Guide to machinery and equipment safety

Contents

Introduction

A guide to machinery and equipment safety is provided to assist persons conducting a business or undertaking (PCBU) and workers to comply with their duties under the *Work Health and Safety Act 2011* (the Act) and the *Work Health and Safety Regulation 2011* (the Regulation).

This guide is an introduction to managing the risks associated with use of machinery and equipment in the workplace.

Relevant persons can use this guide to:

- identify machinery and equipment hazards in the workplace
- eliminate or reduce the risk of those hazards causing harm.

The guide will also be useful to anyone else who is interested in machinery and equipment safety, such as workers and Workplace Health and Safety Representatives (WHSRs). Workplace Health and Safety Queensland (WHSQ) also has additional information and guidance supporting topics introduced in this document. For further information, refer to Section 4.

Consulting workers and workplace health and safety representatives

Consultative processes allow people to provide input and raise potential safety concerns about the work they undertake. Although hazards associated with machinery and equipment are often easily identified, the ways in which people can gain access to, or may be exposed to, hazards require a detailed understanding of how they do their job.

1. Key principles of machinery and equipment safety

1.1 Mechanical hazards

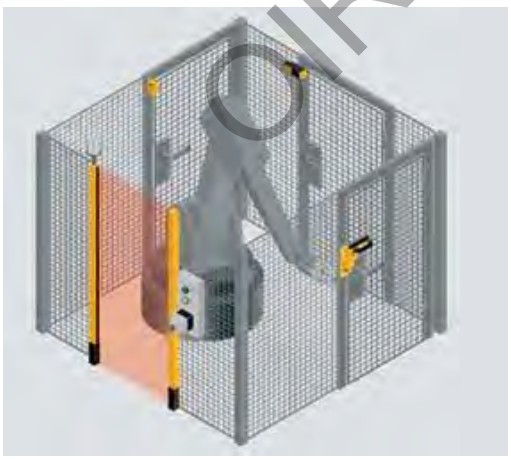
Machinery and equipment have moving parts. The action of moving parts may have sufficient force in motion to cause injury to people.

When assessing machinery and equipment for possible mechanical hazards, consider:

- machinery and equipment with moving parts that can be reached by people
- machinery and equipment that can eject objects (parts, components, products or waste items) that may strike a person with sufficient force to cause harm
- machinery and equipment with moving parts that can reach people, such as booms or mechanical appendages (arms)
- mobile machinery and equipment, such as forklifts, pallet jacks, earthmoving equipment, operated in areas where people may gain access.

Common mechanical hazards and associated risks for machinery and equipment are shown below.

Hazard	Risk
Rotating shafts, pullies, sprockets and gears	Entanglement
Hard surfaces moving together	Crushing
Scissor or shear action	Severing
Sharp edge – moving or stationary	Cutting or puncturing
Cable or hose connections	Slips, trips and falls (e.g. oil leaks)



Robotic arms can reach over their base, move with remarkable speed and high force, and can cause injury if controls to separate people from moving plant are not implemented.

Mobile plant operated in areas where people work m a y cause injury through collision. Traffic control and segregation are forms of control.

1.2 Non-mechanical hazards

Non-mechanical hazards associated with machinery and equipment can include harmful emissions, contained fluids or gas under pressure, chemicals and chemical by-products, electricity and noise, all of which can cause serious injury if not adequately controlled. In some cases, people exposed to these hazards may not show signs of injury or illness for years. Where people are at risk of injury due to harmful emissions from machinery and equipment, the emissions should be controlled at their source.

When assessing machinery and equipment for possible non-mechanical hazards, consider how machinery and equipment can affect the area (environment) around them.

Common non-mechanical hazards are shown below.

Non-mechanical hazards	
Dust	Mist (vapours or fumes)
Explosive or flammable atmospheres	Noise
Heat (radiated or conducted)	Ignition sources (flame or spark)
High intensity light (laser, ultraviolet)	Molten materials
Heavy metals (lead, cadmium, mercury)	Chemicals
Steam	Pressurised fluids and gases
Ionising radiation (x-rays, microwaves)	Electrical

Woodworking dust generated by a buzzer is removed via forced extraction and ventilation.

Welding fumes are extracted via flexible, locatable forced extraction and ventilation system.

1.3 Access hazards

People must be provided with safe access that is suitable for the work they perform in, on and around machinery and equipment. A stable work platform, suited to the nature of the work that allows for good posture relative to the work performed, sure footing, safe environment and fall prevention (if a fall may occur), is a basic requirement. For example, cooling towers on building roofs may have poor access, yet must be attended by a service person at predictable times for water treatment, chemical dosing or monitoring of automated dosing equipment. People performing these tasks must be provided with the means to get themselves and any equipment they require onto the roof with no risk, or minimal risk of fall or injury.

When thinking about safe access to machinery and equipment, consider the following:

- who will be working on or around the machinery and equipment
- people who are required to work in enclosed areas where the atmosphere could be harmful, such as pits, tanks or storage vessels
- what equipment or materials need to be carried to undertake the task
- where and when is access required for operation, maintenance and cleaning
- how will people gain safe access (walkway, gantry, elevated work platform or ladder)
- what work will be carried out during access
- will people be near or exposed to an unidentified mechanical or non-mechanical hazard at the time of access
- has consultation occurred with workers or contractors regarding how they intend to gain access, and what equipment and work platform or structure is best suited for the intended task.

Access

Access needs can be predicted and planning must occur in advance. People need access to machinery and equipment in the workplace (either continually or occasionally) for predictable tasks such as operation, maintenance, repair, installation, service or cleaning. Access may vary during each stage of the machinery and equipment life cycle. For example:

- installation or removal
  - complete access from every area may be required and involve disconnection or connection of services, such as water, air, pipes, installation of electrical cable to switch board
- operation
  - access for set up, operation and adjustment
- maintenance, repair, cleaning, alteration or adaptation
  - access to remote areas may be required.

Permanently fixed gantries, ladders and walkways are incorporated into this machinery and equipment to reduce the risk of a fall from height occurring during operation and maintenance.

Following are examples of common hazards by type of workplace activity.

People who install or dismantle machinery and equipment could:

- work in isolation
- work on machinery and equipment at height, or over machinery and equipment to connect services, such as electricity, air or water
- work in low light, or with bright directional light
- access machinery and equipment from the top, sides or underneath
- work with or near cranes, forklifts or rigging to lift machinery and equipment
- work in confined spaces
- use power tools, welders, extension leads, which present electrical hazards if damaged or wet.

People operating machinery and equipment could:

- be required to place their hands close to the mechanism of the machinery and equipment that does the work, and may be injured if caught or trapped by moving parts
- be exposed to constant harmful noise, radiated energy or fumes being emitted from the machinery and equipment being operated, or are close to
- inadvertently bump or knock poorly placed control levers or buttons
- be required to make adjustments to the mechanism of machinery and equipment while the machine is in motion
- be required to clear away scrap
- make minor adjustments, or reach into the moving mechanism of the machinery and equipment being operated.

People providing maintenance or repair services could:

- work alone
- work on machinery and equipment at height, or over machinery and equipment to connect services, such as electricity, air or water
- access machinery and equipment from the rear or sides
- be required to enter confined spaces of larger machinery and equipment
- be trapped by the mechanism of the machinery and equipment through poor isolation of energy sources or stored energy, such as spring-loaded or counter-balance mechanisms, compressed air or fluids, or parts held in position by hydraulics or pneumatic (air) rams
- move heavy parts when changing the set up of machinery and equipment, or repairing failed parts, such as electric motors or gear box assemblies
- disable or remove normal safety systems to access the mechanism of machinery and equipment.

People providing cleaning services could:

- work alone
- access machinery and equipment from the rear or sides, or in unexpected ways
- climb on machinery and equipment
- enter confined spaces, or larger machinery and equipment
- become trapped by the mechanism of the machinery and equipment through poor isolation of energy sources or stored energy, such as spring-loaded or counter-balance mechanisms, compressed air or fluids, or parts held in position by hydraulics or pneumatic (air) rams
- work with chemicals
- operate electrical equipment in wet areas.

2. Risk control of machinery and equipment hazards

2.1 Risk control of general hazards

Where exposure to machinery and equipment hazards cannot be **eliminated** or **substituted** for machinery and equipment of improved design, **risk controls** must be applied to the hazards to prevent or reduce the risk (chance) of injury or harm. Workplace health and safety laws require the **highest order** control be applied.

Higher order machinery and equipment risk controls are **preventative** by nature, are effective and durable for the environment it is used in, and **deal directly with the hazard at its source**.

Lower order machinery and equipment risk controls, such as personal protective equipment (PPE), can prevent injuries, but are generally not as effective as higher order controls, as they rely more on worker behaviour, maintenance programs and supervision.

Administrative controls use systems of work to reduce risk by providing a framework of expected behaviours. Examples are rotation of staff to reduce exposure to a hazard, or a documented safe system of work, such as 'lockout tagout'. These types of controls rely on extensive instruction, information, training and supervision. In terms of time and ongoing administration by managers and employers to ensure the desired behaviour occurs, administrative controls can be the most expensive and least effective form of hazard control.

Note: The use of **PPE** and **administrative controls** are **low** or **last order controls** used to deal with any residual risk associated with the hazard. As such, these last order controls can be used in support of higher order controls that deal with a hazard at its source and should not be considered as the sole means of control. These types of risk controls require constant monitoring and reinforcement.

Effective machinery and equipment risk controls reflect some or all of the following characteristics:

- the hazard is controlled at its source
- contact or access to the hazard is prevented
- sturdy construction (correct materials with few points of potential failure)
- fail-safe (failure of the control system to be effective will result in machinery shut-down)
- tamper-proof design (as difficult as possible to bypass)
- presents minimum impediment to machinery and equipment operator
- easy to inspect and maintain
- does not introduce further hazards through the risk control action.

Centre lathe: The exposed rotating chuck of a centre lathe can eject parts or tools with great force, cutting fluid fumes are difficult to contain and the machinery requires manual set-up.

CNC lathe: Substituting a centre lathe with a CNC lathe (Computer Numeric Control) is an example of improved risk control of machinery and equipment through improvement in design.

2.2 Risk control of mechanical hazards

Separation is a simple and effective machinery and equipment risk control and may be achieved by distance, barrier or time.

- Distance separation means a person cannot reach the hazard due to distance.
- Barrier separation means an effective barrier or guard denies access and controls ejection of parts, products or waste.
- Time separation means at the time of access, the machinery and/or equipment is disabled.

Examples of separation include:

- physical barriers and guards, such as fences, screens or fixed panels of various materials
- various forms of guarding and interlocking (as described in *AS4024, parts 1601 and 1602, Safety of Machinery*)
- making the hazard inaccessible by reach (where the distance between a person and the hazard forms an effective barrier).

Note: When considering the suitability of distance guarding, consider the safe access requirements of maintenance people who gain access by ladder, scaffold or elevated work platform.

Guarding

A guard can perform several functions including:

- denying bodily access
- containing ejected parts, tools, off-cuts or swath
- preventing emissions escaping
- forming part of a safe working platform.

Guarding is commonly used with machinery and equipment to prevent access to:

- rotating end drums of belt conveyors
- moving augers of auger conveyors
- rotating shafts
- moving parts that do not require regular adjustment
- machine transmissions, such as pulley and belt drives, chain drives, exposed drive gears
- any dangerous moving parts, machinery and equipment.

Where access is not anticipated, a **fixed guard** can be permanently applied by a bonding agent, welding, or secured with one-way screws. If access is generally not required, a permanently fixed barrier is the preferred option.

Where access to the hazard is infrequent, the installation of a **fitted guard**, that can be removed by use of a tool, may be an acceptable control, where the tool to remove the barrier or guard is not normally available to the operator.

Adjustable guarding incorporates movable sections or panels of the guard and allows for material or parts to be fed into the guarded area while still preventing bodily contact.

An old style power press incorporating a manual interlock and adjustable guarding.
If the guard slides up, a connected metal bar separates the clutch mechanism and the press will not activate. The guard can be adjusted to provide an opening by releasing retaining bolts on the guard face to allow individual panels to move. Adjustment must be performed by an experienced person to ensure the resulting opening only provides room necessary to incorporate the material being fed in and prevents hands or fingers intruding into the danger area.

Fences, barriers, guards and interlocked gates separate people from the hazardous action of machinery and equipment.

Tunnel guards provide a tunnel, aperture or chute in which material can be inserted into the machinery and equipment, but due to the restrictive design and depth of the opening, fingers, hands, arms, or the entire person is prevented from intruding into the danger area.

Where frequent cleaning is required, the guard may be constructed of mesh that prevents intrusion of body parts, but allows for hosing. Food production workplaces, that use conveyors in areas where hygiene or food safety is an integral part of the operation, use fixed mesh guarding of conveyor end rollers.

Interlock guarding occurs when the act of moving the guard (opening, sliding or removing) to allow access, stops the action of the hazardous mechanism.

Interlock guarding works by:

- disconnecting the drive mechanism mechanically (e.g. applying a brake or disengaging a clutch or geared mechanism)
- isolating the power source of the drive mechanism (e.g. stopping the motor)
- a combination of mechanical and power disconnection.

Interlock guarding is generally achieved via mechanical or electrical means, but may also include hydraulic or pneumatic control systems.

The energy stored in moving parts (momentum) can cause the mechanism of the machinery or equipment to run on for some time after the source of driving energy has been removed.

For access panels or doors supporting an interlocking device allowing access to mechanical parts that move for periods after the energy source is removed, a separate mechanism to delay release of the retaining or locking mechanism may be incorporated.

Captive key systems rely upon a single key that is shared between the control panel ('on' switch) and the access gate lock of the physical barrier to the danger area. Removal of the key from the control panel can only occur when the switch is in the 'off' position, and the gate will only release the key when in the locked position.

