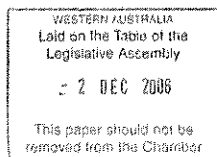


Australian Standard®

Safeguarding of machinery

Part 1: General principles



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This Australian Standard was prepared by Committee SF/41, General Principles for the Guarding of Machinery. It was approved on behalf of the Council of Standards Australia on 23 February 1996 and published on 5 July 1996.

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
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AS 4024.1—1996

Australian Standard®

Safeguarding of machinery

Part 1: General principles

PUBLISHED BY STANDARDS AUSTRALIA
(STANDARDS ASSOCIATION OF AUSTRALIA)
1 THE CRESCENT, HOME BUSH, NSW 2140



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ISBN 0 7332 0412 5

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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Originated as AS 4024.1(Int)—1992.
Revised and designated AS 4024.1—1996.

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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.



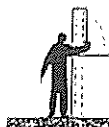
(a) Reaching up



(b) Reaching over barriers



(c) Reaching over barriers



(d) Reaching around



(e) Reaching through

FIGURE 3.1 WAYS OF REACHING INTO A DANGEROUS AREA

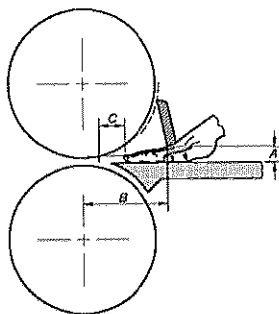
3.2.3 Barriers Guideline values for distances to which people can reach over fixed barriers of various heights are given in Appendix A. These values should be treated as guidelines and modifications considered for particular populations. In most cases, there is little penalty in exceeding the guidelines.

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).

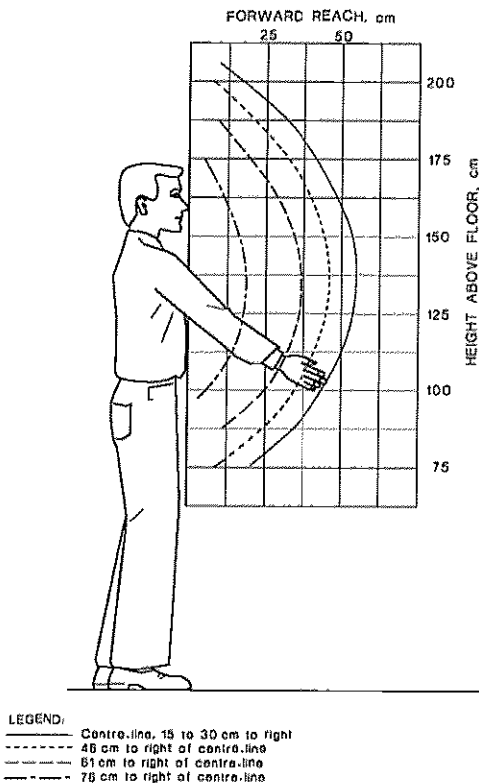


FIGURE 3.3 REACH ENVELOPE FOR 5TH PERCENTILE PERSON WHEN USING ONE HAND ONLY (FOR CONTROLS ONLY)

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.)

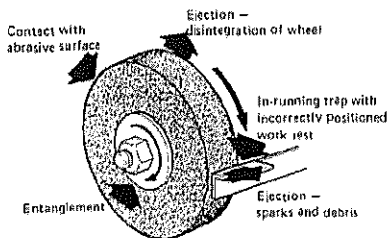


FIGURE 4.1 HAZARDS AT AN ABRASIVE WHEEL

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.

