as the operation and condition of guarding, warning devices, gauges and controls, and housekeeping are recommended at the start of shift or on commencement of another task.

Inspections provide a 'snapshot' of conditions as they exist at a point in time. For this reason they are suited to reviewing compliance with safework practices. In the example given in Clause 15.3.1, an inspection is the method of choice for reviewing compliance whereas it may not yield satisfactory results for the overall procedure.

15.3.3.3 Audits Workplace audits are an extension of inspections, and entail an extensive review of all facets of a procedure to ensure that there are no 'loopholes' developing in the overall strategy. Audits frequently include inspections as part of their format, but are usually carried out over a number of days to ensure all aspects are fully investigated. In the example given in Clause 15.3.1, an audit would almost certainly be required, as it would be most unlikely that all aspects of the procedure could be reviewed in one 'snapshot'. Like inspections, audits may be carried out by all levels of personnel in a workplace, depending upon the need.

15.3.4 Permit to work systems The most common use of a permit-to-work system is during maintenance operations. In circumstances where a procedure in the form of a safe system of work is deemed to be appropriate, it is necessary for management to identify the hazards which are exposed and to develop a safe system of work whereby these hazards are eliminated, or as a last resort recognized by employees so that personal precautions against possible injury can be taken. Oral instructions, requests or promises are liable to be misheard, misinterpreted or forgotten and are therefore not a satisfactory basis for actions on which lives may depend. The unsatisfactory working of such procedures has been proved time and again.

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 to sign such permits. The person responsible for supervising the work should ensure that those persons 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 which 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 to ensure that the system operates correctly is required.

Work in potentially hazardous circumstances can be done in safety by the use of this method. The design of a permit-to-work system will depend on the nature and degree of risk, the complexity of the task and the industry to which it relates.

Where work is to be carried out on machinery, permit to work systems shall incorporate the requirements of Section 14. Where entry into a confined space is involved, permit to work systems shall incorporate the requirements of AS 2865.

15.4 PERSONAL PROTECTION In considering methods of safeguarding machinery, it may also be necessary to consider the provision of personal protection equipment to minimize the risk of injury. This may include special clothing, including safety head-and foot-wear, gloves, hearing protectors and eye protection or breathing apparatus. All those required to wear personal protection equipment shall be given training in its selection, fit, proper use, care and maintenance. Wearing personal protection equipment may affect clearance distances, crushing distances and the ability to operate controls.

15.5 PROVISION OF INFORMATION

15.5.1 General There are various ways in which information should be provided for users of machinery or for persons who may be in the vicinity of machinery. These include training manuals, instruction manuals, instruction placards and warning labels. All information should be presented in English (and other languages where necessary) and be in a logical sequence with good illustrations. Where applicable, standard symbols should be used.

15.5.2 Instruction placards and warning labels Warning labels on the machinery may be appropriate for—

- (a) commissioning and installation, e.g. to indicate lifting procedures or the exposure of dangerous parts prior to the fixing and safeguard during the commissioning phase; and
- (b) operation of the machine, e.g. to indicate dangerous machinery behind a guard such as drive systems or electrical control equipment, or to inform about safe working procedures such as the need to wear eye or ear protection.

Warning labels shall be clear and concise, using (where practicable) standard symbols and colours in accordance with AS 1319.

Instruction placards may be used in the area adjacent to the machinery to explain the legal requirements, e.g. statutory notice outlining the dangers associated with abrasive wheels or to carry reference information on machinery operation.

15.5.3 Installation, operation and maintenance instructions The designer or supplier should provide each machine with sufficient information including drawings, to enable the correct installation, safe operation and maintenance of the machine with particular reference to the following:

- (a) Transport.
- (b) Unloading and lifting, including the weight of the machine and its attachments, with indications where it should be lifted.
- (c) Commissioning and installation, i.e. the limits of travel of all moving elements should be shown.
- (d) Start-up, including description of controls and functions.
- (e) Close-down.
- (f) Setting/process changeover/programming (including robots).
- (g) Adjustment.
- (h) Cleaning.
- (i) Lubrication, refuelling, recharging.
- (j) Repair, including information on foreseeable failures and faultfinding.

15.5.4 Preventative maintenance For all the phases of machine life, the potential hazards should be identified and the safeguards to protect against the hazards, the safeworking and operational procedures required (including emergency procedures) and the emergency equipment which may be needed should be described.

For machinery supplied without tooling, the designer or supplier should indicate that the user may need to provide additional safeguards to the standard guarding in certain circumstances.

For machinery supplied with tooling for a specific workpiece or a range of workpieces, the supplier should indicate the need to review the original safeguards if tooling or workpiece considerations are changed.

APPENDIX A
ERGONOMIC DATA
(Normative)

A1 GENERAL The data below are provided as guides for users who need to design and build guards that prevent persons from encroaching into a danger-zone associated with a machine.

Users should carefully consider whether the data are appropriate for use with the specific workforce which may be taller, shorter or thinner than the population from which the data were taken.

Where doubt exists, measurements of the workforce may be taken and careful trials made to ensure that the danger points are beyond reach. Where such trials are made, the machinery shall be in a safe condition during the trials.

A2 REACHING UP With the body upright and standing at full height, the minimum safety distance when reaching upward is 2500 mm (see Figure A1 and Clause 3.2.1).

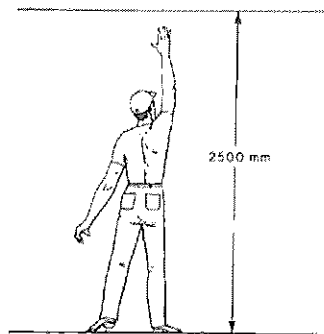


FIGURE A1 SAFETY DISTANCE FOR REACHING UP

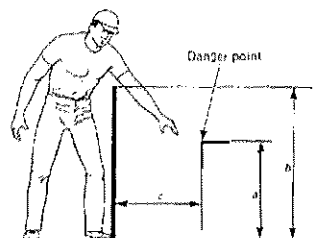
A3 UPPER LIMB REACH DISTANCE WITH FIXED FENCES

A3.1 General Selection of the appropriate safety distance for reaching over a fixed fence shall depend on a risk assessment. The assessment shall be based on the probability of occurrence of injury and the likely severity of that injury.

A3.2 Reaching down and over When reaching down over an edge, e.g. on machine frames or barriers, the safety distance is found from Figure A2.

NOTE: Attention is drawn to the increased danger of overbalancing when reaching over a 1 m high barrier.

A3.3 Reaching under Where clearance is provided under a guard for cleaning spillages, swarf and similar, the clearance should not exceed 200 mm. (See also Figure A3).



LEGEND:

a = distance of danger point from floor

b = height of edge of barrier

c = horizontal distance from edge of barrier to danger point

FIGURE A2 (in part) GUARD DISTANCES

Height of danger zone <i>a</i>	Horizontal distance to danger zone <i>c</i>								
	Height of protective structure <i>b</i> *								
	1 000†	1 200†	1 400†	1 600†	1 800	2 000	2 200	2 400	2 500
2 500	—	—	—	—	—	—	—	—	—
2 400	100	100	100	100	100	100	100	100	—
2 200	500	600	500	500	400	350	250	—	—
2 000	1 100	900	700	600	500	350	—	—	—
1 800	1 100	1 000	900	900	600	—	—	—	—
1 600	1 300	1 000	900	900	500	—	—	—	—
1 400	1 300	1 000	900	800	100	—	—	—	—
1 200	1 400	1 000	900	500	—	—	—	—	—
1 000	1 400	1 000	900	300	—	—	—	—	—
800	1 300	900	600	—	—	—	—	—	—
600	1 200	500	—	—	—	—	—	—	—
400	1 200	300	—	—	—	—	—	—	—
200	1 100	200	—	—	—	—	—	—	—
0	1 100	200	—	—	—	—	—	—	—

* Protective structures less than 1 000 mm height are not included because they do not sufficiently restrict movement of the body.

† Protective structures having a height of 1 600 mm and less should only be used where a risk assessment indicates a low probability of and low severity of injury.

NOTES:

- 1 There should be no interpolation of the values in the Table.
- 2 Barriers are not foolproof and they cannot prevent access to persons intent on gaining access. Therefore, as a person's intent on reaching a dangerous part increases, e.g. by climbing on chairs, ladders or the barrier itself, the protection provided by a barrier decreases.

FIGURE A2 (in part) GUARD DISTANCES

A4 REACHING AROUND WITH UPPER LIMBS When reaching around edges in any position, the safety distance of freely articulating upper limbs is given in Figure A3.

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 not to be allowed to reach a danger point.

Of special importance is the danger area which can be reached when these body parts are introduced through slots.

When applying safety distances, it is to 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 danger point is excluded.

Limitation of movement	Safety distance s_f	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	




*Either the diameter of a round opening, the side of a square opening or the width of a slot opening.

DIMENSIONS IN MILLIMETRES

FIGURE A3 SAFETY DISTANCES FOR REACH ROUND

A5 REACHING IN AND THROUGH REGULAR OPENINGS WITH UPPER LIMBS Safety distances are as given in Figure A4. The dimension of openings (e) correspond to the side of a square opening, the diameter of a round opening or the narrowest dimension of an elongated opening or slot.