Captive key systems do not provide full isolation of the power source, but may provide limited temporary access under controlled conditions.

Administrative controls, such as effective supervision, instruction and training, are required to ensure that only one key is available for the system, and the key is not removed from the access gate or guard by a second operator while a person is exposed to the danger area of the plant. Operations such as maintenance, repair, installation service or cleaning may require all energy sources to be isolated and locked out to avoid accidental start-up.

The narrow throat of the mincer prevents a person's hand from accessing the hazard.

Captive key systems: The key cannot be removed unless it is in the off position. The same key is used to unlock the access gate. Only one key per system is retained by the locking mechanism.

An old style press refurbished with an interlocked safety cage and gate.
The control mechanism uses a combination of pneumatics and electrical interlocking to ensure the danger area of the press cannot be accessed unless the press downstroke action is disabled.
Improved design and technology can be fitted to older machinery and equipment to meet current standards and reflect the latest knowledge regarding ways to control hazards and risks in the workplace.

Other mechanical hazard risk control options

Simultaneous two-handed operation

Where a machine has only one operator, the use of simultaneous two-handed operation buttons can serve as a risk control. This ensures that operation of the hazardous mechanism cannot occur until both hands are clear of the danger area.

The two buttons must be pushed at the same time and are located at a distance from each other that prevents simultaneous operation by one hand.

The operation should be designed so that if either or both of the buttons are released, the hazardous action of the machinery and/or equipment cannot be reached, or if it can be reached, the mechanism returns to a safe state.

Presence sensing systems

If physical guards cannot be used, then a presence sensing system can be used as a control to reduce risk. Presence sensing systems can be used where people enter areas shared by moving production equipment.

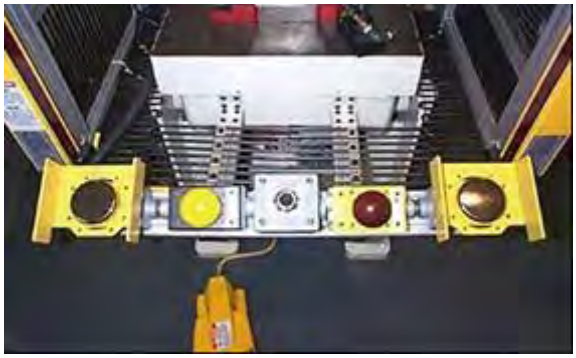
Presence sensing systems are capable of providing a high degree of flexibility with regard to access.

Presence sensing systems detect when a person is in the identified danger area, and stops or reduces the power or speed of the mechanism at the time of entry to provide for safe access.

Presence sensing systems can rely on foot pressure pads, infra-red sensing, light beams or laser scanning. The most appropriate type of sensing device will depend on the operating environment and access requirements.

AS4024.2 provides guidance on design specification, ratings on integrity and reaction times. Manufacturers' specifications for installation and maintenance must also be observed.

Specialist assistance may be required by experienced professionals to ensure the correct selection and installation of presence sensing systems. Companies who manufacture or supply these systems also provide technical support and installation assistance.



A two-handed control option may be suitable to ensure that a machine can not operate until both hands of the operator are clear of the hazard area.

A light curtain used to disable the hazardous mechanism of a machine must resist failure and fault.

Critical safety systems

A critical safety system is a safety control system responsible for ensuring the safety of a person when approaching or accessing a hazard.

Failure of the critical safety system will leave a person exposed to the hazard, and in danger.

Critical safety systems may include barriers or guards fitted to prevent access, or integrated complex interlocking and presence sensing systems. Failure to replace guards, damaged perimeter fences that allow access, and bypassed or disabled interlocking systems, are examples of critical safety systems failures that require immediate attention to ensure the safety of people.

High integrity/fail-safe control

All safety control systems should be designed and built to prevent failure or, in the event of failure, de-activate the operation of the machinery and equipment.

The extent to which a safety control system should tolerate faults is a function of risk (likelihood and consequence), and is described fully in *AS4024.1501 Safety Related Parts of Control Systems*, which explains the categories of control required as a function of increasing risk.

Many different types of machinery and equipment use high integrity safety systems that disable a mechanism at the time of access. Some examples include:

- brake press
- power press
- robotic machine (automated machines)
- injection moulders
- powered guillotines
- programmable lathe and milling equipment
- industrial mixers
- mincing equipment
- plasma cutting tables
- laser cutting tables.

Redundant and self-monitoring fault detection systems
Redundant or dual systems (doubling up) and self-monitoring fault detection systems are also effective methods to prevent failure of critical safety systems.

Selection and installation of these types of complex interactive control measures may require expert or specialist assistance.

The Australian Standards provide information on machinery and equipment safety systems and reflect the current state of knowledge and best practice. The *AS4024 Safety of Machinery* series of publications provides specific information for commonly used machine types in industry, such as woodworking or metalworking machinery.

Components relied on to protect people from harm are designed and built to a high standard, and display compliance ratings relative to their reliability. They must also be correctly installed to ensure their effective operation.

2.3 Risk control of non-mechanical hazards

The first step in selecting suitable and effective controls for non-mechanical hazards is to understand the nature of emissions that can be released by machinery and equipment in the workplace, where those emissions collect and the way they may cause harm.

- Separating people from non-mechanical hazards is necessary where the emission cannot be controlled at the source through elimination or substitution. Hazardous machinery and equipment emission controls rely largely on isolating of people from the hazardous emission. Hoods, lids, covers or impervious guards (solid barriers that prevent escape of the emission) can serve to contain a number of different types of emissions within machinery and/or equipment. For potentially harmful substance exposures from machinery and equipment, such as mist, fumes, vapour or dust, and where it is not possible to control the emission at its source, ventilation and extraction systems are used to remove the hazardous emissions from the work environment.
- Guarding may also serve to mute noise emissions through application of sound absorbing materials. Other emissions, such as lasers, ultraviolet light, bright light or welding flash, can also be safely screened to prevent potential harmful exposure.
- Oil leaks from machinery and/or equipment may present a serious slip hazard. By preventing oil leaks through routine maintenance, or containing leaking oil with a drip tray or through spill containment strategies, the risk the hazard presents is controlled.

Personal protective equipment

Where it is not possible for emissions to be controlled at their source, or removed or reduced through effective ventilation, extraction or diversion, the use of personal protective equipment (PPE) as a final measure must be considered to ensure safety.

PPE is a lower order control and can only be used where higher order controls are not possible or are not totally effective.

Selection and use of PPE requires careful consideration, as there are many different types that reduce the risk of injury of contact or exposure to a hazard.

Incorrect use of PPE, or purchasing inappropriate PPE, can contribute to serious workplace incidents.

PPE that is uncomfortable, restrictive or heavy may create secondary hazards, and, as a result, constant supervision may be necessary to ensure it is used effectively.

Ear muffs

Gloves

Particle half face respirator

Welding mask

Safety glasses

2.4 Risk control of access hazards

Larger machinery and equipment may contain internal areas where a hazardous environment may occur by design, or as a result of the work being done.

A confined space may exist where people require access to a mostly closed area that presents difficult or restricted path of access, where oxygen levels may be depleted or displaced, or where harmful levels of contaminate, such as gas, vapour or dust, exist.

There are legal requirements that must be observed prior to allowing people to enter a confined space.

- Training in confined space entry.
- Issue of entry permits.
- Continuous monitoring and supervision.

Working at height

Providing people with a suitable work platform for the task being undertaken reduces the risk of injury from falling from machinery and equipment.

Often 'safe access' equipment, made available during installation of machinery and/or equipment, is removed after commissioning. Workplace managers may not have considered or recognised the need to provide similar means to gain safe access to parts of machinery and equipment at height, or in awkward locations for maintenance, repair, service or cleaning activities.

Safe access at height can be broken into three categories. Each category has in common the need to provide a stable, safe platform suitable for the work to be undertaken, and to be equipped to support and retain a person within the confines of the platform.

1. **Fixed or permanently installed access platforms:**
   - gantries
   - mezzanine floors
   - fixed platforms
   - stairways.

2. **Mobile elevated work platforms (EWPs):**
   - scissor lifts
   - knuckle booms.

Note: Safe work practices must take into account the risk of trapping an operator between the EWP and a fixed structure (e.g. overhead beams, electrical cables, pipes).

3. **Temporary platforms:**
   - scaffolding
   - ladders.

Where safe working platforms are used and the risk of a fall remains, **travel restraint** and **fall-arrest harnesses** can be used where a suitable point of attachment exists. Harness systems, anchor points and shock absorbing lanyards must be compatible at each point of attachment from the anchor point to the harness, with approved and rated latching devices to ensure the integrity of the system.

When using fall-arrest systems, specialist assistance may be necessary to select appropriate equipment, provide effective training in use and inspection, and develop an emergency retrieval plan to recover a person suspended in a fall-arrest harness. People suspended by a fall-arrest harness for short periods of time may suffer serious health effects, or may have incurred injury during the fall prior to the fall-arrest device deploying. Emergency retrieval plans should allow for immediate local response in safely retrieving people to avoid fatalities.

Note: The *Work Health and Safety Regulation 2011* prescribes specific requirements that must be taken into account when determining risk controls for both **confined spaces** and **working at heights**.

Lockout tagout: Removing and controlling energy sources during access

People performing tasks, such as maintenance, repair, installation, service and cleaning, are highly vulnerable, and have a higher risk of being killed or maimed through inadvertent operation of machinery and equipment they are working in, on or around.

Accidental start-up, or movement of a machine mechanism, can occur:

- if control levers or buttons are bumped or knocked
- if a short circuit of the control system occurs
- when hydraulic or air pressure is released
- when undoing retaining bolts.

It is essential that people who work in, on or around machinery and equipment are not exposed to hazards due to accidental start-up or movement of the machine mechanism. (*AS4024.1603 Safety of Machinery*).

The following is an overview of the lockout tagout process:

- shutdown the machinery and equipment
- identify all energy sources and other hazards
- identify all isolation points
- isolate all energy sources
- de-energise all stored energies
- lockout all isolation points
- tag machinery controls, energy sources and other hazards
- test by ‘trying’ to reactivate the plant without exposing the tester or others to risk (failure to reactivate ensures that isolation procedures are effective and all stored energies have been dissipated).

Identifying energy sources

All energy sources likely to activate the machinery and equipment and expose people to hazards should be identified prior to work beginning.

Such energy sources include:

- electricity (mains)
- battery or capacitor banks
- fuels
- heat
- steam
- fluids or gases under pressure (water, air steam or hydraulic oil)
- stored energy
- gravity
- radiation.

If original designer and installer 'as built' diagrams of machinery and equipment installations are not available, new diagrams and photographs showing location and details of various isolation points of machinery and equipment should be developed as part of the isolation procedures. Isolation points may include switches, valves, energy lines, pipes and power sources.

These diagrams and photographs can then be used, along with written procedures, for information and training.

De-energise stored energies

Any or all of the following steps need to be taken to guard against energy left in the machinery and equipment after it has been isolated from its energy sources:

- inspect the machinery and equipment to make sure all parts have stopped moving
- install ground wires
- release the tension on springs or block the movement of spring-loaded parts
- block or brace parts that could fall
- block parts in hydraulic and pneumatic systems that could move from pressure loss
- bleed the lines and leave vent valves open
- drain process piping systems and close valves to prevent the flow of hazardous material
- if a line must be blocked where there is no valve, use a blank flange
- purge reactor tanks and process lines
- dissipate extreme cold or heat, or provide protective clothing
- if stored energy can accumulate, it must be monitored to ensure it stays below hazardous levels.

Isolation procedures

Isolation procedures in each workplace vary in detail because of differences in machinery and equipment, power sources, hazards and processes. However, if adequate interlocking is not possible, or the maintenance, repair, installation, service or cleaning requires the method of guarding or interlocking to be bypassed or removed, an isolation procedure should be implemented.

Note: Activating operational stop buttons, emergency stop devices or interlock devices is not equivalent to the isolation of power sources, or the release of stored energy.

Lockout

Isolation devices

A wide range of devices is available for locking out energy sources and other hazards that could pose a risk to people working on machinery and equipment.

These devices include switches with a built-in lock, and lockouts for circuit breakers, fuses and all types of valves.

Also readily available are chains, safety lockout jaws (sometimes called hasps), which accommodate a number of padlocks, and sets of robust safety padlocks.

Only devices that incorporate a lock or accommodate one or more padlocks are suitable lockout devices.

One person – one lock

If more than one person is working on the same item of machinery and equipment, each person should attach their own lock to prevent the isolator being opened while their specific task is in progress.

The isolation procedure should identify common lockout points to ensure energy cannot be restored while someone is still working on the machinery and equipment.

If two or more people are working on machinery and equipment that is isolated through several lockout points, each person should attach a lock and tag to each lockout point.

To avoid the need for multiple locks on each lockout point, a lock box may be used. Under this system, each lockout point is locked by only one lock, and the keys to the locks of the machinery's lockout points are placed inside a box that is locked by all the individual locks of people working on the same plant.

One lock – one key

Each person working on the machinery and equipment should have their own lock, key and tag. There should be no duplicate key available for any lock, except a master or duplicate key, for use in an emergency, that is secured and not readily available.

During inspection, repair, maintenance, cleaning or adjustment of the machinery and equipment, the one key to each person's lock should be held only by that person, who is responsible for both locking and unlocking the lockout device.

Multiple energy sources

If more than one energy source or hazard has to be locked out to enable safe shut-down of the machinery and equipment, the single key to each lockout device should be held by the same person.

Tagout

A tag on its own is not an effective isolation device. A tag acts only as a means of providing information to others at the workplace. A lock should be used as an isolation device, and can be accompanied by a tag.