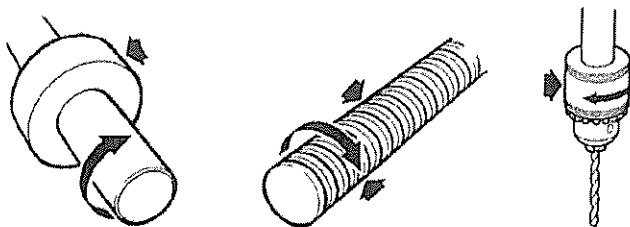


FIGURE 4.2 ENTANGLEMENT CAUSED BY CONTACT WITH A SINGLE ROTATING SURFACE

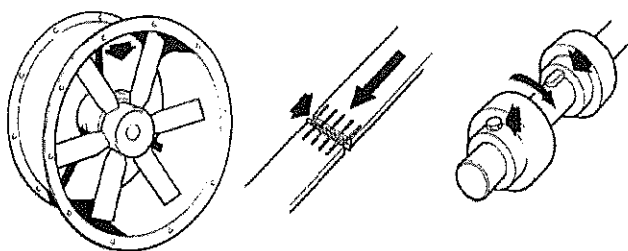


FIGURE 4.3 ENTANGLEMENT CAUSED BY CATCHING ON PROJECTIONS OR IN GAPS

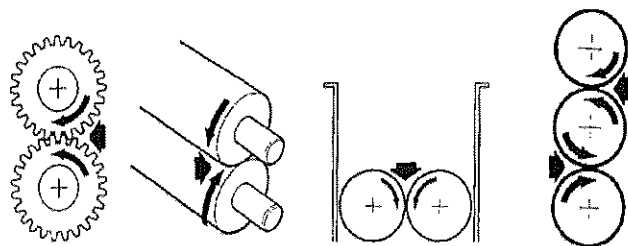


FIGURE 4.4 DRAWING-IN HAZARDS BETWEEN TWO COUNTER-ROTATING PARTS

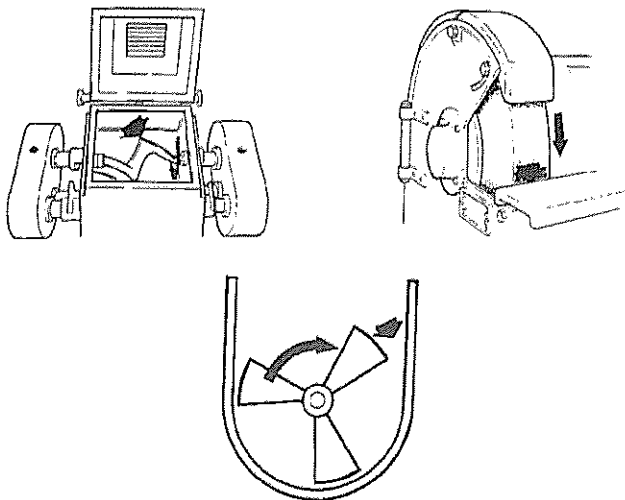


FIGURE 4.5 ENTANGLEMENT CAUSED BY CATCHING BETWEEN ROTATING AND FIXED PARTS

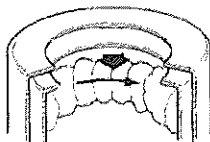


FIGURE 4.6 ENTANGLEMENT CAUSED BY CATCHING IN MATERIALS IN MOTION

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.

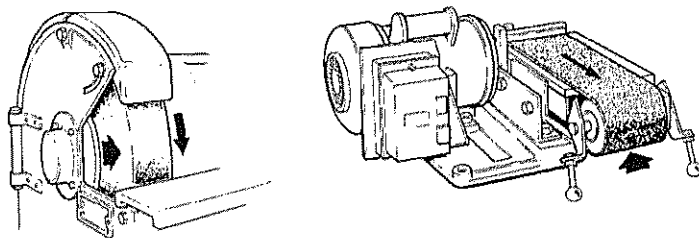


FIGURE 4.7 FRICTION AND ABRASION HAZARDS

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.