Should any opening allow access past the shoulder, safety distances shall be selected using Figure A2.

Part of body	Illustration	Opening	Safety distance s_r		
			Slot	Square	Round
Fingertip		$e \leq 4$	≥ 2	≥ 2	≥ 2
		$4 < e \leq 6$	≥ 10	≥ 5	≥ 5
Finger up to knuckle joint or Hand		$6 < e \leq 8$	≥ 20	≥ 15	≥ 5
		$8 < e \leq 10$	≥ 80	≥ 25	≥ 20
		$10 < e \leq 12$	≥ 100	≥ 80	≥ 60
		$12 < e \leq 20$	≥ 120	≥ 120	≥ 120
		$20 < e \leq 30$	≥ 850	≥ 120	≥ 120
Arm up to junction with shoulder		$30 < e \leq 40$	≥ 850	≥ 200	≥ 120
		$40 < e \leq 120$	≥ 850	≥ 850	≥ 850

DIMENSIONS IN MILLIMETRES

FIGURE A4 REACHING IN AND THROUGH REGULAR OPENINGS

A6 OPENINGS OF IRREGULAR SHAPE To choose a safety distance for upper limbs entering an opening of irregular shape, the following procedure shall be followed:

- Determine—
 - the diameter of the smallest round opening,
 - the side of the smallest square opening; and
 - the width of the narrowest slot opening into which the irregular opening can be inserted (see Figure A5).
- Select the corresponding safety distances from Figure A4.
- The shortest safety distance of the values selected may be used.

A7 LOWER LIMB REACH DISTANCE

A7.1 General The data given in Figure A5 may be used where the risk assessment shows that there is a risk only to the lower limbs. Where there is a risk to both upper and lower limbs, then the longest safety distance appropriate to the aperture size and given in Figure A4 or Figure A6 shall be used.

A7.2 Reaching in and through regular openings The dimension of openings (e), corresponds to the side of a square opening, the diameter of a round opening or the narrowest dimension of an elongated opening or slot.

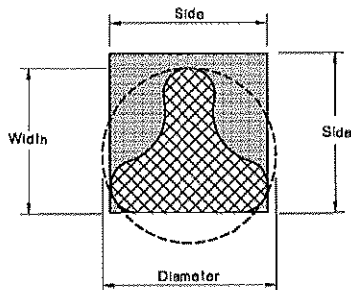


FIGURE A5 IRREGULAR-SHAPED OPENING

Part of lower limb	Illustration	Opening	Safety distance s_r	
			Slot	Square or round
Toe tip		$a \leq 5$	0	0
Toe		$5 < a \leq 15$	≥ 10	0
		$15 < a \leq 35$	$\geq 80^*$	≥ 25
Foot		$35 < a \leq 60$	≥ 180	≥ 80
		$60 < a \leq 80$	$\geq 650^\dagger$	≥ 180
Leg up to knee		$80 < a \leq 95$	$\geq 1\ 100^\ddagger$	$\geq 650^\ddagger$
Leg up to crotch		$95 < a \leq 180$	$\geq 1\ 100^\ddagger$	$\geq 1\ 100^*$
		$180 < a < 240$	not admissible	$\geq 1\ 100^\ddagger$

*If the length of the slot opening is ≤ 75 mm the distance can be reduced to ≥ 50 mm.

†The value corresponds to leg up to knee.

‡The value corresponds to leg up to crotch.




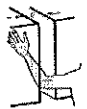

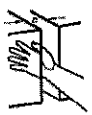


DIMENSIONS IN MILLIMETRES

FIGURE A6 REACHING IN AND THROUGH REGULAR OPENINGS WITH THE LOWER LIMBS

A8 MINIMUM GAPS TO PREVENT CRUSHING A crushing hazard will be generated if either two movable parts are moving towards one another, or one movable part is moving towards a fixed part.

The minimum gap dimensions to minimize the risk from a crushing hazard are given in Figure A7. Care must be taken to assess the risk of a person entering the crush zone in a different body orientation to those given. Where such a risk is considered to be unacceptable, additional measures will be required to minimize the risk, e.g. the use of fixed barriers to prevent access.

In addition, consideration should be given to the increase in hand or body part dimensions as a result of holding tools or workpieces, or from the use of personal protective equipment such as gloves or helmets.

Part of body	Minimum gap <i>a</i>	Illustration	Part of body	Minimum gap <i>a</i>	Illustration
Body	500		Toes	50	
Head (least favourable position)	300		Arm	120	
Leg	180		Hand	100	
			Wrist		
			Fist		
Foot	120		Finger	25	

DIMENSIONS IN MILLIMETRES

FIGURE A7 MINIMUM GAPS TO PREVENT CRUSHING

APPENDIX B

HAZARD IDENTIFICATION

(Informative)

B1 GENERAL Before a hazard can be analysed and any risk associated with the hazard estimated, each hazard must first be identified.

There are a number of ways by which hazards may be identified; however, the earlier during machine design and manufacture that hazards are identified, generally, the easier they are to eliminate.

A list of typical hazards is given in Paragraph B4 and two methods for identification of other hazards are given in Paragraphs B2 and B3. Other methods of identification may be used.

During the process of hazard identification, consultation with those persons who will be using the machinery or who are using similar machines should take place, since many of the hazards and potential means for their elimination will be known to users.

B2 PRELIMINARY HAZARD ANALYSIS (PHA) PHA is an inductive method whose objective is to identify for a specified system, subsystem or component and for all its phases, the hazards, hazardous situations and events that can cause harm or which could lead to an accident. The method is completed with the identification of the probabilities of the accident occurring, the qualitative evaluation of the degree of the possible injury or damage to health and afterwards with proposing safety measures and the results of their application.

PHA shall be updated during the phases of design, building and testing to detect new hazards and to make corrections, if necessary.

The description of the obtained results can be carried out in different ways (e.g. table and tree).

B3 HAZARD AND OPERABILITY STUDY (HAZOP) A HAZOP study is a systematic technique for identifying hazards or operational problems for a whole plant. Each section of a process is examined and all possible deviations from normal operating conditions and how they might occur are listed. The consequences on the process are assessed, and the measures to detect 'probable' deviations that could lead to hazardous events or operational problems are identified.

B4 EXAMPLES OF HAZARDS

B4.1 General This Paragraph provides a non-exhaustive list of hazards which may be present in machinery and also examples of hazardous events related to machinery.

Not all of the hazards will appear in all machinery and it is intended that only those hazards which are applicable to a particular machine will be identified for analysis.

B4.2 Mechanical hazards Mechanical hazards may be caused by many factors in machinery, including the following:

- (a) Machine parts or workpieces, generated by—
 - (i) shape;
 - (ii) relative location;
 - (iii) mass and stability (potential energy within elements which may move under the effect of gravity);

- (iv) mass and velocity (kinetic energy within elements in motion); and
 - (v) insufficient mechanical strength.
- (b) Accumulation of energy within the machine, caused by—
 - (i) elastic elements, such as springs;
 - (ii) liquids or gases under pressure; and
 - (iii) vacuum.
- (c) Elementary forms of mechanical hazards such as—
 - (i) crushing hazards;
 - (ii) shearing hazards;
 - (iii) cutting or severing hazards;
 - (iv) entanglement hazard;
 - (v) drawing-in or entrapment hazard;
 - (vi) impact or puncturing hazards;
 - (vii) friction or abrasion hazards; and
 - (viii) high pressure fluid injection.

B4.2 Electrical hazards Factors relating to electrical hazards include the following:

- (a) Contact with live parts.
- (b) Contact with parts which have become live under fault conditions.
- (c) Approach to live parts carrying a high voltage.
- (d) Electrostatic phenomena.
- (e) Thermal radiation.
- (f) Ejection of molten particles.
- (g) Chemical effects from overloads or short circuits.

B4.3 Thermal hazards Thermal hazards may result in the following—

- (a) burns and scalds caused by direct contact by persons with a heat source, by flames or explosions or by radiation from heat sources; and
- (b) health damaging effects from hot or cold working environments.

B4.4 Noise hazards Hazards generated by noise may give rise to the following—

- (a) hearing loss or other physiological disorders such as loss of balance or loss of awareness; and
- (b) interference with speech communications or acoustic signals.

B4.5 Vibration hazards Hazards generated by vibration from hand-held machinery may give rise to a number of vascular and neurological conditions. Similarly, whole body vibration can cause a number of physiological conditions, e.g. motion-sickness.

B4.6 Radiation hazards Hazards may be generated by a variety of sources including the following:

- (a) Low frequency or radiofrequency radiation or microwaves.
- (b) Infrared, visible and ultraviolet light.
- (c) X-rays and gamma radiation.
- (d) Alpha or beta rays, electron or ion beams and neutron radiation.
- (e) Lasers.

B4.7 Hazards generated by material and substances Many hazards may be generated by the materials used by machinery or during processing. The hazards may arise from the following:

- (a) Contact with or inhalation of harmful fluids, mists, gases, fumes or dust.
- (b) Fire or explosion, e.g. as a result of dust or similar contaminants.
- (c) Biological or microbiological agents.