Tag and lock

Valve lock and tag

Multiple locks

3. Purchasing machinery and equipment list

The following list provides topics for consideration and consultation when purchasing machinery and equipment. It is important to also note that under Sections 22, 23, 24 and 25 of the *Work Health and Safety Act 2011*, designers, manufacturers, importers and suppliers of plant have specific duties.

People

- Who will come into contact with the machinery and equipment?
- What are people required to do?
- How will work be carried out and completed?
- Based on the knowledge of existing machinery and equipment, what improvements should the purchaser specify when buying new machinery and equipment?

Documentation and training

- What supporting documentation will accompany the new machinery and equipment?
- To what standards has the machinery and equipment been manufactured (Australian, European, Japanese, American)?
- What support is offered by machinery and equipment suppliers (service, training, maintenance)?
- What operating and maintenance information is supplied with the new machinery and equipment?
- Is the supplied information sufficient to provide the basis of a workplace training package?
- If the machinery and equipment is refurbished or second-hand, how do the risk controls compare with similar new machinery and equipment?
- Have you allowed extra resources to upgrade existing risk controls to reflect current state of knowledge?

Location

- Where is the machinery and equipment to be located, and how much space does it require?
- Is there enough room to access the machinery and equipment for servicing, maintenance, repair or cleaning?
- Do people walk past or work in close proximity to the proposed machinery and equipment location?
- Is there enough light?
- Is there sufficient ventilation?

Operations and maintenance

- Will the machinery and equipment introduce more noise to the workplace?
- Will the machinery and equipment perform a task other than what it was designed for?
- What types of emissions does the machinery and equipment produce when operated or cleaned, such as noise, fumes, light and heat?
- What are the expected hours of machinery and equipment operation?
- How will the material arrive, and how is the product going to be removed after the process is complete?
- Are there environmental factors, such as hazardous atmospheres of flammable vapours or dust or water, that may affect the machinery and equipment, the operators or maintenance?
- Does the machinery and equipment have confined spaces?
- Does the machinery and equipment have valves or isolation points located at height?

Various

- Will the machinery and equipment fit through the door?
- Is the floor of the workplace strong enough to support the machinery and equipment?
- Do you understand that if you purchase machinery and equipment outside Queensland, then you also take on the obligations of the importer?
- Do you understand the obligations of an importer?
- Do you understand that if you alter or adapt machinery and equipment to perform an alternate function, then you also take on the obligations of the designer for those alterations?
- Do you understand the obligations of a designer?
- If the machinery and equipment is mobile, where will it operate and who may be in the area?
- In what terrain will the mobile machinery and equipment operate?

4. Information and guidance

Further information about machinery and equipment can be obtained by accessing the Office of Fair and Safework Queensland website at www.worksafe.qld.gov.au or by calling the Workplace Health and Safety Queensland Infoline on 1300 362 128.

Legislation:

- *Work Health and Safety Act 2011*
- Work Health and Safety Regulation 2011
- *Electrical Safety Act 2002*
- Electrical Safety Regulation 2013

Australian Standards:

Australian Standards are the accepted standards for safeguarding machinery, plant and other issues. They are developed, published and distributed by Standards Australia. Contact details for Standards Australia are:

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Other useful publications:

- *Managing the risks of plant in the workplace Code of Practice 2013*
- *How to manage work health and safety risks Code of Practice 2011*
- *Mobile Crane Code of Practice 2006*
- *Tower Crane Code of Practice 2006*
- *Managing risks of hazardous chemicals in the workplace Code of Practice 2013*
- *Managing noise and preventing hearing loss at work Code of Practice 2011*
- *Rural Plant Industry Code of Practice 2004*
- Relevant manufacturer's instructions and operator's instructions/manuals

Guide to safeguarding common machinery and plant

Workplace Health and Safety Queensland

Think Safe – **Work Smart**

Queensland **the Smart State**

Queensland Government
Department of Industrial Relations

Contents

April 2006

Purpose

The Guide to safeguarding common machinery and plant has been developed to help people conducting a business or undertaking (including employers and self-employed people) and workers to ensure common machinery and plant in the workplace is safe and without risk to health and safety.

This guide raises awareness of a range of hazards associated with common machinery and plant, as well as risks that may result from these types of hazards. Practical advice is provided in relation to the methods that can be used to safeguard common machinery and plant in the workplace, and advice on how to select and implement the appropriate safeguards.

This is achieved by using a risk management approach whereby hazards are identified, the degree of risk of each hazard is assessed, control measures are identified and implemented and finally, monitoring and review of the effectiveness of the chosen control measures is performed.

It should be noted that the information contained in this document is intended for guidance only, and that there may be additional hazards and subsequent risks at your workplace which have not been specifically addressed in this guide. You are still required under the *Workplace Health and Safety Act 1995* to identify and assess these risks and ensure that appropriate control measures are implemented and reviewed to prevent or minimise exposure to these risks.

Note: This guide should be read in conjunction with the primary source document, the Plant Code of Practice 2005. In addition to this, other important documents that should also be read in conjunction with this guide are the Workplace Health and Safety Act 1995, Risk Management Advisory Standard 2000, Australian Standard 4024.1 – 1996 Safeguarding of machinery - General principles, other Australian Standards as identified in Appendix 5 and relevant manufacturer's instructions and operator's instructions/manuals.

Section 1 – What is machinery and plant?

Machinery is a collective term for machines and their parts. A machine is considered to be any apparatus that has interrelated parts and is used to perform work.

Plant has a broader meaning and includes machinery. Other items of common plant in the workplace include equipment, implements and tools. Fittings, connections and accessories are also considered to be plant.

This guide focuses on the guarding of machinery commonly found in workplaces, but also considers other items of plant. To remind readers of this, the guide discusses machinery and plant together.

Section 2 – The risk management process

The hazards associated with operating common machinery and plant are not always obvious, and there are generally a number of elements that will affect safe operation. The risk management approach will help you make a judgment about the risks associated with these hazards and implement appropriate control measures.

The risk management approach is outlined under the *Workplace Health and Safety Act 1995* and involves:

1. identifying hazards
2. assessing risks that may result because of the hazards
3. deciding on appropriate control measures to prevent or minimise the level of the risks
4. implementing the chosen control measures
5. monitoring and reviewing the effectiveness of the chosen control measures.

These five steps are commonly known as the risk management process. This process is outlined comprehensively in the *Risk Management Advisory Standard 2000*.

2.1 Identifying machinery or plant hazards

The first step in assessing the risks associated with machinery and plant is to identify all items of plant used in the workplace. An inspection of the workplace should be carried out looking for any of these items. The desired outcome of this step is a list of all items of machinery and plant that pose potential hazards.

The hazards associated with machinery and plant include mechanical, biological, chemical, psychological and ergonomic hazards. Mechanical hazards are a major cause of injury associated with the operation, maintenance and repair of machinery and plant. Mechanical hazards include cutting and severing, crushing, shearing, impact and entanglement.

Start by identifying all machinery and plant operated at the workplace and associated with any work performed. Include common items that pose potential hazards that may not normally be thought of as 'machines' or plant. These items may include office machines, such as paper guillotines and automatic staplers.

Check both inside and outside the work environment for machinery and plant that may pose a risk to people in the workplace (e.g. garbage compactors operated outside). If work is normally done at other locations, mobile plant and tools used at these locations should also be included.

Once all machinery and plant has been identified, the hazards associated with these items can be identified. **Critically inspect each piece of machinery and plant and the way it is operated to identify any parts, processes or operating procedures that may cause harm.**

A method of identifying machinery and plant hazards is to consider the following factors:

- tasks (operating, cleaning, adjusting, setting-up, maintaining, repairing or working on a machine, e.g. power press, food slicer)—consider all activities that take place
- locations (proximity to other machines and work processes, fixed plant, portable plant and tools)
- installation of plant (safe and correct installation)
- production processes (forming, finishing)
- use of mobile plant at other locations
- safe transportation of mobile plant.

By considering these factors, the full range of hazards associated with the machinery or plant can be identified.

Where machinery and plant hazards are not immediately obvious, there are many other activities that can be undertaken to help identify them. These include:

- testing, particularly of plant and other equipment and noise levels
- scientific or technical evaluation
- analysing records and data including workers' compensation claims, incidents and near misses, worker complaints, sick leave and staff turnover
- acquiring information from designers, manufacturers, suppliers
- acquiring information from other organisations such as unions, employer bodies, occupational health and safety consultants
- environmental and medical monitoring
- undertaking worker surveys.

Examining the activities performed at the workplace and the related danger zones (such as moving parts) of plant and machinery will assist in identifying hazards. These hazards may include, but are not limited to those illustrated below.

These machines and items of plant are shown in their unguarded state to demonstrate the hazards and danger zones.

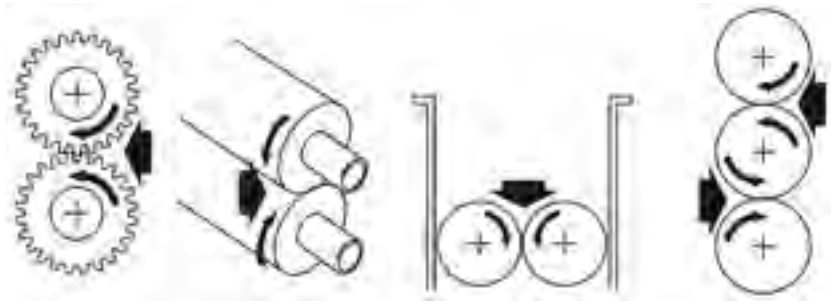


Illustration 1 - drawing in points between two counter-rotating parts

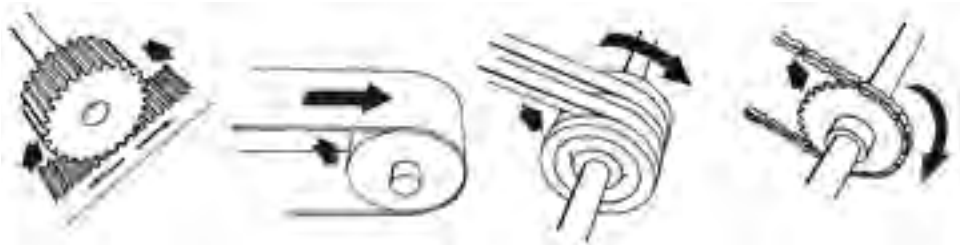


Illustration 2 – in-running nip points between rotating and tangentially moving surfaces

Illustration 3 - shear points between a machinery part and a work piece

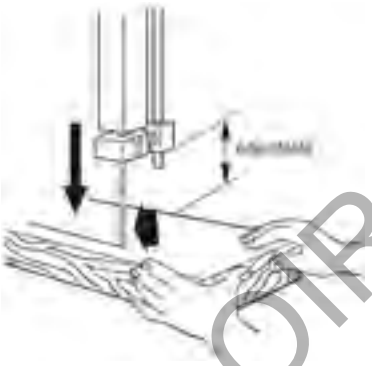


Illustration 4 - cutting areas on a band saw

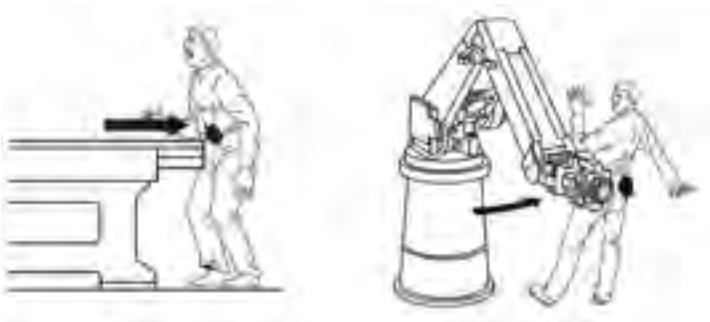


Illustration 5 - impact and crushing areas

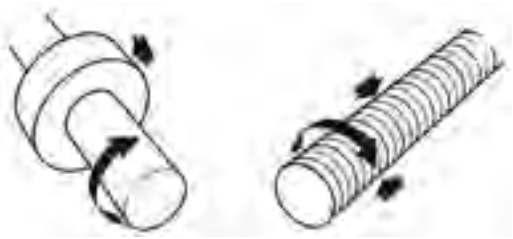


Illustration 6 - entanglement caused by contact with a single rotating surface

Illustration 7 - stabbing points caused by moving parts of machinery or material

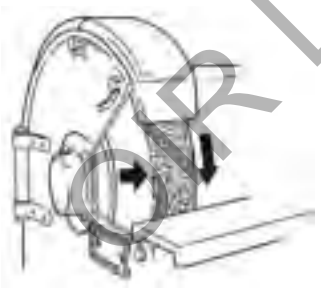


Illustration 8 - abrasion areas

Illustration 9 - flying particles

Illustration 10 - protrusions can cause injury from entanglement

Many of the types of hazards illustrated can usually be effectively managed by the installation of physical barriers. Examples of ways to control these hazards are addressed in section 3 (Guard design) and section 4 (Guards for different machine types).

Before proceeding to the next step of assessing risk, you should identify if the hazards are issues about which there is a regulation or code of practice (made under the *Workplace Health and Safety Act 1995*) or guidance material (produced by Workplace Health and Safety Queensland). The *Code of Practice for Plant 2005* also encourages people to consult a range of Australian Standards and overseas standards to assist in the process of ensuring machine safety and safe operation.

It is also important to consider that there are other specific hazards associated with machinery and plant that are not associated with the actual mechanical operation. The risks associated with these hazards should also be identified, assessed and managed. These risks include:

- release of substances—machinery or processes may release or produce substances or materials, maybe as a by-product, which is hazardous. Examples include fumes, chemicals and metal filings
- noise—noise levels may change at different stages of use
- hot or cold machinery or plant parts—sources of heat can include friction, molten material, hot metal shavings, hot gases, naked flames, radiant heat.