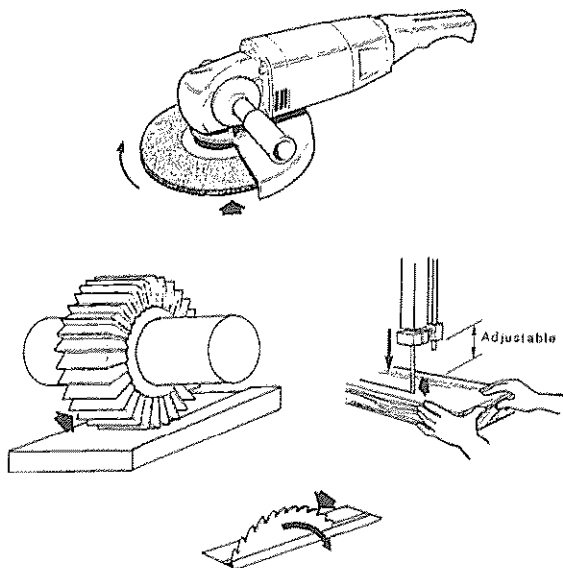


FIGURE 4.8 CUTTING HAZARDS

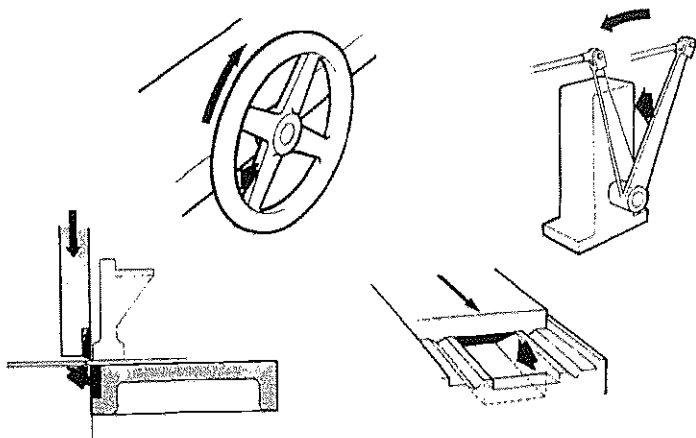


FIGURE 4.9 SHEAR HAZARDS BETWEEN TWO MACHINE PARTS

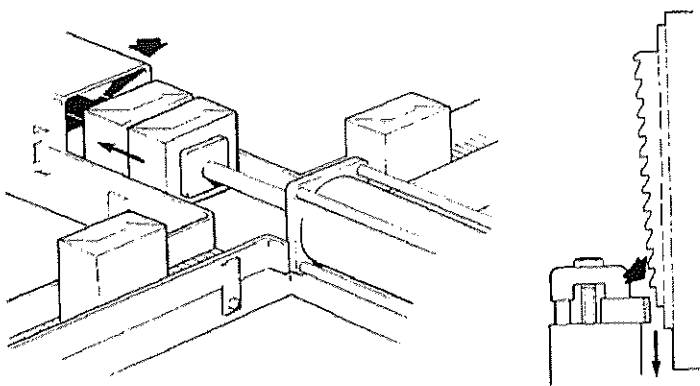


FIGURE 4.10 SHEAR HAZARDS BETWEEN A MACHINERY PART AND A WORKPIECE

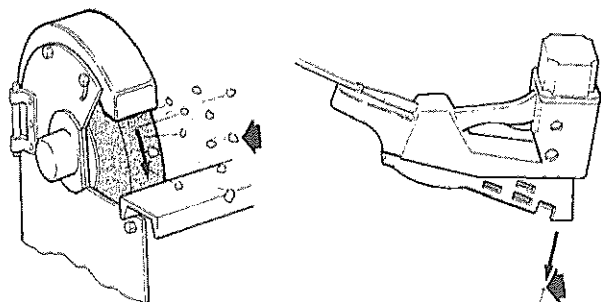


FIGURE 4.11 STABBING AND PUNCTURE BY FLYING OBJECTS

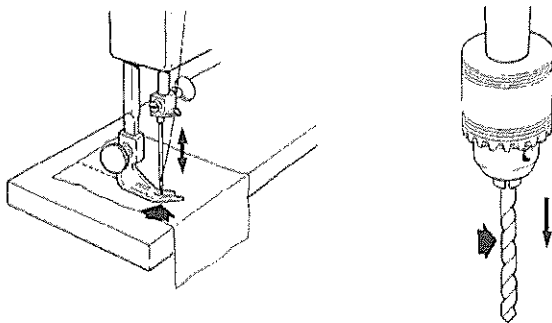


FIGURE 4.12 STABBING AND PUNCTURE BY MOVING PARTS OF MACHINERY OR PIECE OF MATERIAL

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.