B4.8 Neglect of ergonomic principles Hazards may be generated by not paying sufficient attention to the principles of ergonomics. These hazards may include the following:

- (a) Unhealthy posture or excessive effort.
- (b) Inadequate consideration of anatomical factors.
- (c) Inadequate local lighting.
- (d) Mental overload, boredom or stress.
- (e) Human error or human behaviour.

B4.9 Combination of hazards Several hazards may be present in the one machine. Care must be taken to ensure that all foreseeable hazards are identified.

B5 HAZARDOUS EVENTS Examples of events which may result in risk from the hazards in Paragraph B4 are as follows:

- (a) Unexpected start-up, unexpected overrun or overspeed arising from—
 - (i) failure of the control system;
 - (ii) restoration of energy supply after an interruption;
 - (iii) external influences on electrical equipment;
 - (iv) influences such as gravity or wind;
 - (v) software errors; or
 - (vi) operator errors.
- (b) Inability to stop the machine in the shortest possible time.
- (c) Variations in the rotational speed of tools.
- (d) Failure of the power supply.
- (e) Failure of the control circuit.
- (f) Errors of fitting, e.g. plug and socket may be connected incorrectly or filters incorrectly installed.
- (g) Break up during operation.
- (h) Falling or ejected objects or fluids.
- (i) Loss of stability or overturning machinery.
- (j) Slip, trips or fall of person which is related to the machinery.

B6 ADDITIONAL HAZARDS AND EVENTS DUE TO MOBILITY The mobility of some machinery may lead to some additional hazards and hazardous events. Examples of these hazards and events include the following:

- (a) The hazards and events relating to the travelling function which include—
 - (i) movement when starting the engine or motor;
 - (ii) movement without a driver at the driving position;
 - (iii) movement without all parts in a safe position;
 - (iv) excessive speed of pedestrian controlled machinery;
 - (v) excessive oscillations while in motion; and
 - (vi) insufficient ability of machinery to be slowed, stopped and immobilized.

- (b) Hazards and events relating to working positions, including the driver's position on the machine which may lead to the following:
 - (i) People falling onto or from the work position.
 - (ii) Insufficient oxygen or the presence of exhaust gases at the work position.
 - (iii) Fire.
 - (iv) Mechanical hazards at the workplace.
 - (v) Insufficient visibility from the work positions.
 - (vi) Inadequate lighting.
 - (vii) Inadequate seating.
 - (viii) Noise or vibration at the work positions.
 - (ix) Inadequate means of evacuation or emergency exits.
- (c) Hazards and events relating to the control system, which include—
 - (i) poor location of controls or control devices, and
 - (ii) poor design of actuation mode of controls or control devices.
- (d) Lack of stability.
- (e) Hazards relating to the power source or transmission of power or, arising from the transmission of the machinery which include—
 - (i) hazards from the engine or any batteries;
 - (ii) hazards from the transmission of power between machines; and
 - (iii) hazards from coupling and towing.
- (f) Insufficient instruction to, or training of, the driver.
- (g) Unauthorized use.
- (h) Insufficient visual or acoustic warning devices (flashing lights or horns).

B7 ADDITIONAL HAZARDS AND EVENTS DUE TO LIFTING A number of hazards arise when a large mass is to be raised, lowered or moved from one location to another with the aid of mechanical lifting devices or trucks. These hazards include the following:

- (a) Falling loads, collisions or machine tipping caused by—
 - (i) lack of stability;
 - (ii) uncontrolled loading, overloading or overturning;
 - (iii) uncontrolled amplitude of movements;
 - (iv) unexpected or unintended movement of load;
 - (v) inadequate holding devices or accessories;
 - (vi) lifting of persons;
 - (vii) insufficient strength of parts;
 - (viii) inadequate design of drums or pulleys;
 - (ix) incorrect selection or mounting of chains, ropes or accessories;
 - (x) lowering the load using a friction brake;
 - (xi) abnormal conditions of assembly, use, testing or maintenance;
 - (xii) insufficient visibility from the driving or operating position; and
 - (xiii) inadequate communication or signalling.

APPENDIX C

METHODS FOR ANALYSING HAZARDS AND ESTIMATING RISKS

(Informative)

C1 GENERAL There are many methods of hazard analysis and risk estimation and only a few are given in this Appendix. Also included are risk analysis techniques which combine hazard analysis with risk estimation.

Each method has been developed for particular applications. So it may be necessary to modify them in detail for the special application for machinery.

There are two basic types of risk analysis; one is called the deductive method and the other the inductive method. In the deductive method the final event is assumed and the events which could cause this final event are then sought.

In the inductive method the failure of a component is assumed. The subsequent analysis identifies the events which could result from this failure.

C2 'WHAT-IF' METHOD For relatively uncomplicated applications, the process is reviewed from raw materials to product. At each handling or processing step 'what if' questions are formulated and answered to evaluate the effects of component failures or procedural errors on the process.

For more complex applications, the 'what if' method can be best applied through the use of a 'checklist' and by dividing the work in order to assign certain aspects of the process to the persons having the greatest experience or skill in evaluating those aspects. Operator practices and job knowledge are audited in the field, the suitability of equipment and materials of construction are studied, the chemistry of the process and the control systems are reviewed and the operating and maintenance records are audited. Generally, a checklist evaluation of a process precedes use of the more sophisticated methods described below, unless the process has been operated safely for many years and has been subjected to periodic and thorough safety inspections and audits.

C3 FAILURE MODE AND EFFECT ANALYSIS (FMEA) FMEA is an inductive method where the main purpose is to evaluate the frequency and consequences of component failure. Therefore it may not be suitable when operating procedures or operator error are significant.

FMEA can be more time consuming than a fault tree, e.g. because for every component every mode of failure has to be considered. Failures which have a very low probability of occurrence may not have to be analysed in depth however but this decision should be recorded in the documentation.

C4 DEFI METHOD DEFI is a method which uses the injection of faults into a computerized system to estimate the rate of failure to danger of a particular system.

C5 MOSAR METHOD (METHOD ORGANIZED FOR A SYSTEMIC ANALYSIS OF RISKS) MOSAR is a complete approach in 10 steps which, considers the system to analyse (machinery, process and installation) as being made of subsystems in interaction, identifies the hazard, the hazardous situations and the events that may cause harm with the use of a first table.

The adequacy of the prevention means is studied with a second, then a third table taking into account their interdependency.

The operating safety study using known tools (FMEA, HAZOP and similar) underlines the possible dangerous failures. This leads to the elaboration of scenarios shown as logical trees in which the scenarios are sorted in a gravity table elaborated with the consensus of concerned persons.

A table set by consensus links the severity with the objectives to be met by preventive measures and indicates the number of technological barriers (with no human intervention) and utilization barriers (with human intervention).

The prevention barriers are then incorporated into logic trees and the residual risks are analysed via an acceptability table defined by consensus.

C6 FAULT TREE ANALYSIS FTA is primarily a means of analysing (not identifying) hazards. Hazardous or top events are first identified by other techniques such as HAZOP. Then all combinations of individual failures that can lead to that hazardous event are shown in the logical format on the fault tree. By estimating the individual failure probabilities and then using the appropriate arithmetical expressions, the top-event frequency can be calculated. The impact of process change on the top-event frequency can readily be evaluated and thus, FTA makes it easy to investigate the impact of alternative preventive measures. It has also been found useful in determining the cause of accidents.

C7 DELPHI TECHNIQUE A large circle of experts is questioned in several steps, whereby the result of the previous step together with additional information is communicated to all participants.

During the third or fourth step the anonymous questioning concentrates on those aspects for which no agreement has been reached.

Basically DELPHI is a forecasting method which is also used in generating ideas. The method is particularly efficient due to its limitation to experts.

APPENDIX D

TWO-HAND CONTROL DEVICES

(Normative)

D1 SCOPE This Appendix specifies the safety requirements of a two-hand control device as defined in Clause 9.3.3. It describes the main characteristics of two-hand control devices for the achievement of safety. This Appendix does not apply to devices intended to be used as enabling devices, hold-to-run devices and as special control devices.

The Appendix does not specify with which machines two-hand control devices may be used. Nor does it specify which types of two-hand control devices should be used.

The Appendix provides requirements and guidance on the design and selection of two-hand control devices including the prevention of defeat, the avoidance of faults and the assessment of two-hand control devices containing a programmable electronic system (see Paragraph D4) when indicated by the risk assessment.

This Appendix applies to all two-hand control devices regardless of the energy source, including those which are or are not integral parts of a machine and those which consist of one or more separate elements.

D2 CHARACTERISTICS OF SAFETY FUNCTIONS

D2.1 General The characteristics of safety functions described in Paragraphs D2.2 to D2.7 shall be included in two-hand control devices.

D2.2 Relationship between input signal and output signal The input signal applied to each of the two control-actuating devices shall together initiate and maintain the output signal from the two-hand control device only so long as both input signals are applied. The form of the output signal (e.g. in number of channels, by pulse and shape) may vary according to the design requirements in each case. It shall always be regarded and identified as a single output signal by the machine control circuit.

D2.3 Cessation of the output signal The release of either one or both control-actuating devices shall initiate the cessation of the output signal.