> Section 6 (Other machinery safety issues) provides more information in relation to these specific issues.

2.2 Assessing the risk of identified hazards

A risk assessment seeks to prioritise identified hazards so that risks associated with each hazard (those that have the potential to cause harm) can be eliminated or reduced. Identified hazards are assessed to determine their real potential to cause injury.

Where a hazard is identified, an assessment of risks associated with the hazard should be undertaken. Separate risk assessments should be carried out for each machine and any associated system of work used with that machine. If any alteration or modification is made to the machine, a risk assessment should be repeated.

There are three steps in assessing risks:

Step 1 For each hazard, estimate the **likelihood** of an incident or accident occurring at the workplace or while conducting the work activity. Existing control measures should be considered separately, as they may not necessarily control the risk, but create additional hazards.

Step 2 For each hazard, estimate the **consequences** of an incident or accident occurring at the workplace or while conducting the work activity. Existing control measures should be considered separately, as they may not necessarily control the risk, but create additional hazards.

Step 3 Combine these estimates of likelihood and consequence to determine a risk rating for each hazard. This can be easily read from the Risk Assessment Priority Chart. This chart ranks the risks in terms of their priorities.

For example if the possibility of injury from a particular item of plant or machinery plant is POSSIBLE (could happen, but rarely) and the consequences of such an injury are MAJOR (serious injuries), then the risk score is 4.

Risk Assessment Priority Chart

Likelihood: Probability How likely that it *could* happen?	**Consequences:** How *severely* could it hurt someone?			
	EXTREME **death, permanent disablement** *catastrophic* kills, disables, permanent injury	MAJOR **serious bodily injury** *major* significant injury, *not* permanent	MODERATE **casualty treatment** *minor* first aid only, no lost time	MINOR **first aid only, no lost time**
Very likely Could happen frequently	1	2	3	4
Likely Could happen occasionally	2	3	4	5
Possible Could happen but rarely	3	4	5	6
Unlikely Could happen, probably never will	4	5	6	7

The following scores indicate how important it is to do something about each risk:

Score	Action
1, 2 or 3	Do something about these risks immediately
4 or 5	Do something about these risks as soon as possible
6 or 7	These risks may not need immediate attention

Once each risk has been rated, a prioritised list of workplace risks requiring action can be developed.

A template for a Risk Assessment Form is included in appendix 3. This will help to assess the risks posed by machinery. This form can be photocopied as many times as needed. It is suggested that one form be used per machine, or part of a machine if there are several hazards. This form may be adapted for other things such as purchase, installation, maintenance and work processes relevant to machines in the workplace.

2.3 Deciding on control measures

Once each hazard has been rated, a prioritised list of workplace risks requiring action can be developed. The Risk Assessment Form (appendix 3) will help to assess the risks posed by machinery.

Once a prioritised list has been made, control measures to eliminate or reduce the assessed risks can be decided on. Where an assessment identifies a need to control a risk to health and safety,

that risk should be eliminated, or where it cannot be eliminated, minimised to a safe level. Control measures should be chosen from the most preferred method to the least preferred method by using the hierarchy of control.

Under the *Workplace Health and Safety Act 1995*, a person must consider the appropriateness of control measures in the following order:

A. eliminate the hazard or prevent the risk
B. if eliminating the hazard or preventing the risk is not possible, minimise the risk by the control measures listed below. These control measures must be considered in the following order:
   1. substitute the hazard with a hazard of lesser risk
   2. isolate the hazard from anyone who may be at risk
   3. minimise the risk by engineering means
   4. apply administrative measures
   5. use personal protective equipment.

The hierarchy of control measures is explained in more detail below.

Elimination—this is the most effective method of control and should always be attempted first. For example, discontinue dangerous practices or remove or dispose of dangerous equipment.

When elimination is not practicable
Eliminating a machine or process from your workplace may not always be practicable. In these situations the following control measures should be considered in the following order.

Substitution—replacing a material or process associated with plant with a less hazardous one will reduce risk. For example, replace an unstable pedestal fan with a wall or ceiling mounted model, or use a less hazardous process or part such as moulded plastic process instead of pressed metal manufacturing process.

Isolation—isolating (or separating) a process or machine from workers can be achieved by either distancing the process or machine with the rest of the workplace, or by inserting a physical barrier between the process or machine and worker. For example, install acoustic booths around noisy equipment or use remote handling equipment such as a push-stick.

Engineering—the design/redesign and installation of equipment to counteract hazards are considered engineering controls. For example, install an exhaust ventilation system to extract dangerous fumes, or redesign an electrical system to allow for the installation of emergency stop buttons within easy reach of operators of machinery or plant.

When exposure is not or cannot be minimised by other means?
Control by the above means is not always practicable. Even where one or more of the above control measures has been implemented, additional control measures should be considered.

The following methods should not be relied upon as the primary means of risk control, until the above controls have been considered. They are dependent on human behaviour and require management, enforcement and commitment to work effectively. They may be used as an interim measure until higher level controls are implemented.

Administration—administration controls are procedures or instructions you can put in place to minimise exposure to a risk. These controls can include the time of work, hours of work, who does the work and who has access to work areas, machinery or plant. For example, train workers in the proper procedures and processes for operating machinery or plant, and limit exposure to or the amount of time spent doing hazardous work activities.

Personal protective equipment—personal protective equipment means clothing, equipment or substances which, when worn correctly, protect part or all of the body from risks of injury or disease at work or in the workplace. For example, it includes protective eyewear, protective hearing devices, sturdy gloves or mesh gloves to prevent cutting injuries. The control of exposure to machinery or plant risks should be secured by one or more measures other than the provision of personal protective equipment. Use of personal protective equipment is the least effective method of controlling risk, although a long-term strategy using other methods may require the short-term use of personal protective equipment to attain this aim. For example, you may decide to replace noisy machinery or plant with a quieter version. In the interim, protective hearing devices are provided to workers exposed to the noisy machinery or plant.

To prevent or minimise exposure to a risk, a combination of the above methods can be implemented concurrently. For example, a combination of isolation, administrative and personal protective equipment control measures can be used at the same time. By using a combination of control measures, risk is reduced further and there is less reliance on a single control measure should it fail.

The chosen method of controlling the risk should be recorded. A sample format of recording control measures can be found in the *Risk Assessment Form* (appendix 3). If the preferred control measure cannot be implemented immediately, the form can be used to note the controls intended to be used immediately as a short-term solution, and what is intended to be done later as a long-term solution. Implementation timeframes should be recorded and the document reviewed regularly.

2.4 Implementing control measures

The selected control measures need to be implemented for machinery or plant requiring safeguarding to ensure there is no risk to workers or others. This means undertaking those activities necessary to allow the control measures to function or operate effectively. Implementing control measures involves:

- **Developing work procedures**
  Work procedures should be developed in relation to the new control measures to ensure their effectiveness. Management, supervision and worker responsibilities need to be clearly defined in the work procedures. In relation to the use of machine guarding, the manager's role may involve ensuring the appropriate guarding is purchased and that it is installed correctly. The supervisor's role may involve ensuring the workers operate the machine only with the guarding in place. The role of workers may involve using the machine with guarding in place as instructed or the maintenance of the machine and guard.
- **Communication**
  Workers should be informed about the control measures to be implemented. It is important to clearly communicate the reasons for the changes. Information may also need to be provided to others who may enter the workplace, including cleaners, visitors and contract staff.
- **Providing training and instruction**
  Training and instruction should be provided for the workers, supervisors and others in relation to the new control measures. This may include safe use and operation of guards, breakdown procedures, and repair and maintenance as appropriate.
- **Supervision**
  Adequate supervision should be provided to ensure that the control measures are being used correctly.

- **Maintenance**
  Maintenance relating to control measures is an important part of the implementation process. Work procedures should clearly identify maintenance requirements to ensure the ongoing effectiveness of the new control measures.

2.5 Monitoring and reviewing effectiveness of control measures

The final step in the risk management process is to monitor and review the effectiveness of control measures. For this step, it can be useful to ask questions such as:

- Have control measures been implemented as planned?
- Are these control measures being used, if so, are they being used correctly?
- Are control measures working?
- Have changes made to control exposure to the assessed risks resulted in what was intended?
- Has exposure to the assessed risks been eliminated or adequately reduced?
- Have implemented control measures resulted in the introduction of any new hazards?
- Have implemented control measures resulted in the worsening of any existing hazards?

In order to answer these questions, you can:

- consult with workers, supervisors and health and safety representatives
- measure exposure (e.g. take noise measurements in the case of isolation of a noise source)
- refer to occupational health and safety consultants and representatives of industry associations, unions and government bodies
- refer to manufacturer's instructions
- monitor incident reports.

You should set a date to review the entire workplace health and safety risk management process. Reviews should be conducted at least once every 12 months, however may be required more frequently depending on individual variables at the workplace. The frequency of reviews should be determined by the risk management process.

Risk management is ongoing and the results of risk management should be updated, whether or not the process is complex and whether or not the results are recorded. The risk management process should be repeated at intervals and whenever there is reason to suspect the results are no longer valid because:

- new plant is introduced
- plant is modified so it deviates from the original design
- there is a change in work practices associated with plant
- there is a complaint from workers.

2.6 Keeping documentation and records

Adequate recording of the risk management process undertaken in regards to plant and machinery will help you to demonstrate that you have been actively working to ensure workplace health and safety, should you need to prove this.

Keeping records will also help you keep track of what you have done and are planning to do. This should maximise the effectiveness of the process. A template for recording the entire risk management process is provided in appendix 4. This template can be photocopied as many times as needed. It is suggested that one form be used per machine, or part of a machine if there are several hazards. This template should be used in conjunction with the Risk Assessment Form (appendix 3).

The detail and extent of recording will depend on the size of your workplace and the potential for major workplace health and safety issues.

Case study

There are a number of ways in which the risk management process can be carried out. A case study has been used in this section of the guide to demonstrate one method of conducting the risk management process. This case study assesses the risk from mechanical type hazards, specifically cutting and severing hazards associated with using a machining centre.

A machining centre is a numerically controlled machine tool, capable of performing multiple machining operations and able to change tools automatically from a magazine or similar storage unit. The operations that may be performed include milling, boring, drilling, cutting and tapping.

It should be noted that cutting and severing hazards are just one of the many mechanical hazards associated with machinery and plant. Other mechanical hazards include crushing, shearing, impact and entanglement. There are also other types of hazards, other than mechanical hazards, which are associated with machinery and plant. These hazards include biological, chemical, psychological and ergonomic hazard types. For the purpose of the case study, only cutting and severing hazards are outlined.

When identifying hazards associated with plant and machinery, it is beneficial to list the situations or tasks where the hazard may occur, any associated activity with these situations and the related danger zones.

Appendix 1 contains a list of hazards and some descriptions of these hazards as they relate to machinery and plant. This list should be consulted when undertaking a risk assessment on machinery and plant and will assist to identify hazards, associated activities and situations and danger zones.

The case study below lists the hazardous situations, associated activities and related danger zones relevant to cutting and severing hazards present when using a machining centre.

1. Identify hazards

Description of hazard	Example of related hazardous situation	Associated activity	Related danger zone
Cutting and severing	Spindle or tool running or cutting	Spindle running	At spindle or tool

2. Assess risks

There are three parts to this step:

(a) Estimate the likelihood of an incident or accident occurring at the workplace.

Likelihood: How likely that it could happen?	
Very likely	could happen frequently
Likely	could happen occasionally
Unlikely	could happen but rare
Very unlikely	could happen, probably never will

In this example, the possibility (likelihood) of injury from a person coming in contact with a running or cutting spindle or tool is assessed as likely, i.e. it could happen occasionally.

(b) Estimate the consequences of an incident or accident occurring at the workplace.

Consequences: How severely could it hurt someone?

Extreme	death, permanent disablement
Major	serious bodily injury
Moderate	casualty treatment
Minor	first aid only, no lost work time

The consequence of the running or cutting spindle or tool coming in contact with a person is assessed as extreme, i.e. death or permanent disablement (such as an amputation).

(c) Combine these estimates of likelihood and consequences to determine a risk rating for each risk. This can be easily read from the Risk Assessment Priority Chart below. This chart ranks the risks in terms of their priorities.

Risk Assessment Priority Chart

Likelihood: Probability How likely that it *could* Happen?	**Consequences:** How *severely* could it hurt someone?			
	EXTREME death, permanent disablement	**MAJOR serious bodily injury**	**MODERATE casualty treatment**	**MINOR first aid only, no lost time**
Very likely Could happen frequently	1	2	3	4
Likely Could happen occasionally	2	3	4	5
Possible Could happen but rarely	3	4	5	6
Unlikely Could happen, probably never will	4	5	6	7

The following scores indicate how important it is to do something about each risk:

Score	Action
1, 2 or 3	Do something about these risks immediately
4 or 5	Do something about these risks as soon as possible
6 or 7	These risks may not need immediate attention

In this example, a risk rating of 2 is calculated. This score means that something must be done about this risk immediately. The assessment can now be repeated for all other identified hazards and situations.

3. Determine controls

Associated activity	Related danger zone	Risk assessment		Control
		Score	Action	
Spindle running	At spindle or tool	2	Do something about these risks immediately	Elimination not possible. Substitution not possible at this point in time and will be considered as a long-term solution at the end of the machining centre's life. Machining centres will be safeguarded wherever possible by fixed and/or interlocking moveable guards. If floor-mounted, the guards shall be securely fixed, of adequate height and fixed at a sufficient distance from the danger zones. Protective devices may be used where fixed and interlocking guards are not possible (see AS 4024). Means shall be provided for the movement of machine axes for emergency purposes (e.g. release of trapped people). These means are for example: a) with power off: - relief valves to depressurise systems under pressure - manual release of power-actuated brakes provided that weight-balancing exists b) with power on: - manual control facilities of power-piloted valves/drives - control facilities to start counter motions.