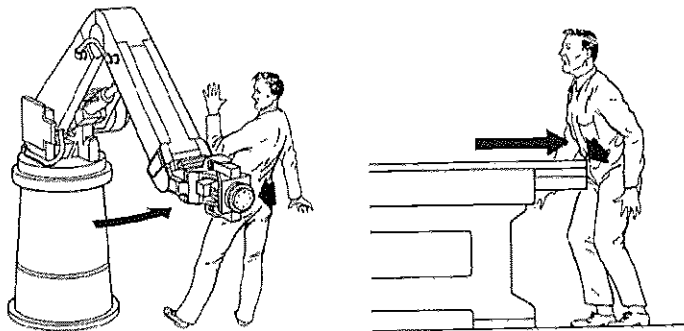


FIGURE 4.13 IMPACT HAZARDS

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.

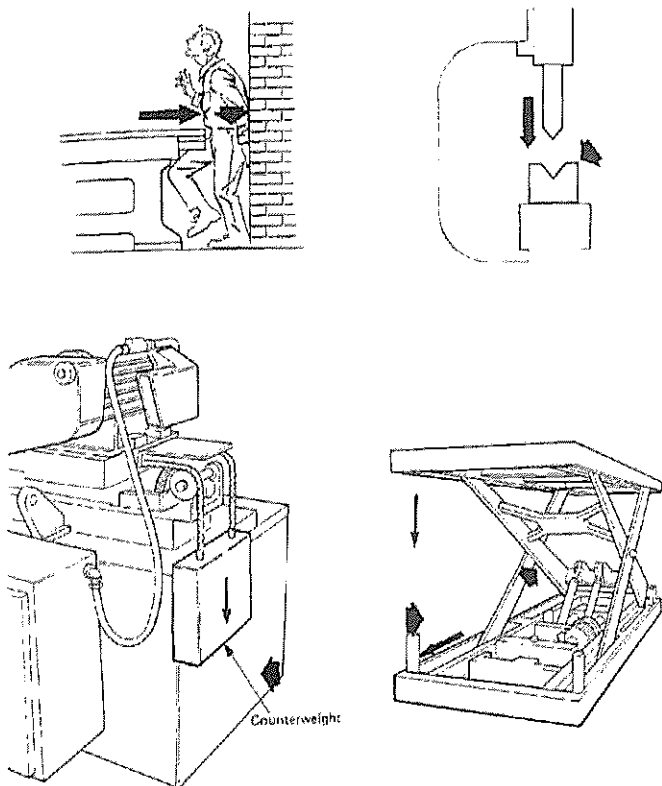


FIGURE 4.14 CRUSHING HAZARDS

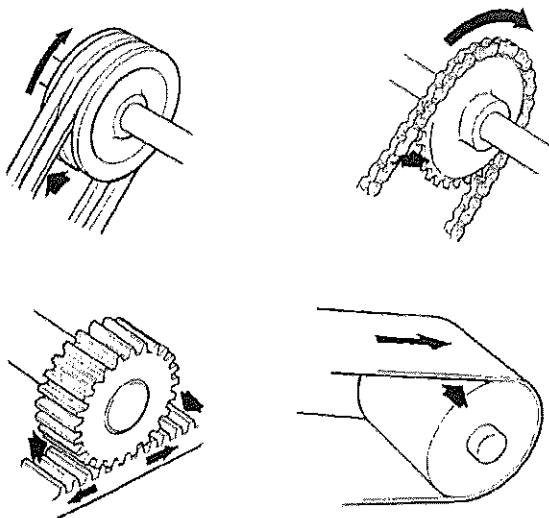


FIGURE 4.15 DRAWING-IN HAZARDS BETWEEN ROTATING AND TANGENTIALLY MOVING SURFACES

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.