D2.4 Prevention of accidental operation The probability of operating the control-actuating devices accidentally shall be minimized.

D2.5 Prevention of defeat The protective effect of the two-hand control device shall not be easily defeated. See Figure D1 for measurement tests to prevent defeat.

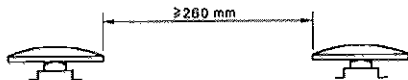
D2.6 Reinitiation of the output signal The reinitiation of the output signal shall only be possible after the release of both control-actuating devices.

D2.7 Synchronous actuation An output signal shall be generated only when both control-actuating devices are actuated in a time which is less than or equal to 0.5 s (see Figure D2).

Mechanical two-hand control devices shall only generate an output signal by satisfying particular spatial requirements for the travel of both of the control-actuating devices.

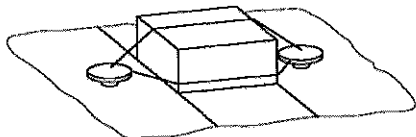
If the control-actuating devices are not actuated synchronously the output signal shall be prevented and it shall be necessary to release both control-actuating devices and to reapply both input signals.

NOTE: Where two or more two-hand control devices are used to operate one machine, synchronous actuation is required only within each two-hand control device and is not required between devices.



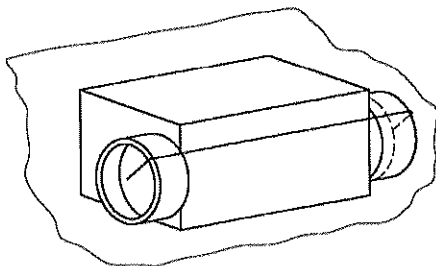
NOTE: Separation of the control-actuating devices by a distance equal to or more than 260 mm.

(a) Prevention of defeat using one hand: separation by distance



NOTE: Separation of the control-actuating devices by one or more shields or an elevated area designed in such a way that the control-actuating devices cannot be touched with the ends of a 260 mm cord representing the finger-span.

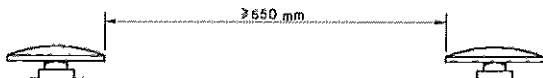
(b) Prevention of defeat using one hand: separation by an elevated area



NOTE: Separation of the control-actuating devices by collars and by orientation in such a way that the control-actuating devices cannot be touched with the ends of a 260 mm cord.

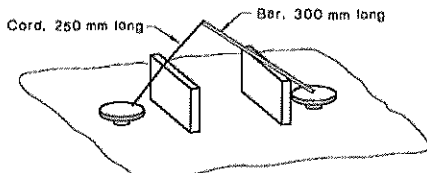
(c) Prevention of defeat using one hand: separation by collars and by orientation

FIGURE D1 (in part) MEASUREMENT TESTS FOR THE PREVENTION OF DEFEAT



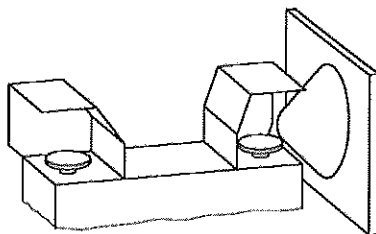
NOTE: Separation of the control-actuating devices by a distance not less than 550 mm and not greater than 600 mm.

(d) Prevention of defeat using one hand and elbow



NOTE: Separation of the control-actuating devices by the provision of one or more shields, or an elevated area, designed in such a way that the control-actuating devices cannot be touched at the same time with both ends of measuring equipment consisting of a 300 mm rigid bar, not exceeding 5 mm diameter, and a 250 mm cord attached to it. The bar represents the forearm and the cord the hand and is to be applied in all possible operating positions.

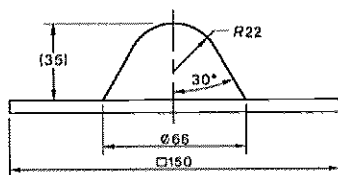
(e) Prevention of defeat by using one hand and elbow



NOTE: Separation of the control-actuating devices by shields which are designed towards the operating side and also the rear in such a way that the control-actuating devices cannot be operated from the operating side with the tip of the test cone representing the elbow.

(f) Prevention of defeat by using one hand and elbow

FIGURE D1 (in part) MEASUREMENT TESTS FOR THE PREVENTION OF DEFEAT



DIMENSIONS IN MILLIMETRES

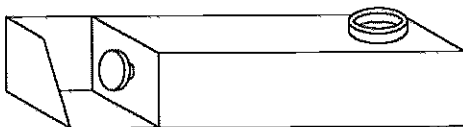
(g) Test cone



NOTES:

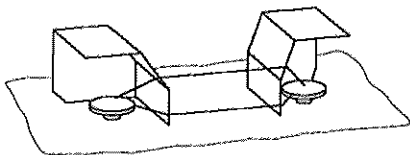
- 1 Control-actuating devices with different types of directions of operation.
- 2 For this configuration use also cord and bar and test cone for collar.
- 3 For this configuration use also cord and bar and test cone for collar and for shield.

(h) Separation by collar and by shield

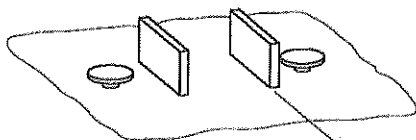


(i) Separation by collar, by shield and by orientation
For this configuration, use test cone

FIGURE D1 (in part) MEASUREMENT TESTS FOR THE PREVENTION OF DEFEAT



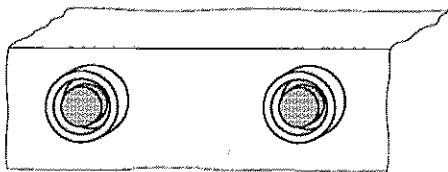
(j) Prevention of defeat using forearm or elbow



At least 1100 mm
above floor
or level access

NOTE: Arrangement of the control-actuating devices on a horizontal or nearly horizontal surface at least 1100 mm above floor or level of access.

(k) Prevention of defeat by position



NOTE: Arrangement of the control-actuating devices on a vertical or nearly vertical surface with protective collar(s) around the control-actuating devices and/or shield(s).

(l) Separation by collars and by position

FIGURE D1 (In part) MEASUREMENT TESTS FOR THE PREVENTION OF DEFEAT

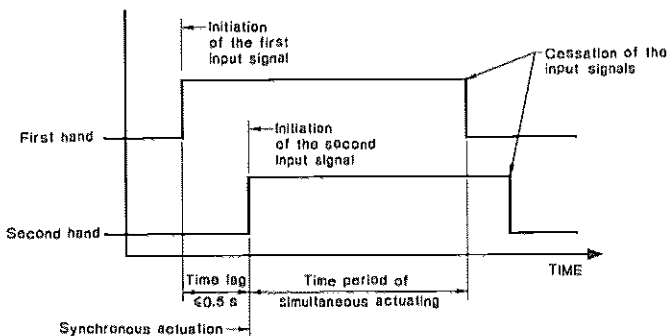


FIGURE D2 INPUT SIGNALS OF SYNCHRONOUS ACTUATION

D3 REQUIREMENTS RELATED TO CATEGORIES OF CONTROL

D3.1 Behaviour The behaviour of a two-hand control device in the case of failure shall be in accordance with the selected category of control.

The category of control of two-hand control devices shall not be less than the category of control of the relevant safety related part of the machine control system.

D3.2 Use of two-hand control When the risk assessment indicates the requirement of single fault safety, the two-hand control device shall comply with the following:

- The single fault in the two-hand control shall not lead to the loss of the safety function(s).
- The two-hand control device shall not be converted into a one-hand control device as a consequence of the one fault.
- An output signal shall not be generated as a consequence of the one fault.

NOTE: These requirements do not mean that all faults will be detected. Consequently, the accumulation of undetected faults may lead to the loss of the safety function and to an unintended output of the two-hand control device.

D4 USE OF PROGRAMMABLE ELECTRONIC SYSTEMS Where a programmable electronic system (PES) is used to achieve the functional characteristics of a two-hand control device, the safety performance of the hardware and software of the PES shall be validated to the level indicated by the risk assessment.

Secure means shall be provided for the software and the hardware of the PES to ensure that the designed functional characteristics cannot be tampered with.

The output signal of a two-hand control device shall not be generated and transferred solely by a single channel PES to the machine control system.

NOTE: There is still considerable development in the ways in which programmable electronic systems are being validated.

D5 GENERAL REQUIREMENTS

D5.1 Ergonomic requirements There will sometimes be a conflict between good ergonomic principles and the necessity to design a two-hand control device which will prevent defeat or accidental actuation (e.g. the size of openings and the need to wear gloves during some operations).

Means and measures to achieve safety need to reflect a balance between the need to follow good ergonomic principles, and the need to provide measures to prevent defeat and accidental actuation.

The balance shall provide adequate safety for the particular risk.

D5.2 Operating conditions, environmental influences The components of a two-hand control device shall be selected, installed and linked together in such a way that they withstand the operating stresses expected, and fulfil the requirements of the relevant standards (e.g. with regard to switching capacity and switching frequency) and the relevant standards dealing with the environmental influence expected (e.g. vibration, impact, temperature, foreign bodies, moisture, oil and electromagnetic fields).