Controls would now need to be chosen for all other hazards associated with the machining centre. These would be considered in order of the hazards, with the highest risks first.

4. Implement controls

Associated activity	Related danger zone	Implementation
Spindle running	At spindle or tool	Prior to interlocking moveable safeguards being fitted, the following activities will be performed. These activities relate to the use of the machining centre after being fitted with the safeguards: (a) work procedures will be developed, with input from workers, for machine centre use, cleaning, maintenance and emergencies (b) training, instruction and information will be provided to workers regarding operating, cleaning, maintenance and emergencies (c) supervision will be provided to ensure correct use and that procedures are followed.

5. Monitor and review controls

Associated activity	Related danger zone	Monitoring and reviewing
Spindle running	At spindle or tool	Supervisor to continually monitor compliance with developed procedures. Retraining (including instruction and information provision) to be provided when there is a change to work practices or machine use and at least every 6 months. Operation, cleaning, maintenance, emergency and other procedures will be reviewed when there is a change to work practices or machine use and at least every 6 months. Safeguard to be maintained regularly (at least every month). Safeguard to be reviewed as control when there is a change to work practices or machine use and at least every six months. When the time comes to replace the machine, elimination and substitution (safer alternatives) will be considered.

Monitoring and review procedures would now be developed for all hazards associated with the machining centre.

Section 3 - Guard design

3.1 Types of guards

> Technical assistance may be found in relevant Australian Standards. The standards with particular relevance to safeguarding common machinery and plant are listed in Appendix 5, together with a brief description of their contents. These standards should be consulted for additional information.

There are a number of different types of guards available, all suited to particular purposes. Depending on the situation, a combination of two or more of the following measures may be used to ensure workers' safety. The range of guards includes but is not limited to fixed, interlocking, hinged, movable barrier, automatic, distance and trip guards. Examples of these types of guards are detailed below.

3.1.1 Fixed guards

Fixed guards are stationary guards and prevent contact between moving machinery parts and any part of the body. They offer protection only when properly fixed in position. Fixed guards should be easy to remove and replace, but only be able to be opened or removed with the aid of a tool and when the machine is not in operation.

Illustration 11 - An example of a fixed guard.

3.1.2 Interlocking guards

Interlocking guards prevent machinery and plant from being operated, unless the guard is in place. Interlocking guards such as enclosure guards are known as movable guards and have the moving part interconnected with the control system. Interconnections are usually electrical, mechanical, hydraulic or pneumatic.

Examples of movable interlocking guards, which are interlocked with the power source of the hazard to ensure that whenever the guard door is not closed the hazard power is switched off, are shown below:

Illustration 12 - An example of a hinge door guard (interlocking movable guard)

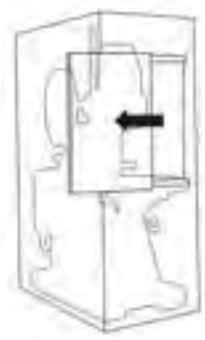


Illustration 13 - An example of a sliding door guard (interlocking movable guard)

3.1.3 Automatic guards

Automatic guards are self-adjusting and automatically move into position as the machine or cycle starts. They are also known as push-away guards. These are only suitable on slow machines.

Illustration 14 - An example of a push-away guard (automatic guard)

3.1.4 Distance guards

Distance guards prevent access to dangerous areas through a barrier or fence. Any access points through the guard (e.g. gates and doors) must be secured with a lock or interlocking system.

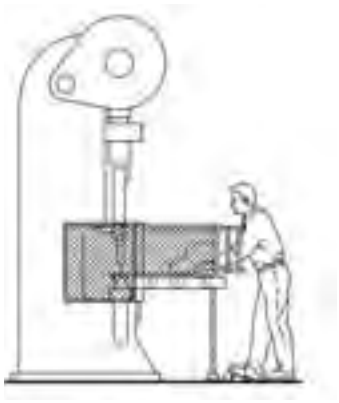


Illustration 15 - An example of a distance guard fitted to the press brake

3.1.5 Trip guards

Trip guards are presence-sensing and stop the machine when a person gets into a position where they are liable to be injured. Photoelectric curtains, laser scanners and pressure mats are examples of this type of guard.

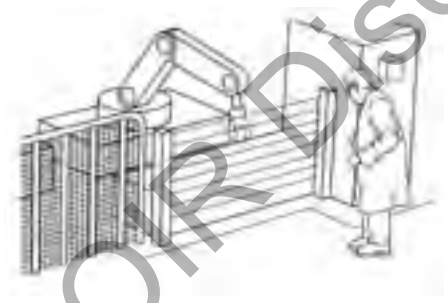


Illustration 16 - An example of a photoelectric light curtain used as a trip guard. When any of the beams are blocked by intrusion towards the hazard area, the light curtain control circuit switches off the hazard power.

> *AS4024.1 Safeguarding of machinery – General principles* provides more information in relation to types of guards and categories of reliability. This standard should be consulted for additional information.
>
> *AS61508.1 Functional safety of electrical/electronic/programmable electronic safety-related systems – General requirements* provides more information in relation to safety integrity levels. This standard should be consulted for additional information.

3.2 Basic rules for guard design

The primary function of a guard is to provide a physical barrier between a worker and the dangerous parts of machinery or plant. When selecting control measures, careful attention to design and layout at the outset can avoid later problems. Basic rules for guard design include:

- ensure the materials used are of suitable strength and good quality
- having any sort of guard may not be enough. Poorly designed or inappropriate guarding has contributed to injuries from machinery or plant. Ideally a guard should be custom-designed for the machine and the work process
- interlock devices may need to be used in conjunction with other types of guarding to ensure safety
- avoid second best when designing a guard. If a guard is used from another machine, it must be checked carefully to ensure that it is not defective, that it fits the target machine, is of suitable strength and quality for the new application and that it achieves the aim of controlling the risk presented by the target machine.

In determining the most appropriate control measure for the hazard, risk and machine, other issues or risks should also be taken into consideration. Guarding can play a useful role in both dust and noise reduction. In many cases, issues of wear, heat and ventilation affect operating efficiency and may also have consequences for worker health and safety.

3.3 Servicing considerations

Guards should be designed for easy removal and replacement. These types of guard make tasks such as regular cleaning, maintenance and machine adjustment or belt changes easier, particularly if this work needs to be done frequently. Safe procedures for removal of guards for repair, or to clear jams or breakdowns must be considered. In all cases, guards should be designed so they can only open or be removed with the aid of a tool and when the machine is not in operation.

Servicing issues include:

- documented safe work procedures, including reference to manufacturer's recommendations
- proximity to hot or sharp parts
- cool down or warm up periods
- lock-out provisions or permission for guard removal
- sufficient room to perform tasks without risk of injury or strain
- any additional hazards arising from maintenance procedures (e.g. testing while machine is unguarded ['dry run'], working at heights, use of solvents)
- maintenance of servicing records.

3.4 Ergonomic considerations

The following tables and illustrations will provide help to assess where and what sort of guarding is needed to keep a danger point on a machine safely out of reach, taking into account the physical characteristics of workers.

3.4.1 Reach measurements

Machines are designed for an average worker—typically a 172 cm (5 ft 8 in) male. If workers are significantly taller or shorter than 172 cm, then employers should consider whether the standard machine guarding methods and work processes are still safe.

The design and positioning of guards should provide at least the following clearance:

Reach	Minimum distance assumed
Arm reach	Greater than or equal to 850 mm from under arm to fingertip
Elbow reach	Greater than or equal to 550 mm from the inside elbow to fingertip
Wrist reach	Greater than or equal to 230 mm from wrist to tip of middle finger
Finger reach	Greater than or equal to 130 mm
Vertical reach	2500 mm maximum when standing on toes

3.4.2 Guard placement

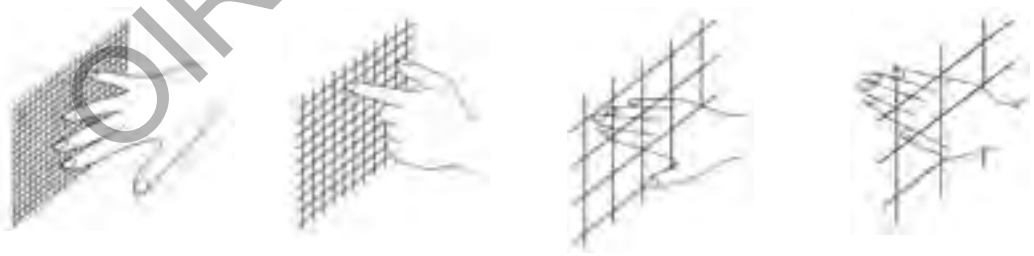
The size of mesh or other openings in the guard and the distance of the guard from the danger point can be selected based on the following guide:

Mesh size openings up to and including 9 mm	Distance of guard from danger point virtually the same
Mesh size over 9mm but less than 40 mm	Guard at least 200 mm from danger point
All types of guards	Distance between bottom opening and floor not to exceed 250 mm

Simple gap/distance formula

The following formula provides an easy method for determining the required **gap** or mesh openings, and the **distance** the guard should be from the danger point:

$$\text{Gap} = \frac{\text{Distance}}{10} + 6\text{mm}$$

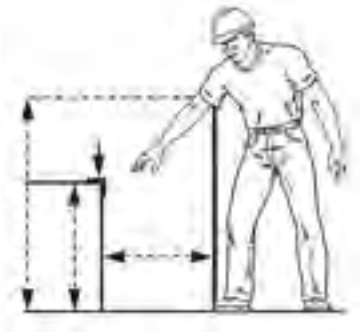


No admittance | Reach restricted to root of finger | Reach restricted to root of thumb | Reach restricted to hand thickness

Reaching down and over

In the following diagram and table:

A = distance of danger point from the floor or working surface
B = height of the barrier
C = horizontal distance to be maintained between edge of barrier and danger point



Note: Barriers must not be able to be stepped over.

A – distance of danger point from floor (mm)	B – height of the barrier (mm)							
	2400	2200	2000	1800	1600	1400	1200	1000
	C – horizontal distance to be maintained between barrier and danger point (mm)							
2400	-	100	100	100	100	100	100	100
2200	-	250	350	400	500	500	600	600
2000	-	-	350	500	600	700	900	1100
1800	-	-	-	600	900	900	1000	1100
1600	-	-	-	500	900	900	1000	1300
1400	-	-	-	100	800	900	1000	1300
1200	-	-	-	-	500	900	1000	1400
1000	-	-	-	-	300	900	1000	1400
800	-	-	-	-	-	600	900	1300
600	-	-	-	-	-	-	500	1200
400	-	-	-	-	-	-	300	1200
200		-	-	-	-	-	200	1100

Section 4 - Guards for different machine types

4.1 Exposed rotating cutting processes

Exposed rotating cutting machinery includes cut-off saws, milling machines, friction cutting and boring equipment. The hazard arises from the exposed blades, and risks include cutting flesh or limbs, or entanglement.

The most appropriate types of guards are fixed or moving guards.

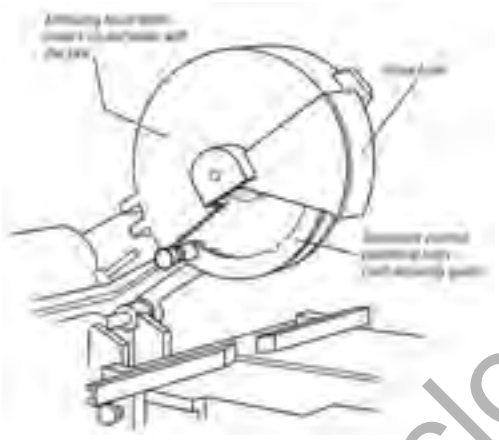


Illustration 17 - Self-adjusting guard for a drop saw

A particular point to note is the self-actuating visor fitted to the fixed guard. If this visor is not affixed, the cutters teeth are exposed when the machine is at the top of its stroke. As the cutter is lowered the visor automatically rises.

4.2 Pulleys and drives

Pulleys and drives are used in a range of machinery. The main hazard is nip-points, and all need to be guarded so as to be out of reach for operators to prevent the risk of entanglement.

Fixed guards are preferred for pulleys and drives. In some cases, a hinged section may be appropriate to enable access during machine setting. Such control measures must be designed and installed so that a tool is required to remove and replace a guard.

Illustration 18 - Fixed guard for a pulley and drive constructed of wire mesh and angle section preventing access to transmission machinery

4.3 Rotating shafts and rollers

Fixed guards are preferred for rotating shafts and rollers. Guards must provide protection against loose clothing and long hair getting entwined with rotating shafts. Appropriate work processes may include the requirement that operators not wear loose clothing, and tie long hair back or wear head covering. Examples of rotating shafts include couplings, spindles, fan-shafts and ironing rollers.

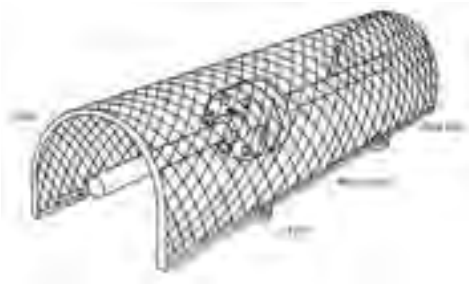


Illustration 19 - Fixed guard on rotating shaft/coupling

4.4 Safety devices

Safety devices are designed to sense a person or part of the body and initiate the stopping of a dangerous motion performed by the machine before access can be gained to a dangerous area surrounding the machine. Safety devices also ensure that a person or part of the body cannot gain access to a dangerous area of the machine as a result of the design, placement or junction of machine controls. Some examples of how safety devices can be used are illustrated below.