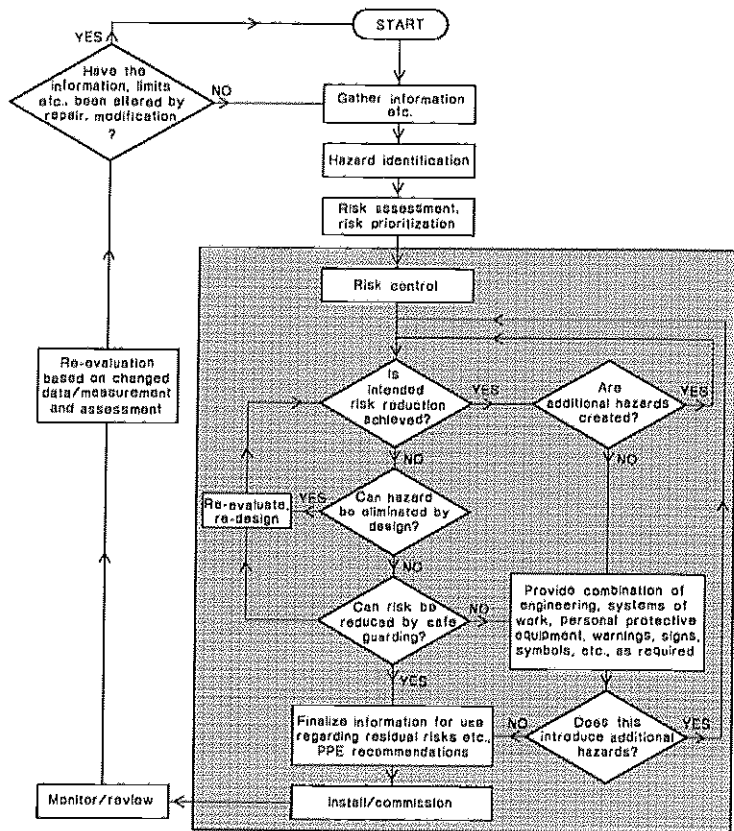
Risk assessment relies on judgemental decisions. These decisions shall be supported by qualitative methods complemented, as far as possible, by quantitative methods. Quantitative methods are particularly appropriate when the foreseeable severity and extent of harm are high.

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.

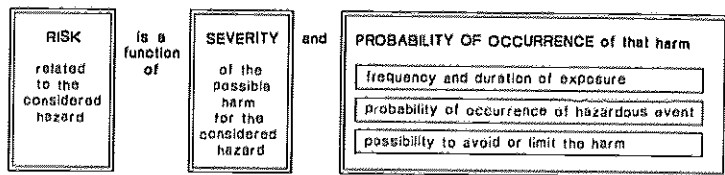


FIGURE 5.2 ELEMENTS OF RISK

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.

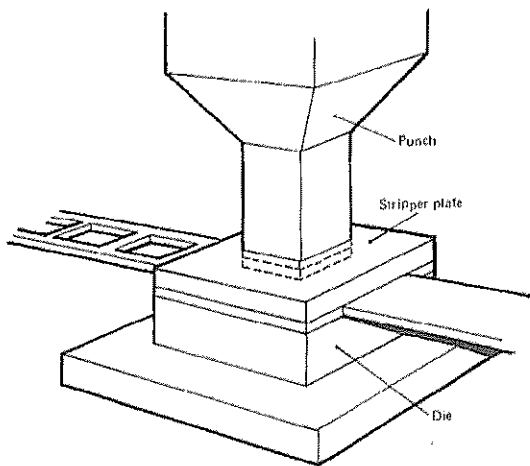


FIGURE 6.1 ENCLOSED TOOLS AT A POWER PRESS

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:

- (a) Filling the gaps, such that the shear trap is minimized (see Figures 6.1 and 6.2).
- (b) Reducing the maximum clearance between moving parts so that parts of the body cannot enter the gap.
- (c) 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.)