D5.3 Enclosures Enclosures and their mountings shall be designed to withstand the expected operating and ambient stresses. Corners or edges shall be round or bevelled so as to avoid injury. Covers and parts which are intended to be removed or opened shall be constructed so that they can only be removed or opened with the aid of a tool. Fasteners shall be of the captive type.

When enclosures are mounted on stands, the stands shall be provided with facilities for secure mounting to the enclosures and to the floor.

Enclosures shall be mounted and positioned so that the operator, after releasing an actuator, cannot reach the danger zone during the hazardous situation (see Paragraph D5.8).

If the enclosure supporting the control-actuating devices is adjustable, it shall be provided with means for locking it in position (for mobile two-hand control devices, see Paragraph D5.7).

D5.4 Selection, design and installation of control-actuating devices Control-actuating devices shall be selected, designed, arranged and installed in such a way that they can be actuated without undue fatigue (e.g. as a result of awkward posture, unsuitable movements or high operating forces). Control-actuating devices shall not be red, nor shall they form any crushing or shearing points with any other parts.

D5.5 Prevention of unintended output signals by acceleration forces Foreseeable forces caused by acceleration to the two-hand control device shall not cause an output signal (e.g. falling over, accidental impact or shockloading).

D5.6 Unintended operation of mobile and portable hand held machines A two-hand control device shall be designed to prevent its unintended operation due to the normal handling of the mobile or portable hand-held machine which it controls. It shall be designed so that separate and dissimilar actions of the control-actuating devices are required to give the input signal to start the dangerous motion of the machine.

NOTES:

- 1 The provision of the two control-actuating devices in separate handles will not satisfy this requirement unless their method of operation is different.
- 2 The provision of a lock-out facility on one of the control-actuating devices would provide a higher level of safety.

D5.7 Mobile two-hand control devices The actuators and the supporting enclosure of a mobile two-hand control device shall be stable in normal use and shall be fitted with means to prevent movement while in use.

NOTE: This may be fulfilled by including a large mass or any other suitable means.

Facilities shall be available for maintaining and checking the required safety distance between the control-actuating devices and the danger zone, e.g. by distance rings to maintain the distance. (See Figure D3.)

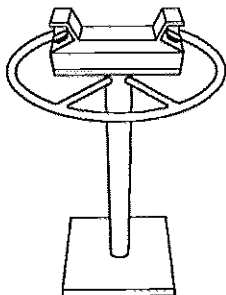


FIGURE D3 MOBILE TWO-HAND CONTROL DEVICE WITH DISTANCE RING

Pipes, cables and connections shall be protected against damage using the considerations of Paragraph D5.2.

D5.8 Safety distance To calculate the required safety distance between the control-actuating devices and the danger zone the following shall be taken into account (see Clause 9.3.3):

- (a) Hand/arm speed.
- (b) The shape and arrangement of the two-hand control device.
- (c) The response time of the two-hand control device.
- (d) The maximum time taken to stop the machine, or remove the hazard, following cessation of the output signal from the two-hand control device.
- (e) The intended use of the machine.

D6 INFORMATION FOR USE Information shall be provided by the manufacturer or his authorized representative on the installation, use and maintenance of the two-hand control device. The information may be given in the form of drawings, diagrams, tables or written information.

APPENDIX E

INTERLOCKING DEVICES

(Normative)

E1 GUARD-OPERATED INTERLOCKING DEVICE WITH ONE CAM-OPERATED POSITION DETECTOR

E1.1 Principle One single detector, actuated in the positive mode, monitors the position of the guard (see Clause 10.6 and Figures E1 and E2).

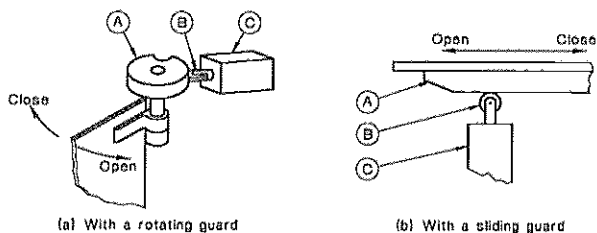


FIGURE E1 CAM-OPERATED POSITION DETECTOR

E1.2 Advantages These include the following:

- (a) Positive mechanical action of the cam (A) on the actuator (B) of the position detector (C).
- (b) Impossible to defeat by manually operating the actuator without moving cam or detector.

E1.3 Disadvantages These include the following:

Fails to danger in case of—

- (a) wear, breakage, etc. causing malfunction of the actuator; or
- (b) maladjustment of the detector or cam relative to its mounting.

E1.4 Remarks These include the following:

- (a) As the absence of the guard is not detected, it is essential that the guard cannot be dismantled without tools.
- (b) See also Clauses 10.7 and 10.8.

E1.5 Example: Electriflex interlocking device incorporating one single cam-operated switch (see Clause 10.12.2.1)

E1.5.1 Advantages These include the following:

- (a) Positive mechanical action of the guard on the actuator of the switch.
- (b) Positive opening operation of the break contact of the switch.

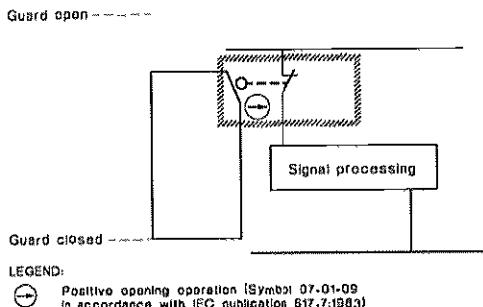


FIGURE E2 ELECTRICAL INTERLOCKING DEVICE USING CAM-OPERATED SWITCH

E1.5.2 Disadvantage Fails to danger in case of the following:

- (a) Failure of the mechanical link between guard and switch.
- (b) Electrical bypassing of the switch.

E2 GUARD-OPERATED INTERLOCKING DEVICE WITH TONGUE-OPERATED SWITCH

E2.1 Principle:

The device comprises the following—

- (a) a circuit-breaking element (D) see Figure E3; and
- (b) a mechanism which, when operated, causes the circuit-breaking element to be opened and closed (for electrical devices: positive opening operation).

A specially shaped part (tongue) is fixed on the guard (e.g. riveted) so that this tongue cannot be easily removed.

The circuit-breaking element only ensures the continuity of the circuit when the tongue is inserted into the detector.

When the tongue is withdrawn (when opening the guard), it operates the mechanism which opens the circuit-breaking element.

E2.2 Advantages These include the following:

- (a) Only a small displacement of the guard is needed for the detector to change its state.
- (b) Especially suitable for use—
 - (i) on the opening edge of a guard (door);
 - (ii) with guards which can be removed without the use of tools; and
 - (iii) with guards having neither a hinge nor a guide connecting them to the machine.

E2.3 Disadvantage Can be defeated by using a tongue which is not attached to the guard.

E2.4 Remark For measures against defeat, see Clause 10.12.2.2.

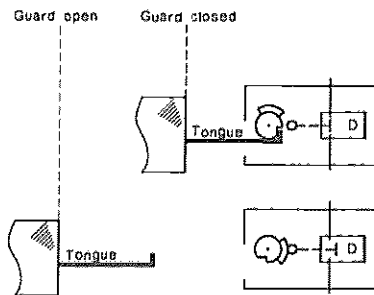


FIGURE E3 TONGUE-OPERATING SWITCH

E3 DIRECT (MECHANICAL) INTERLOCKING BETWEEN GUARD AND START/STOP MANUAL CONTROL

E3.1 Principle When the start/stop manual control (in this case a lever) is in the raised position, it prevents the guard being opened. Lowering the lever causes the device it actuates to positively interrupt circuit continuity (thus directly interrupting power to the actuator(s) if the device is part of the power circuit, or generating a stop command if it is a control device). When in the lower position, the lever makes it possible to open the guard. As long as the guard is open, it prevents the lever being lifted, (see Figure E4).

E3.2 Advantage Reliability through simplicity, especially when used as a power interlocking device (see Clause 10.4.2).

E3.3 Remark The lever (or its equivalent) is designed to withstand the expected forces and cannot be easily dismantled. A mechanical stop prevents overtravel of the guard.

E4 CAPTIVE-KEY INTERLOCKING DEVICE

E4.1 Description A combination of a switch and a lock is secured to a fixed part of the machine. The operating key is held captive on the moving part of the guard, (see Figure E5).

E4.2 Principle The following operating principle of captive-key interlocking devices is described by the sequence of operations for guard opening:

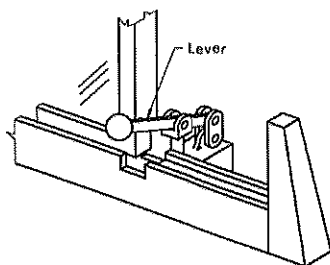
- Turn handle to switch off (stop command is given).
- Further turn to unlock guard.
- Open guard (key disengages from lock).

E4.3 Advantages These include the following:

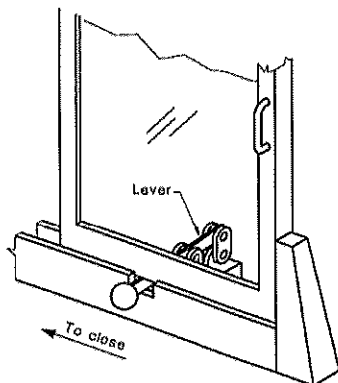
- Ensures that the circuit-breaking element will be opened before the guard can be opened.
- Especially suitable when the guard is hinged or can be removed completely.