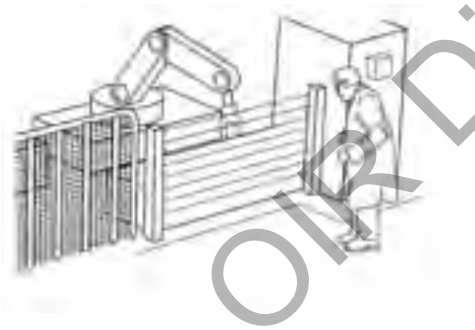


Illustration 20 - An example of a photoelectric light curtain used as a trip guard. When any of the beams are blocked by intrusion towards the hazard area, the light curtain control circuit switches off the hazard power.

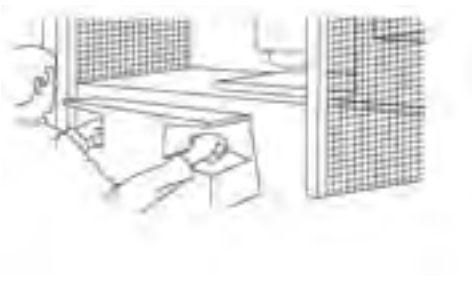


Illustration 21 – Two-handed controls

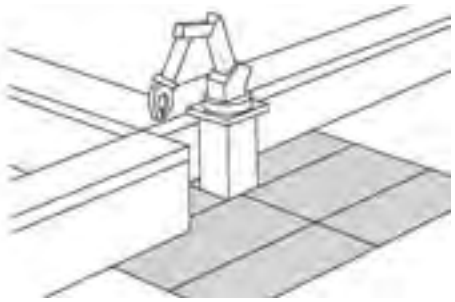


Illustration 22 - Pressure sensitive mat

4.5 Combination of guarding and safety devices

A combination of guarding and safety devices can be used to ensure all hazards and risks associated with the machine have been addressed. Illustrated below is an example where a combination of guarding and safety devices has been used.

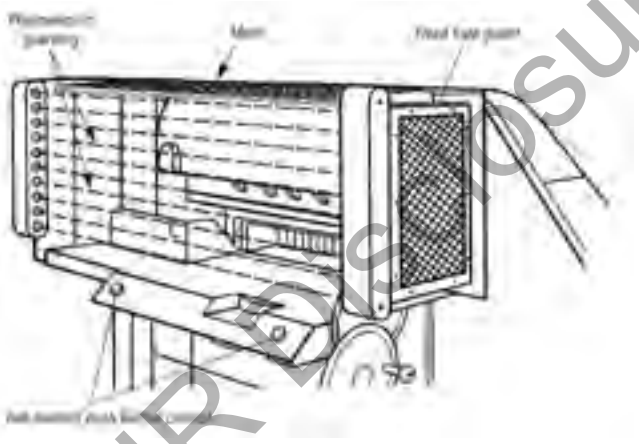


Illustration 23 - Paper cutting guillotine featuring a combination of guarding and safety devices such as photoelectric guarding, fixed side guard and two-handed push button controls.

4.6 Safe work rules and practices

4.6.1 Isolation

With the exception of those circuits required for safety systems, all machinery should be fitted with a means of isolation from all energy sources. Such isolators should be clearly identified and be capable of being locked if reconnection could place people at risk.

An appropriate isolation method is a lock-out/tag-out system, in which one or more padlocks are fitted to the isolation switch, with keys being held by the operators or maintenance personnel. Their name and reason for the lock-out are written on the tags attached to the padlock. When the task is completed, the locks and tags are removed and power can be restored.

4.6.2 Emergency stop devices

Emergency stop devices must be located where an operator can easily reach them. Poorly located devices may encourage dangerous practices, such as reaching across moving parts, a failure to shut down machinery or plant when a problem occurs, or situations where the machine or plant can be started by one worker while another is in a dangerous location (e.g. cleaning a bin).

The number of emergency stop devices required needs to be considered. If the machine or plant is large, several devices may be necessary. When there are multiple devices, safe operating practices must be adopted so that machinery or plant is not restarted when it is undergoing maintenance or other temporary operations. A lock-out/tag-out system, as outlined above, is therefore an essential part of isolating an energy source to prevent accidental plant start-up.

4.6.3 Inspection, cleaning, repair, maintenance and emergency procedures

To safeguard operators and other staff, cleaning, repair, maintenance and emergency procedures must be in place and understood by workers. A regular inspection regime should be in place to identify any problems with plant and machinery and safeguards. Any additional hazards associated with these activities must be identified and assessed as part of the risk management process. Special precautions need to be taken where workers undertaking these tasks are obscured, or where there are multiple operating switches. Apply isolation procedures whenever maintenance or repair requires people to enter the danger area around machinery.

4.6.4 Opening and removing guards

Guards must only be able to be opened or removed with the aid of a tool and when the machine is not in operation.

4.6.5 Weight

Large machinery or plant may require extensive guarding, and these guards may need to be removed for maintenance access. While some sections may remain fixed, it is preferable that the guard be divided into easily removable sections. Sections should be designed to be removed and handled easily by one person. Appropriate placement of handles on movable sections will facilitate ease of removal, lifting and handling and thus reduce the risk of manual handling injuries.

4.6.6 Interactions

Guards that move out of the way for each operation (automatic guards) need special consideration. Watch for potential risks in the interactions between **guard** and **machine**, between **guard** and **person** and between **guard** and **work-piece**.

4.6.7 Colour coding

It is good practice for all safety guards to be painted the same colour. For example, use high visibility yellow (provided it is different to the general machinery colour) so that it can be clearly seen when a guard has been removed or when it is not in its proper place. It is also good practice to paint the surfaces behind the guard a different colour (e.g. blue or red), so that when the guard has been removed, the exposed colour is clearly visible. It is then easy to identify that the guard has been removed and workers are alerted to possible danger.

Section 5 – Safeguarding of power presses, conveyors and robotics

Due to their inherent risks, some machinery and plant requires specific guarding. Specific guards and practices are provided here for conveyors and for robotics and for the two categories of power presses—power stamping presses and brake presses. These machines present a number of hazards and risks requiring control.

5.1 Power stamping presses

Power stamping presses are machines used for stamping various materials by the closing action of two parts—one moving (punch) and one stationary (die). The product is formed when the punch and die are brought together by force generated by a motor and flywheel. There are two main drive systems—key clutch and hydraulic. Operation my be either by automatic feed or by manual operation, where each individual piece of material to be formed is placed into the die area by the operator. It is in this mode of operation that most power press injuries occur.

5.1.1 Hazards and risks

The main hazard of a power stamping press is where the punch and die come together to form the product. The impact would have a crushing, cutting or shearing motion which creates a risk of having a part of the body crushed or cut. Drive belts have in-running nip points which present a risk of entanglement and abrasion.

5.1.2 Control measures

Depending on the type of job to be carried out, there are various ways of guarding these presses. Options include:

- **Fixed guarding:**
  A fixed guard has no moving parts and offers protection only while the guard is in its correct position. Operator access to the hazardous area is prevented, however with the aid of a tool, slides can be adjusted to allow work to be fed through the guard into the stamping area.
- **Interlocked guarding:**
  An interlocking guard is a guard which has a movable part, which is interconnected with the power or control system of the machine so that until the guard is closed, the interlock prevents the machine from operating. With the key-clutch type of press fitted with interlocked guarding, it is also necessary to fit an anti-repeat device to prevent a power stroke in the event of a clutch failure.
- **Presence-sensing devices** (photoelectronics):
  Presence-sensing devices (photoelectronics) detect the presence of a person, or part of a person, in a defined area, and prevent the dangerous parts of machinery from moving while anyone is in that area. Presence-sensing devices are only suitable for hydraulic machines, and installation of these devices should comply with *AS4024.1 Safeguarding of machinery – General principles.*
- **Two-handed controls:**
  Two-handed controls are only suitable for hydraulic machines. This system requires both hands to operate the machine controls and should be designed in accordance with the following:
  - controls should be separated and protected to prevent spanning with one hand only
  - it should not be possible to set the dangerous parts in motion unless the controls are operated within half a second of each other
  - if one or both controls are released, movement of the dangerous parts should be stopped immediately

- the 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 stopped
- rear and side guarding of the machine is required.

- **Administrative controls:**
  Regular maintenance of 'key-clutch' presses is extremely important. Inspection and maintenance records should be kept to demonstrate that maintenance has been carried out. Regular systems audits and safety inspections should be carried out to ensure that standard practice matches stated procedures. Safety inspections should include the condition and operation of the following:
  - flywheel bearing and shaft
  - extractor cam and key
  - anti- repeat device
  - brakes
  - guards
  - safety devices
  - controls.

Maintenance problem areas

1. Clutch mechanism
2. Brake
3. Fywheel bearing
4. Pitman screw
5. Clutch interlock
6. Guard control
7. Linkage and attachments
8. Toolsetter's disconnection
9. Distortion and deterioration of guard gates
10. Guard over foot pedal

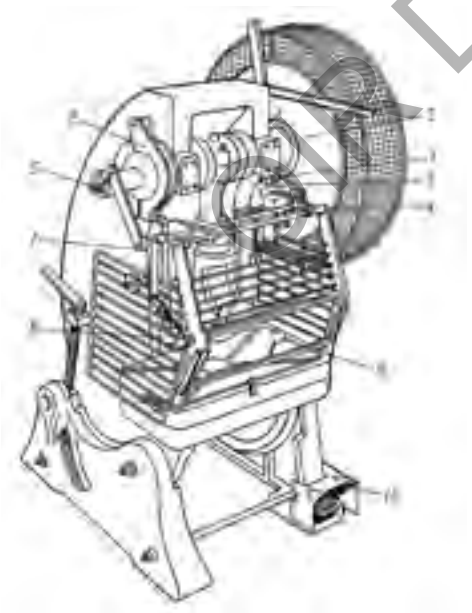


Illustration 24 - This is a power stamping press. Performing maintenance on power presses can bring maintenance people into contact with hazardous areas on the power press. The above illustration identifies common problem areas on a power press.

Flywheel seizure: The flywheel journal bearings must be kept well-lubricated and clean. The majority of presses have ball or roller-bearings, but some imported machines do have rolling keys. The design of rolling key clutches is such that plain bronze bearings are a necessity. Any metallic fragment entering the bearing, or a simple lack of lubrication, could cause the bearing to seize on the journal of the crankshaft and an uninitiated stroke to occur.

5.2 Press brakes (mechanical and hydraulic)

A press brake is a machine generally limited to linear bending and forming of material (e.g. sheet metal and heavy gauge material).

5.2.1 Hazards and risks

The main hazard of a press brake is where the punch and die come together to form the product. The impact would have a crushing, cutting or shearing motion which creates a risk of having a part of the body crushed or cut. Drive belts have in-running nip points which present a risk of entanglement and abrasion. Hydraulic hoses may pose a risk if they leak or burst. Risks may include spills creating a slip hazard and hydraulic fluids coming into contact with workers.

5.2.2 Control measures

Depending on the type of job to be carried out, there are various ways of guarding these presses. Where press brakes are being used for specific repetitive jobs, fixed guards may be appropriate. However, for general use, where workers have to hold or stabilise the material, or need frequent access to closing dies, these machines would require presence-sensing devices to ensure safe operation. Presence-sensing devices may be light curtains or light beams. Automatic stops must also be guarded and back-gauging equipment is recommended.

Presence-sensing systems—light curtains

Light curtains consist of several pairs of light box units and a control box. Each light box pair has a transmitter and receiver. The transmitter generates a curtain of high intensity, micro-second infra-red light pulses, across the machine operator's work area. This curtain of light is transmitted an appropriate distance from the hazardous area as determined in accordance with *AS4024.1 Safeguarding of machinery – General principles*, or as determined by a risk assessment. Any intrusion into this light curtain produces a signal for the control box to stop the machine. In order to assist the operator, these light curtain systems have a variety of operating modes which may be set according to the type of work being done. For example:

- continuous stroking mode—when the control pedal is depressed, the machine will move from the top of the stroke and continue to stroke while the pedal is depressed. If the light curtain is penetrated while the machine is down-stroking, the machine will stop
- top-to-top mode—the machine operates as in the continuous mode, except that, regardless of whether the operator releases the foot pedal, the machine will stop at the top after one cycle
- bottom stop mode—the machine starts from the top of the stroke when the pedal is depressed, and stops leaving a daylight gap between the top and bottom beam, in accordance with AS4024.1 Safeguarding of machinery – General principles or as determined by a risk assessment. At this point the light curtain is muted or bypassed. Depressing the pedal again moves the machine to the bottom of the stroke and returns it to the top where it stops and at this point the light curtain is reactivated

- bottom stop-to-bottom stop mode—similar to the bottom stop mode except the machine does not stop at the top of the stroke. It stops at the 6 mm gap mute position, or when the light curtain is obstructed on the down stroke
- pulsing mode—the light curtain is muted or bypassed and the machine can be moved down in 10 mm increments with each depression of the pedal. This mode allows the operator to stand inside the curtain for close work
- link mode—is used for mechanical presses and is similar to the bottom-stop mode, except the initial down stroke is controlled by an electric foot-switch and at the 6 mm mute point, the pedal controlling the mechanical friction clutch is operated to finalise the stroke of the machine.

Presence-sensing systems—light beams

This type of guarding system consists of three infra-red light beams mounted on the press-brake blade. The front beam protects the operator, while allowing work to be performed close to the blade. The centre beam sets the mute bypass point. The rear beam protects people at the rear of the machine, eliminating the need for mechanical guarding.