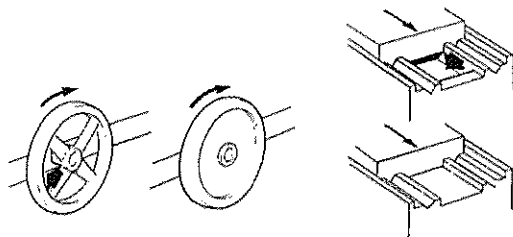


FIGURE 6.2 REMOVAL OF SHEAR TRAP BY DESIGN

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.

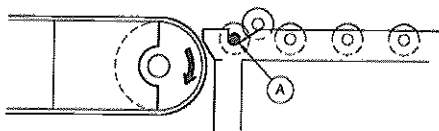
Reducing the sharpness, speed, force or torque and inertia will reduce the risk of impact, stabbing and puncture injuries; however, such reductions will not normally eliminate the need for appropriate guarding.

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.

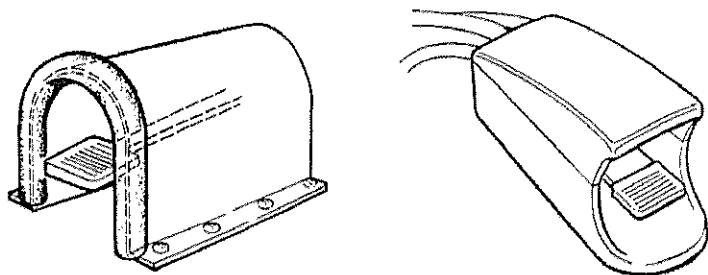


FIGURE 6.4 PEDALS PROTECTED FROM ACCIDENTAL OPERATION BY MEANS OF A COVER

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.

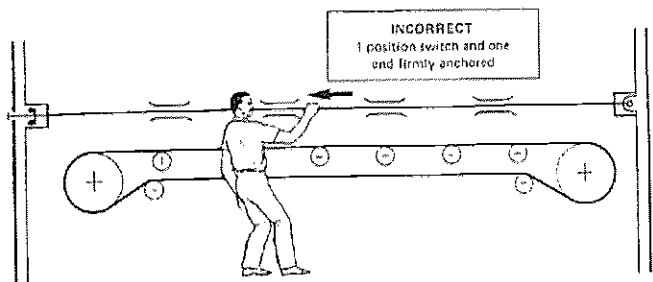
The system should be designed so that the failure of a single spring is a failure to safety, causing the emergency stop to operate. The system should operate with the application of a force not exceeding 70 N by a movement normal to the axis of the wire not exceeding 300 mm. As the movement of the wire 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.

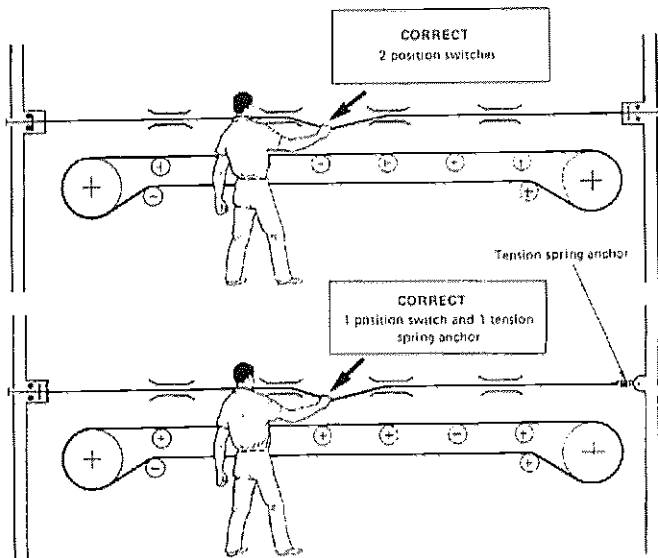


FIGURE 6.5 EMERGENCY STOPPING OF LONG MACHINES

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 motor 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.