E4.4 Remarks These can consist of the following:

- Can be combined with a time-delay unit. Thus, it becomes an interlocking device with guard locking and conditional unlocking.
- Alignment of the key and lock can be aided by providing a location pin or pins which engage in bushes prior to the key entering the lock.



'Start/stop' lever prevents the guard being opened
(a) Guard closed



Guard prevents lifting 'start/stop' lever, thus preventing
restoration of circuit continuity
(b) Guard open

FIGURE E4 DIRECT INTERLOCK

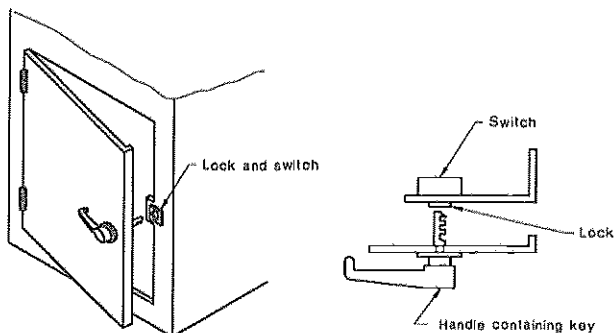


FIGURE E5 CAPTIVE KEY INTERLOCK

E5 TRAPPED-KEY INTERLOCKING DEVICE

E5.1 Principle A trapped-key interlocking device is an interlocking device relying upon the transfer of keys between a control element and a lock fixed on the guard (see Figure E6).

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 as in the captive key interlocking device.

The essential feature of the system is that the removable 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 circuit-breaking element to be actuated, then a key-exchange box (D) is necessary. All keys shall be transferred and locked in before the access key, which is of a different configuration, can be released for transfer to the guard lock. Where there is more than one guard, the exchange box will accommodate an equivalent number of access keys.

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

E5.2 Advantages These include the following:

- (a) No reduction of integrity due to the distance between guard and control system.
- (b) No need for electrical wiring to each guard.
- (c) Suitability when the guard is placed in hostile environment.
- (d) Can be used when the guard is capable of complete removal.
- (e) Particularly suitable when several different types of power source are present on the machine and for power interlocking.

- (f) Personal keys can be released for access to guarded areas where persons could become enclosed.

E5.3 Disadvantages These include the following:

- Not suitable for applications requiring very fast access times.
- Duplicate keys can become available for defeating (see Clause 10.12.1).

E5.4 Remarks Delay between opening of the circuit-breaking element and unlocking of the guard is ensured merely by key-transfer time (increased, if necessary, by a time-delay device).

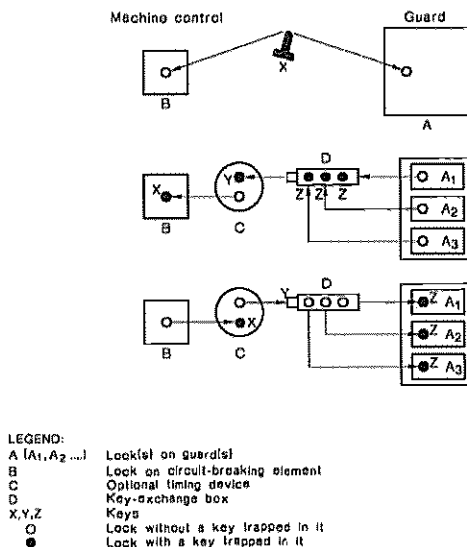


FIGURE E6 TRAPPED KEY INTERLOCK

E6 PLUG AND SOCKET INTERLOCKING DEVICE (PLUG/SOCKET COMBINATION)

E6.1 Principle Circuit breaking by unplugging.

A plug and a socket (or base) are used as an interlocking device, one part mounted on the machine, the other part connected to the guard. See Figure E7.

E6.2 Advantage Reliability through simplicity.

E6.3 Disadvantages Generally not suitable for applications requiring very frequent access.

E6.4 Remarks

E6.4.1 Hinged guard These consist of the following

- Pins and sockets are accessible when the plug is removed from the socket. It is then easy to complete the circuit using electric lead(s) when the guard is open.
- A possible measure to prevent this method of defeat is by the use of a multi-pin connector. Since the wiring arrangement is complex, it is more difficult to remake the circuit when the guard is open.

E6.4.2 Sliding guard These consist of the following:

- Both pins of the plug are linked to ensure that, when the guard is closed and the plug inserted into the socket, the circuit is complete.
- As the plug remains fixed to the guard and the guard covers the socket when open, it is not possible to restore the integrity of the circuit by inserting a bridging link into the socket.

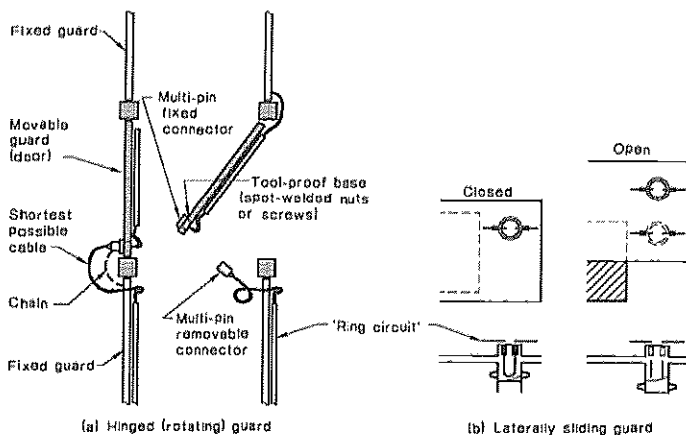


FIGURE E7 PLUG AND SOCKET INTERLOCKS

E7 GUARD-OPERATED INTERLOCKING DEVICE INCORPORATING TWO CAM-OPERATED POSITION DETECTORS

E7.1 Principle One detector is actuated in the positive mode. The other one is actuated in the non-positive mode (see Clause 10.6 and Figures E8 and E9).

E7.2 Advantages These include the following:

- Duplication of detectors avoids single fault failure to danger.
- Diversification of redundant components reduces the risk of common-cause failure.
- The non-positively actuated detector detects the absence of the guard.

E7.3 Remark Without monitoring, one faulty detector remains undetected, until a fault in the second detector results in failure to danger.

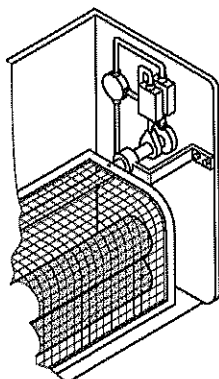


FIGURE E8 CAM-OPERATED POSITION DETECTORS

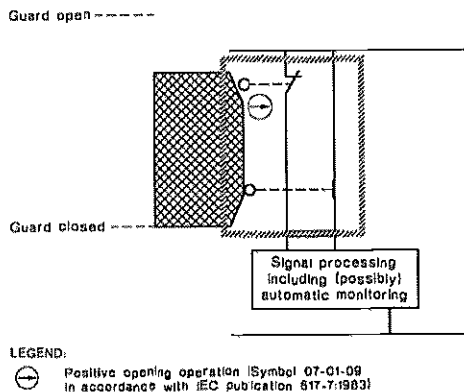


FIGURE E9 TYPICAL INSTALLATION

E8 MECHANICAL INTERLOCKING BETWEEN A GUARD AND A MOVABLE ELEMENT

E8.1 Principle Direct mechanical interlocking between a guard and a hazardous movable element. The function ensured is that of an interlocking guard with guard locking (see Figure E10).

E8.2 Remarks These consist of the following:

- (a) The application is limited to very simple mechanisms.
- (b) Manual positioning of the movable part may be required to make it possible to open the guard.

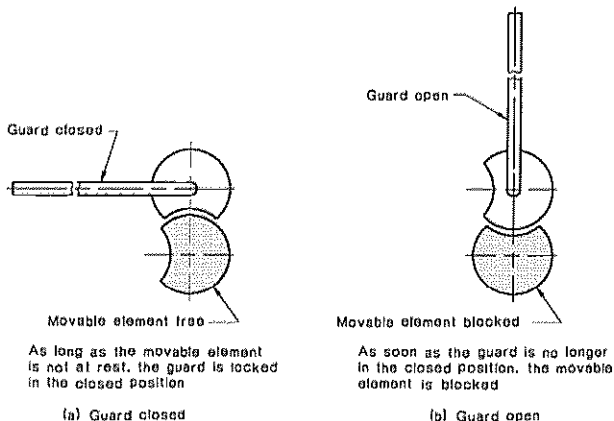


FIGURE E10 MECHANICAL INTERLOCK

E9 ELECTRICAL INTERLOCKING DEVICE INCORPORATING MAGNETICALLY ACTUATED (MAGNETIC) PROXIMITY SWITCHES

E9.1 Principle A coded magnet, fitted to the guard, actuates a normally open and a normally closed reed switch (see Figure E11).