On occasions it may not be possible to perform work with the guarding system in place. Specific guidance for the systems to be implemented when guarding is removed or switched off (muted), is detailed in Clause 6.4.3 of *AS1219 – 1994 Power presses – Safety requirements*. However, if the work to be performed requires guarding to be removed on a regular basis, the machine may not be suitable for the application. Measures should therefore be taken to use another machine or to modify the existing machine so that the guard does not have to be removed.

In the event of the need to invoke clause 6.4.3, and regardless of whether option (a), (b) or (c) in that clause is selected, there is still a requirement to install suitable guarding to protect operators from hazards at the rear and sides of the machine. In the event that option (c) of clause 6.4.3 is selected, all seven requirements listed in (c) must be met.

Additionally, a safe system of work should be documented and the operation supervised by a competent person.

> *AS1219 - 1994 Power presses – Safety requirements* provides more information in relation to guarding devices, their design, manufacture and the safeguarding of power stamping presses and brake presses. This standard should be consulted for additional information.

5.3 Conveyors (bulk handling)

Conveyors are a means of transporting materials from one point to another. Different types include belt conveyors, screw conveyors and bucket conveyors.

5.3.1 Hazards and risks

The main hazards of a conveyor are the numerous in-running nip points which present a risk of entanglement, crushing and abrasion. The drive system itself may also pose risks of entanglement or abrasion.

5.3.2 Control measures

Fixed guards which enclose in-running nip points and the drive mechanism are often the most effective ways of safeguarding conveyors. The following examples show the numerous danger points on a standard conveyor and ways to guard the head and tail sections of the conveyor. All guards should be designed for easy removal and should require the use of a tool for removal and replacement.

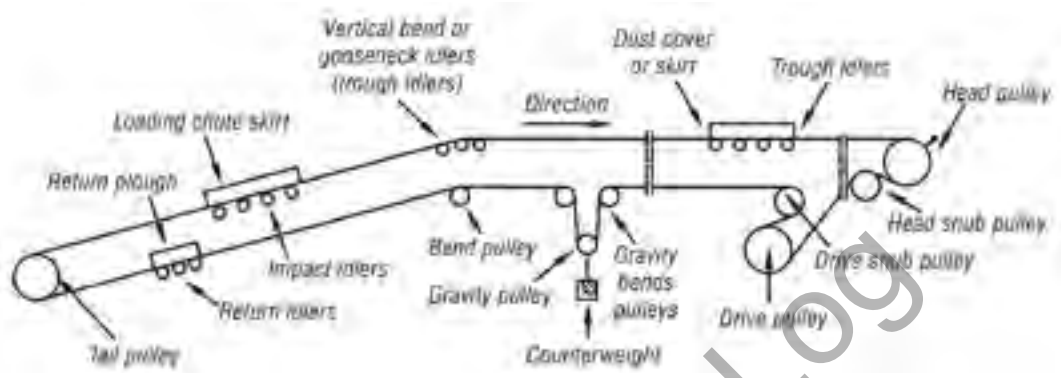


Illustration 25 - Danger points on a standard conveyor

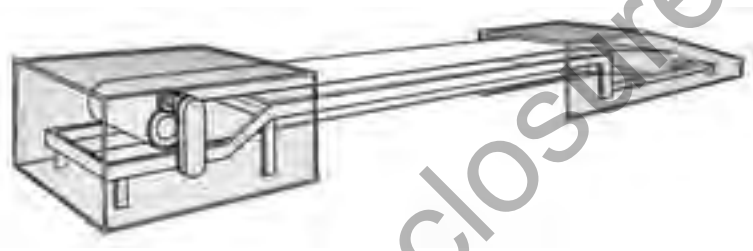


Illustration 26 - Typical guard for head and tail section of a conveyor

It is important to note that physical guarding is not the only guarding option for conveyor systems. Other safeguards include:

- **Electrical isolation (lock-out/tag-out)**
  Although safeguards are provided which prevent access during most phases of machinery or plant life, they may not be effective at all times because of the need to gain access to hazardous areas during maintenance, set-up, etc. Isolation procedures should be developed by the employer which are appropriate for the particular machine. These procedures could include various types of locks, keys and danger tags. A typical lock-out/tag-out system for conveyor drives would be to apply a lock to the isolation switch, as well as a danger tag with the maintenance person's name on it.
- **Start and stop controls**
  Conveyors should be provided with appropriate drive power isolation, whether electrical, hydraulic, pneumatic or mechanical. Isolation should be secured by means of a lock-out/tag-out system. At each conveyor start location, a clearly labelled 'stop' control should be provided. Where the start control is in a position from which the whole of the conveyor operation cannot be viewed, a visible or audible signal should be provided to warn people in the vicinity.
- **Emergency stop controls**
  A lanyard type pull-wire emergency stop is the most suitable emergency stop for exposed belt type conveyors where workers are required to access the belt area when the conveyor is in use (e.g. placing and removing parcels at a transport depot). The lanyard type allows access to the emergency stopping facility from all of the points where a person may be working during the conveyor's use. Emergency stop controls must be manually reset before the conveyor can be restarted from its normal start control.

- **Access provisions**
  Machinery design should allow all routine adjustment, lubrication and maintenance to be carried out without removing guards or extensive dismantling of components. Lubrication and routine maintenance facilities should be incorporated outside the danger area wherever practical. However, when people require access to the danger area, for example for machine setting, safe isolation procedures should be used.
- **Lighting**
  Provide local lighting on the machine for lighting the work area when the machine or guards render normal lighting inadequate for safe operation. Local lighting should also be provided in regular maintenance areas that are poorly lit, for example inside certain electrical compartments where electrical isolation is necessary for access.

> *AS1755 – 2000 Conveyors - Safety requirements* provides more information in relation to minimum safety requirements for the design, installation and guarding of conveyors and conveyor systems. This standard should be consulted for additional information.
>
> *AS1680.1 – 1990 Interior lighting – General principles and recommendations* provides more information in relation to the general principles and recommendations for lighting. This standard should be consulted for additional information.

5.4 Robotics

A common misconception is that robotic operations are 'safe' because there is little or no worker interaction, however most health and safety issues with respect to robotics are in relation to installation, repair and maintenance. While operation may be safe, a risk assessment must be undertaken to ensure workers' safety during all phases of the machinery life and use. Robots have often been used to remove the more traditional hazards associated with machinery and also to perform some high-risk operations, for example in the biotechnology field.

The risk management process should be followed, with reference to manufacturer's instructions, during installation (commissioning), testing and start-up, repair and maintenance.

5.4.1 Hazards and risks

Robots have inherent dangers including unpredictable action patterns, high speed operations, ability to move in free space, and ability to be reprogrammed or reconfigured to change their use and application. Some of the hazards associated with industrial robot operation include:

- **Impact**
  Robots may move in a direction not anticipated or planned, at high speed in linear or rotary directions. The robot may also eject work-pieces, off-cuts or molten metal. Workers are at risk from being hit by the robot or parts of the work.
- **Trapping points**
  Trapping points may be created by movements of the robot or associated equipment such as work carriages, pallets or transfer mechanisms. On the robot itself, trapping points may be identified on the arm of the robot, between the arm and the column, and between the arm and fixed objects. Workers may be crushed or become entangled by the robot or the process.
- **Control errors**
  Control errors result from intrinsic faults within the control system of the robot (e.g. software, electrical interference, program corruption and sub-controls associated with the electrics, hydraulics and pneumatics).

- **Human error**
  Human error could occur during programming, teaching, and maintenance and repair, or in work handling close to the robot or at load/unload stations.
- **Failure or malfunction**
  Failure or malfunction of electrics, hydraulics and pneumatics.
- **Biological or chemical hazards**
  Hazards may occur where robots are being used to reduce the risks from hazardous or infectious processes. Workers may risk inhaling or absorbing hazardous substances. In this case, particular attention must be paid to the process itself and to any breakdown or emergency procedures that may result from spillage, contamination or breach of the system.
- **Environmental hazards**
  Hazards include dust vapour, fumes, lasers, radiations, and flammable and explosive atmospheres. Workers may risk inhaling or absorbing hazardous substances, burns and other injuries.

5.4.2 Control measures

Hazards associated with moving parts, other than at point of operation, should be eliminated by design, or else protection must be provided against the hazards. Industrial robotic installations may be safeguarded by one or more guarding and presence sensing devices. Enclosure is a frequent control measure for robotic systems.

The highly technical and programmable nature of robots means that additional safeguards should be considered in addition to the guarding of dangerous moving parts. Measures should be taken to prevent unauthorised access to controls and to protect the robot system from unintended operation.

Attention must also be paid to controlling hazards in adjacent areas—for example, loading or unloading stations and associated equipment. In particular, removal of associated equipment such as conveyors, transfer systems and trolleys, must not allow access to restricted areas. If so, these points must be guarded.

Control systems

Actuating (start) and control systems for robotics are usually of the programmable electronic type. These must be protected against unauthorised access, for example by location in a lockable control cabinet or room. Controls should be constructed or located to prevent unintentional operation. This can be achieved by shrouding, guarding, gating, appropriately positioned or otherwise designed to prevent accidental operation.

Master switches

Master switches must be provided to isolate all motive power from the robot and may be the same device as an emergency stop device. This master switch should be capable of being locked in the isolating position and require manual resetting.

Fixed or distance guards

Guards may be used where the guard will not interfere with the mechanism of the robot. It must be necessary to use tools to remove the guards in order to gain access to the restricted danger area. Guards or fences must be located to prevent people from reaching in to a restricted area. Any openings provided for feeding material into the process should be designed to prevent access by any part of a person.

Interlocked guards

Interlocked guards initiate an emergency stop when opened. While such a guard must prevent initiation of automatic operation, it may maintain power for other functions. Return to automatic operation would therefore require both the closing of the interlocked guard and the activating of a start procedure.

Presence-sensing devices

Presence-sensing devices must be designed and positioned to detect entry into a restricted space or danger area and to cause the automatic operation of the robot to cease when entry is detected. The failure of this device would also cause the robot to cease operation.

- Photoelectric systems consist of a combination of a photoelectric device (e.g. a light curtain or beam), robot control system, drive and brake units and, where appropriate, an overall performance monitor. Interruption of the light curtain will cause the operation of the robot to cease, therefore it should not be possible to stand or place a body part between the light curtain and the hazardous part of the process. Photoelectric devices can be set to control the size of any penetration (e.g. a hand but not the arm or an arm but not the body).
- Pressure-sensitive mats operate by means of a number of suitably spaced electrical or fluid switches or valves contained within a mat covering the approaches to a restricted space. Pressure on the mat will cause the automatic operation of the machine to cease. Such a guard must be designed so that it is not possible to circumvent or overstep a pressure-sensitive mat into a restricted area.

Training

Inadequate training may increase the risks at most stages of robot operation. Appropriate training is considered essential when controlling the risks associated with industrial robot machines.

Safe work systems

Safe work systems are a recommended control measure to minimise some of the risks associated with robotics. A documented safe work system involves recording procedures for entry (including who is permitted to perform identified tasks), access, maintenance and repair.

Inspection and maintenance activities may provide a different set of hazards to performance or monitoring of work, and must also be assessed in terms of hazards and risks.

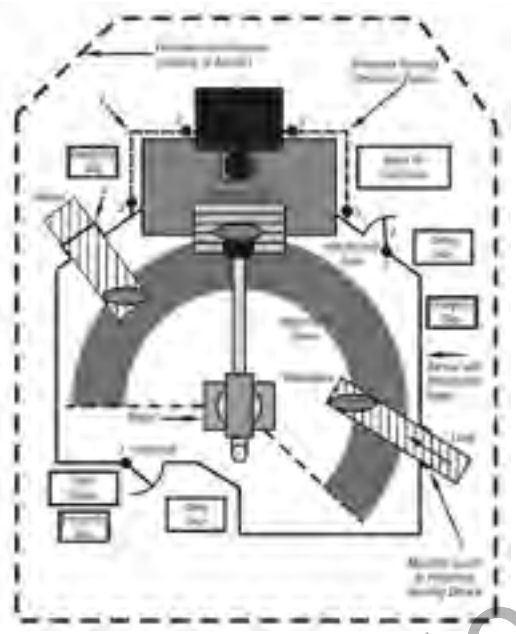


Illustration 27 - Typical manufacturing system using a robot as the material handling system where perimeter marking/barrier, fixed barriers with interlocked gates, presence-sensing devices, warning devices and additional system emergency stop devices are used.

AS2939 – 1987 Industrial robot systems – Safe design and usage provides more information in relation to the requirements of the design, construction, safe guarding and installation of industrial robots. This standard should be consulted for additional information.

Section 6 - Other machinery safety issues

It should be noted that the following sub-sections are not an exhaustive list of 'other machinery safety issues'. *AS4024.1 Safeguarding of machinery – General principles* provides more information in relation to a number of other issues not mentioned in this section. This standard should be consulted for additional information.

6.1 Work organisation

Management has a key role in establishing and maintaining systems and processes that monitor and evaluate potential hazards. Following the risk management process will assist employers and people conducting a business or undertaking to ensure the safety of their workers and those conducting work activities. Commitment is required from all workers, from senior management right down to the shop floor. Production rates and deadlines should be planned so that they can be attained without compromising safe work practices.

For machine guarding to work effectively, the movement of materials on-site and the job procedures appropriate to the machinery must be thoroughly understood. Safe machinery operating procedures or instructions for machinery or plant should be developed, and workers appropriately trained to ensure safe work practices are maintained.

New risks should not be introduced into the workplace because of the introduction of new technology, new machinery or plant, or modifications to existing machinery of plant. At these times risk assessments must be performed, ideally in consultation with workers.