E9.2 Advantages These include the following:

- (a) Compact; no external moving parts.
- (b) High resistance to dust, liquids.
- (c) Easily kept clean.

E9.3 Disadvantages These include the following:

- (a) Sensitive to electromagnetic interference.
- (b) No positive opening of contacts.
- (c) Possible contact welding in case of overcurrent.

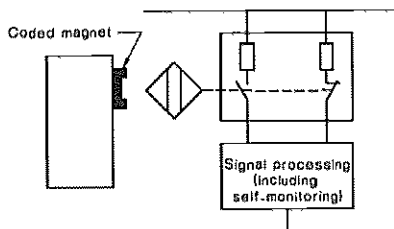


FIGURE E11 ELECTRICAL INTERLOCKING DEVICE (MAGNETIC)

E9.4 Remarks These include the following:

- (a) The disadvantages quoted above make it necessary for the magnetic switches to be automatically checked at each switching cycle, and for overcurrent protection to be provided (see Clause 10.15.5).
- (b) The device is designed so as to require a coded magnet in order to be actuated. This prevents it being defeated in a simple manner.

E10 ELECTRICAL INTERLOCKING DEVICE INCORPORATING TWO PROXIMITY DETECTORS

E10.1 Principle D_1 and D_2 are proximity detectors, able to detect metal parts (in this case, the guard). (See Figure E12).

E10.2 Advantages These include the following:

- (a) No moving parts.
- (b) High resistance to dust, liquids.
- (c) Easily kept clean.
- (d) Compact.

E10.3 Disadvantages These include the following:

- (a) Sensitive to electrical interference.
- (b) No positive opening operation of contacts.
- (c) Possibility of contact welding causing failure to danger if no overcurrent protection is ensured.

E10.4 Remarks These include the following:

- (a) As long as it is open, the guard conceals D_1 , thus preventing defeat of this detector by simple means.
- (b) It can be an advantage to have in the interlocking device, two switches with substantially different technological properties so that it is highly improbable that the same spurious phenomenon can affect them simultaneously (this is known as diversity or heterogeneous redundancy and is intended to prevent 'common-cause failures').

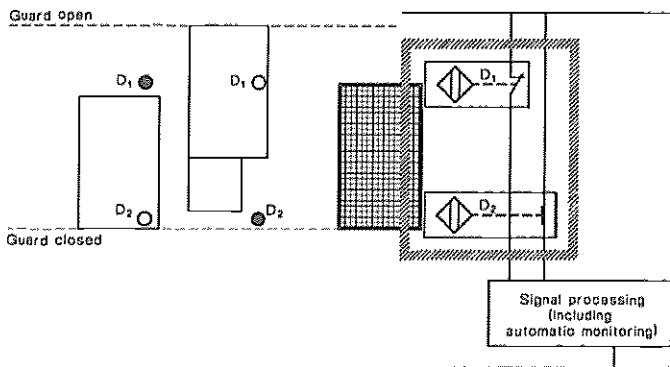


FIGURE E12 ELECTRICAL INTERLOCKING DEVICE (PROXIMITY DETECTORS)

E11 PNEUMATIC/HYDRAULIC INTERLOCKING DEVICES

E11.1 Principle Two independent interlocking devices (A and B) are provided: A acts on the electrical control circuit (with automatic monitoring); B acts on the hydraulic circuit power interlocking. (See Clause 10.4.2 when direct interruption of the power circuit is possible). (See Figure E13.)

E11.2 Remark This solution is particularly useful in very severe environmental conditions which may induce 'common cause failures' (i.e. simultaneous failures having the same cause) of components with the same technology: e.g. melting of the insulating layer of conductors on a machine working under hot conditions or simultaneous failure to two proximity detectors under the effect of electric or electromagnetic interference.

E12 INTERLOCKING DEVICE WITH SPRING APPLIED/POWER RELEASED GUARD LOCKING DEVICE

E12.1 Principle

E12.1.1 Variant A Interlocking function ensured by detecting separately guard position and lock position. C₁ detects the position of the guard and C₂ detects the position of the lock. (See Figure E14.)

Release of the lock when the hazard has disappeared can be controlled either by a timing device (timer) or by a stop-detection device.

E12.1.2 Variant B Interlocking function ensured by detecting lock position only. In detecting the lock position, one single detector (C) also monitors the guard position, provided that the condition 'C cannot close if the guard is not closed' is rigorously and reliably performed due to good design and construction of the 'guard-lock-contract (C)' assembly. (See Figure E15.)

E12.2 Remark (valid for both variants) Whatever device (electromagnet or cylinder) is used to actuate the lock which keeps the guard closed, it is essential that fail-safe conditions be established; i.e. if power supply is cut, the lock remains in the position in which it renders the guard immobile.

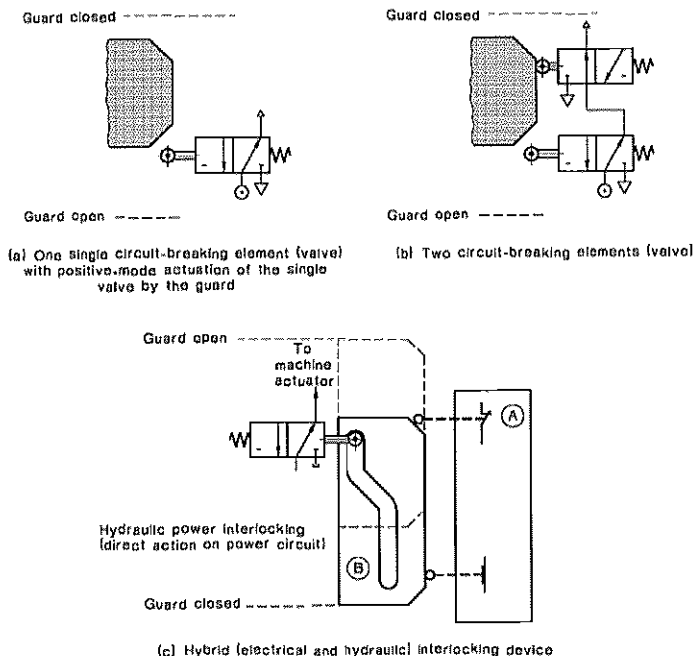


FIGURE E13 PNEUMATIC OR HYDRAULIC INTERLOCKS

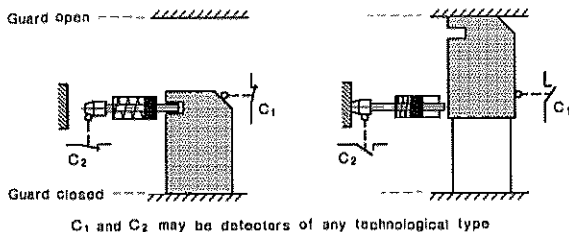


FIGURE E14 SEPARATE DETECTION OF GUARD POSITION

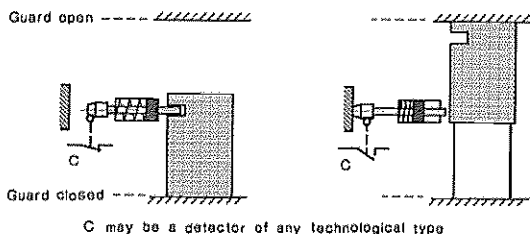


FIGURE E15 INTEGRATED DETECTION OF GUARD POSITION

E13 INTERLOCKING DEVICE WITH GUARD LOCKING, AND MANUALLY OPERATED DELAY DEVICE

E13.1 Principle The threaded pin is turned by hand (unconditional unlocking). The time clapsing between the switch opening and guard release is set so that it is longer than the time taken to stop the hazardous functions (see Figure E16).

When opened, the guard prevents the pin being screwed in again, thus closing the switch contacts.

E13.2 Advantage Reliability through simplicity.

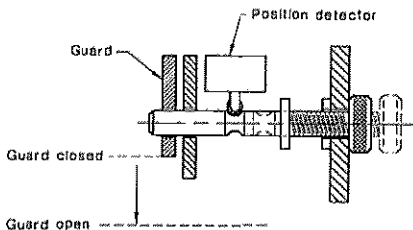


FIGURE E16 MANUALLY OPERATED DELAY

APPENDIX F

GUIDANCE FOR THE SELECTION OF CATEGORIES

(Normative)

F1 SCOPE This Appendix describes a simplified method selecting the appropriate categories of interlock as reference points for the design of various safety aspects of a control system.

To quantify risk is often very difficult and this method is only concerned with the contribution to risk reduction made by the interlocks within the control system under consideration and providing it is intended to guide the designer in a choice of category based on interlock behaviour in case of a fault. However, this is only one aspect and other influences will also contribute to the assessment that adequate safety has been achieved. These influences include, for example component reliability, the technology used, the particular application, and they can indicate a deviation from the expected choice of category.

F2 METHOD The severity of injury (denoted by S) is relatively easy to estimate, e.g. laceration, amputation or fatality. For the frequency of occurrence, auxiliary parameters are used to improve the estimation. These parameters are—

- (a) frequency and exposure time to the hazard (F); and
- (b) possibility of avoiding it (P).

Experience has shown that these parameters can be combined as shown in Figure F1 to give a range of risk from low to high. It is emphasized that this is a qualitative process which gives only an estimation.

In Figure F1, the preferred categories are indicated by a large filled circle. In some applications the designer can deviate to another category indicated by either a small circle or a large unfilled circle. Other categories than those preferred can be used, but the intended system behaviour in case of faults should be maintained and the reasons for deviating given. These reasons can include the use of different technologies, e.g. well-ried hydraulic or electromechanical components (category 1) in combination with an electrical or electronic system (category 3 or 4). When lower categories (small circle in Figure F1) are selected, additional measures can be required, e.g. over dimensioning; the use of techniques leading to fault exclusion or the use of dynamic monitoring.

F3 GUIDANCE IN SELECTING PARAMETERS S, F AND P FOR RISK ESTIMATION

F3.1 Severity of injury (S1 and S2) In estimating the risk arising from a fault in the safety components of a control system only slight injuries (normally reversible) and serious injuries (normally irreversible and those including death) are considered.

To make a decision, the usual consequences of accidents and normal healing processes should be taken into account in determining S1 and S2, e.g. bruising or lacerations without complications would be classified as S1, whereas an amputation or death would be classified as S2.

F3.2 Frequency or exposure time to the hazard (F1 and F2) A generally valid time period when parameter F1 or parameter F2 should be selected cannot be specified. However, the explanation below can facilitate making the right decision in cases of doubt.

F2 should be selected if a person is frequently or continuously exposed to the hazard. It is irrelevant whether one or several persons are exposed to the hazard on successive exposures, e.g. for the use of lifts.

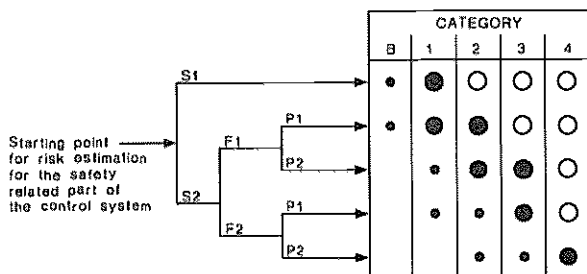
The period of exposure to the hazard should be evaluated as a proportion of the total time for which the machine is used.

The frequency of exposure should be evaluated in terms of the number of times an operator is exposed to the hazard during machine operation. For example, if it is necessary to reach regularly between the tools of the machine during cyclic operation in order to feed and remove workpieces, then F2 should be selected. If access is only required from time to time, then F1 can be selected.

F3.3 Possibility of avoiding the hazards (P1 and P2) When a hazard arises it is important to know if it can be recognized and whether it can be avoided before it leads to an accident. For example, an important consideration is whether the hazard can be directly identified by its physical characteristics or whether it can only be recognized by technical means, e.g. indicators. Other important aspects which influence the selection of parameter P include—

- (a) operation with or without supervision;
- (b) operation by experts or non-professionals;
- (c) speed with which the hazard arises (e.g. quickly or slowly);
- (d) possibilities for hazard avoidance, e.g. by taking flight or by intervention of a third party; and
- (e) practical safety experiences relating to the process.

When a hazardous situation occurs P1 should only be selected if there is a realistic chance of avoiding an accident or of significantly reducing its effect. P2 should be selected if there is no realistic chance of avoiding the hazard.



LEGEND:

S Severity of injury

S1, Slight (normally reversible) injury

S2, Serious (normally irreversible) injury, including death

F Frequency of exposure and/or exposure time to the hazard

F1, Seldom to quite often and/or the exposure time is short

F2, Frequent to continuous and/or the exposure time is long

P Possibility of avoiding the hazard

P1, Possible under specific conditions

P2, Scarcely possible

B.1 to 4, categories for safety related parts of control systems

● Preferred

● Possible categories which require additional measures, see B1

○ Over dimensioned

FIGURE F1 POSSIBLE SELECTION OF CATEGORIES

APPENDIX G
SELECTION OF CATEGORY AND INTERLOCK SYSTEM
(Normative)

G1 GENERAL One of the key objectives in machinery design is ensuring that reliability and integrity are maximized. The same objective exists when designing safeguarding systems or control measures introduced when hazards cannot be eliminated and some residual risk is evident. The design must ensure that faults within the safety related parts of control systems fail to safety and shall not lead to a hazardous situation at the machine.

The greater the level of risk reduction to be provided by the safety related parts of a control system, the higher the level of safety performance required of those parts and the higher the level of integrity of the safeguarding system.

G2 CATEGORY OF CONTROL SYSTEM SELECTION The designer should select the control system appropriate to the category of the safety related parts identified from the flow chart in Figure G1. From this category, the appropriate level of interlocking or safeguard may be determined.

It is permitted that the designer choose an interlocking system which provides a level of integrity greater than required.

Similarly, a lower level may be used; however, expert guidance should be sought since additional measures must be taken to ensure the safety of persons near the machine.

The process for selection is as follows (see also Appendix F and Figure G 1):

- (a) Select the appropriate severity of injury on the flow chart likely to arise from the risk (S1 or S2).
- (b) Select the frequency of exposure or time of exposure to the risk from the flow chart (F1 or F2).
- (c) Select the appropriate possibility of avoiding the hazard (P1 or P2).
- (d) Determine the appropriate category of control system (B, 1, 2, 3 or 4), by following across the matrix to the preferred category, and reading from the top of the chart.
- (e) Determine the appropriate interlock category number (1 to 6) by reading off from the right-hand side of the matrix.

G3 EXAMPLES OF USE

G3.1 Machine details The examples below are intended to show that the control and safeguarding requirements for identical machinery can vary with exposure to the hazards.

The machine is a small electrically operated hydraulic press used in the clothing industry to insert studs. Each stud is loaded into the machine, manually in the first example and automatically in the second example. The press has a stroke of at least 30 mm and cycles either four times per minute for the manually loaded machine or eight times per minute for the automatically loaded machine.

In both cases, the press must be guarded to prevent injury.

G3.2 With manual loading Using Figure G1, it is decided that the severity of injury is serious, i.e. an irreversible crushing injury. The path down the flow chart is therefore S2.

The frequency of approach of four times per minute is classed as frequent to continuous and the path chosen is therefore F2.

Avoiding the hazard is scarcely possible as the operator's fingers must enter the trapping space at each cycle. The path is therefore P2.

Reading across the matrix shows that the preferred category of control system is 4, while the preferred interlock category is 6.

The type of interlock required is therefore a dual control system interlocking with cross monitoring, which is self-checking. (See Table G1).

G3.3 With automatic loading Using Figure G1 it is determined that the severity of injury is again serious, therefore the path is again S2.

NOTE: Automating the process has no effect on the potential or expected severity of injury which would be incurred in the event of a system failure.

The frequency of access can be classed as seldom, since the loading of studs into the press has been automated. The only reason for the operator to enter the trapping space would be for occasional maintenance. The path chosen is therefore F1.

The hazard would normally be avoided during operation since no access is required during the operational phase.

Exposure to risk is only possible under conditions such as failing to isolate the machine during maintenance. Therefore the path selected is P1.

Reading across the matrix shows that the preferred category is either 1 or 2 while the preferred interlock is a category 3.

This type of interlock still requires dual control system interlocking; however, the use of cross monitoring, self-checking or indication of failure are not required. (See Table G1).

TABLE G1
INTERLOCK CATEGORY AND SYSTEM TYPES

Interlock category No.	Type of system
6	Dual-control system interlocking with cross-monitoring. Monitoring function self-checked.
5	Dual-control system interlocking with cross-monitoring. Monitoring function not self-checked.
4	Dual-control system interlocking without cross-monitoring, but provided with indication of failure
3	Dual-control system interlocking without either cross-monitoring or indication of failure.
2	Single-control system interlocking provided with indication of failure.
1	Single-control system interlocking without indication of failure.

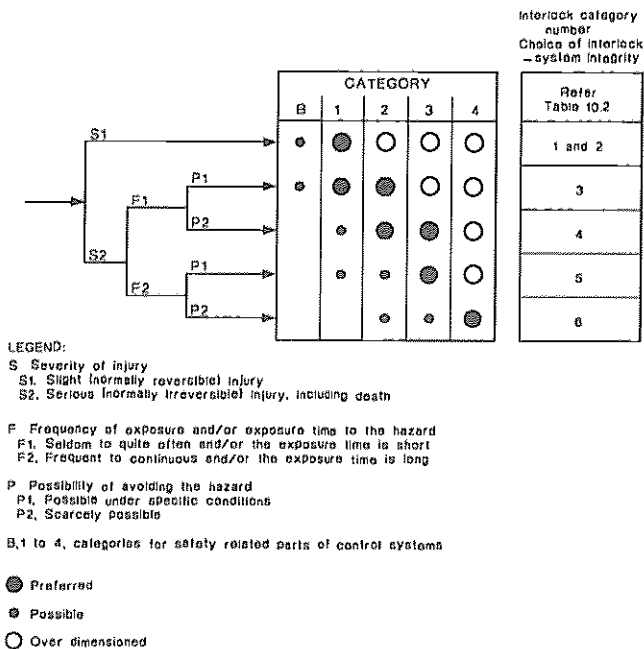


FIGURE G1 POSSIBLE SELECTION OF CATEGORIES

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