6.1.1 Layout

Machine guarding will be more effective if it is used in conjunction with proper attention to layout. Machines which are poorly located or too close together may not be safe, even if guarded. There are a number of basic points to consider in relation to layout:

- avoid congestions or worker movements near machinery that are likely to increase the risk of injury
- the layout should eliminate or minimise hazardous movements in relation to operation, cleaning or maintenance (e.g. blockage)
- where waste materials are generated, the layout should include space for storage or accumulation until cleared. They should not be allowed to clutter walkways or work areas
- the layout should consider 'traffic flow' by identifying the movements of trucks, materials and people. By defining simple, well marked and well understood traffic areas and directions, the likelihood of people coming near dangerous machinery, and therefore the risk of injury, can be reduced
- proximity of moving parts in relation to other machinery or plant and fixtures in building.

6.1.2 Housekeeping

Untidiness can cause slips, trips and falls. Injuries can be avoided by:

- keeping work areas, walkways and other access paths clear and clean. They should be clearly marked
- preventing spills which may cause slips. Design machinery and work processes to minimise lubrication oil loss or spillage. Clean up spills as soon as possible after they occur, and avoid any oily residues on the floor. Provide a rough anti-slip floor where this is not practical.

6.1.3 Work practices

All processes relating to machinery or plant should be documented. In particular, directions about operation, cleaning, maintenance, and problems that may be encountered should be clearly stated in a way that ensures the safety of the worker. Systems should be in place that prevent workers from bypassing guarding mechanisms.

Supervision is essential to ensure that a system of safeguards is used correctly.

Changes to machinery (new plant or modifications) may require changes to existing work procedures and processes to ensure the guarding does not create new problems. Documentation and work manuals should be updated at the same time.

6.2 Work environment

There are a number of general types of workplace hazards associated with machinery. These include noise, energy (electricity or hydraulics), manual handling (lifting, repetitive movements), substances (solvents, cleaners, chemicals), the work environment (such as confined spaces, lighting, ventilation and access), and the actual plant and equipment in use. The risks associated with these hazards must also be assessed and controlled.

6.2.1 Dust

A dusty workplace can be dangerous. Dust and other airborne contaminants can have direct and severe long-term effects on workers' health, which could include respiratory problems, skin disorders and even cancer. Dust can also cause injury by clogging machinery, inducing sudden breakdowns and obscuring moving parts and other hazards. The discomfort caused by dust on the skin, clothing and protective equipment can also compromise safety.

Some measures for reducing the risk of injury or illness resulting from dust include:

- installing a dust collection system that removes dust from the environment and can save clean up time
- use of a simple lid, cover or shield on saws, augers and other machinery to reduce dust levels
- housekeeping procedures such as frequent cleaning or damping down.

Such guarding may also reduce the level of noise and improve worker comfort and productivity.

6.2.2 Lighting

Ample lighting is needed for the operation of machinery so that machine movements, controls and displays can easily be seen. Poor lighting can affect people both physically and psychologically, causing eye-strain and tiredness.

The following issues should be considered with respect to lighting and machinery:

- direction and intensity of lighting
- contrast between background and work area, applicable to both work environment and control panels
- colour of the light source
- reflection, glare and shadows
- the stroboscopic effect of fluorescent lighting on moving machinery which makes moving parts of machinery look as if they are stopped
- the stroboscope effect of rotating beacons in mobile plant in the internal environment.

AS1680.1 – 1990/Amdt 1 – 1990 Interior lighting – General principles and recommendations provides more information in relation guidance on lighting quantities. This standard should be consulted for additional information.

6.2.3 Noise

Noise, particularly excessive noise, interferes with concentration and can cause operator stress (itself a source of errors), which can lead to mistakes. Noise may also prevent a verbal warning being communicated. The Workplace Health and Safety Regulation 1997 includes provisions with respect to noise levels in the workplace. Noise levels should be measured to ensure compliance with recommended standards.

Control measures for noisy plant and machinery include:

- providing sound-proof enclosures, which may be combined with machine safeguarding
- limiting exposure periods
- providing appropriate, properly fitted hearing protection for operators and other affected workers. It should be noted that incorrectly selected hearing protection can artificially distract the worker, causing them to loose concentration.

Guarding can be made as part of the noise solution. In many instances, carefully designed guarding of moving parts can aid noise reduction and help remove the stress associated with prolonged noise exposure.

6.2.4 Hot and cold environments

A comfortable temperature is safer to work in. Accidents are more likely to happen if people need to work where the temperature is outside a comfortable work range. Extreme heat or extreme cold may also effect machinery operation in various ways.

Some of the control measures to consider when work is conducted in hot and cold environments include:

- providing appropriate personal protective equipment, selected with consideration of the tasks to be performed. In cold environments, bulky insulated clothing may restrict movement, reduce manual dexterity and increase entanglement risks
- limiting exposure periods
- providing sufficient drinking water and air flow for outdoor workers or hot workplaces
- following manufacturers instructions or seeking their advice about machine operation in extreme temperatures.

6.2.5 Ventilation

Some processes and machines generate heat and fumes during operation. People working nearby must be adequately protected from inhaling dangerous fumes and from contacting hot parts.

To control the risks, guarding should:

- allow adequate air flow, for example, through a mesh guard so that equipment does not overheat
- be insulated or distance guarded to reduce the risk of burns
- include ducting if necessary to vent hot air or fumes away from workers
- include filters, if required, to remove dangerous particulates from the air.

6.2.6 Confined spaces

Confined spaces can be created in or around machines when guarding is removed or deactivated to allow for cleaning, maintenance or access to the area surrounding the machine.

Confined spaces present a risk to health and safety and can potentially contain many hazards, some of which are not visibly detectable.

The Workplace Health and Safety Regulation 1997, part 15 (Confined spaces), section 145, deals with using confined spaces and identifies relevant sections of *AS/NZS 2865 – 2001 Safe working in a confined space* that must be complied with.

AS/NZS 2865 – 2001 Safe working in a confined space sets out the particular requirements and procedures to ensure the health and safety of all people required to enter or work in a confined space.

AS4024.1 Safeguarding of machinery – General principles also provides more information in relation to the environmental factors discussed above. Both the regulation and these standards should be consulted for additional information.

6.2.7 Electrical safety

Dangerous situations can arise as a result of the failure of electrical safety control systems. System failure can be caused by several factors such as environmental conditions, suitability for the specific safety application and insufficient system monitoring and maintenance.

The Electrical Safety Act 2002 and the Electrical Safety Regulation 2002 provide a legislative framework to prevent people from being killed or injured and property from being destroyed or damaged from electricity. The Act and the regulation should be consulted for additional information.

AS1543 – 1985 is currently being reviewed and will become *AS6024.1 – 200X Safety of machinery – Electrical equipment of machines Part 1: General requirements*. This standard will provide requirements and recommendations for the electrical equipment of industrial machines with regard to safety of people and property, consistency of control response and ease of maintenance. The draft is not to be regarded as an Australian Standard and should only be consulted for additional information when Standards Australia has released it as such.

AS4024.1 Safeguarding of machinery – General principles also provides more information in relation to the specific requirements regarding overall system design in relation to electrical safety control systems. This standard should be consulted for additional information.

6.3 Minimising human error

Human or worker error is not always the result of carelessness or negligence, but follows from normal human characteristics. The desire for extra speed, less work and making tasks easier, are some of the leading reasons why guards are bypassed or removed. Also, people naturally become bored and distracted with repetitious work, which may cause loss of concentration. Designers, manufacturers and employers should be aware of these factors in designing machines and developing safe work practices.

Machine guarding solutions must take human issues into account, which is another reason to get those using the machine involved in developing solutions. In the long term, a carefully considered solution will almost always prove to be less costly and more efficient.

Factors contributing to human error include, but are not limited to:

- vigilance
- information handling capacity
- ergonomics
- psychological or cultural environment
- habit
- fatigue
- level of training.

Vigilance

Refers to a worker's ability to be alert to danger or problems during operation and is a higher requirement than 'staying awake'. It implies active interaction with and awareness of the work environment. Having regular rest breaks has the potential to improve work performance and assist workers with remaining alert to any danger or problems that may arise during operation. Workers can naturally become bored and distracted with repetitious work, which may cause loss of concentration and an overall decrease in alertness and awareness to danger or problems. Job rotation provides workers with variety so that they do not become bored with repetitive tasks, and therefore increases the likelihood of workers maintaining a high level of alertness and awareness.

Information handling capacity

Vital information can be overlooked if it is presented too quickly, or if it comes together with other information (information overload). If a person has to monitor more than one 'channel' of information at any one time, they should have a clear order of priority.

Ergonomics

Ergonomics is the study of human and machine interaction. Poor operator comfort (e.g. no attention to the location of stools, buttons) can contribute to losses of concentration and result in errors.

> *HB59 – 1994 Ergonomics – The human factor – A practical approach to work systems design* produced by Standards Australia provides more information in relation to designing the workplace and the environment in such a way that the most efficient use is made of human capabilities, without succeeding human capacities. The handbook should be consulted for additional information.

Fatigue

The safe use of machinery is more than attending to guarding. Long hours of work, shiftwork or long periods without adequate breaks can lead to loss of concentration, slow reflexes and increased risk of error. Excessive heat, poor ventilation, lighting and shiftwork also contribute to fatigue, losses of concentration and error, all of which should be taken into account when looking at machine guarding.

> *The Workplace Health and Safety Queensland Fatigue Management Guide* provides more information in relation to fatigue and strategies on how to best manage it in the workplace.

Psychological or cultural environment

A corporate culture of safety creates positive beliefs and values regarding the management of risks in the workplace, and consequently reduces work-related injury and illness.

Habit

People can continue a habitual activity despite indications of danger. Clear labelling of controls and clear, simple warning notices can help. People also get used to a particular arrangement of controls. Use standardised controls as much as possible, and ensure that location of the controls is appropriate. The action used to operate a control should also be compatible with the effect on the machinery, for example, switching a control towards the left moves material into the machine in the same direction. This element deserves particular attention when considering the purchase of replacement machines, especially if the new controls are reversed or located differently.

Training

It should not be assumed that people already know or can informally learn about machinery or plant safety. Training must be provided to workers on any required personal protective equipment, newly introduced equipment or modifications to existing machinery. All people who supervise, manage or operate machinery or plant, should receive appropriate training and instruction for health and safety. Training should include safe operating procedures and any precautions that may be needed to control the hazards of the machines they operate.

6.4 Registrable plant

Owners of plant listed in schedule 2 of the *Workplace Health and Safety Act 1995* and schedule 3 of the *Workplace Health and Safety Regulation 1997* must not use the plant, or permit the plant to be used at a workplace unless the plant is registered.

Owners who want to register plant must apply to Workplace Health and Safety Queensland on the prescribed form. A fee is payable and a certificate of registration is issued, with registration being renewed each year. Notification of change of ownership of registered plant must be given.

Registrable plant listed in schedule 3 of the Regulation includes airconditioning units, specified amusement devices, building maintenance units, cooling towers, escalators, mobile elevating cranes, tower cranes, truck-mounted concrete placing booms and specified boilers, lifts and pressure vessels

6.5 Registrable plant design

The design of plant listed in schedule 4 of the Regulation must be registered with Workplace Health and Safety Queensland.

An application for registration of details of plant design will be registered with Workplace Health and Safety Queensland if it is made in the prescribed form and is accompanied by the prescribed fee and representational drawings of the plant design. An employer must not use or permit the use of, any plant listed in schedule 4 unless the employer possesses a copy of the written notice of the registration of the plant design from Workplace Health and Safety Queensland.

Registrable plant design applies to vehicle hoists, elevating work platforms, specified cranes and hoists, lifts, escalators, domestic lifts, people movers, amusement devices (as classified), and certain boilers and pressure vessels. Applicable design standards are listed.

Section 7 - Further information

7.1 Standards Australia

Standards Australia develops and maintains more than 7000 Australian Standards and related publications. These documents are used in countless daily business transactions and facilitate trade between individuals, corporations and nations. To obtain further assistance in relation to Australian Standards, Standards Australia can be contacted through their Customer Service Centre:

National Customer Service Centre

Telephone: 1300 65 46 46
Facsimile: 1300 65 49 49
Overseas Telephone calls (02) 8206 6010
Overseas Faxes (02) 8206 6020
Email: sales@sai-global.com
Web shop: www.standards.com.au

7.2 Consulting engineers

There are a number of consultants who can offer advice on safeguarding machinery or plant. If it is decided to use a consultant, shop around and make sure the consultant is fully conversant with Queensland legislative requirements, and that they take an approach to the problem that is consistent with the principles identified in this guide. Ask them for evidence of previous work in the area and check out the work for yourself, talking if possible with other employers. Small employers can pool with other employers in the area in order to spread the costs. This type of cooperation makes sense as it saves time and money.

7.3 Workers

Remember the workforce when it comes to seeking solutions. They work with the machinery and plant every day and they can often not only help better identify a problem, but also help with devising the most efficient and cost-effective solutions. Workplace safety committees or health and safety representatives should be involved, but even if these do not exist at the particular workplace, workers should still be involved. In the end, they have a direct interest in safeguarding their own health.

Even if experts or consultants are brought in, there will be a need to ensure that workers are informed and involved. A guard may look fine from an engineering viewpoint, but it also needs to take account of worker comfort and ease of operation. Workers are in the best position to judge the effectiveness of guards on the machines they are using.

7.4 Industry associations and similar workplaces

Industry associations, unions etc. can be used to obtain additional information. Their existing networks and contacts can be useful in identifying specific workplaces that perform similar types of work and therefore may be experiencing similar types of issues in relation to safeguarding machinery or plant.

7.5 Workplace Health and Safety Queensland

When considering machine guarding needs, or if unsure about how to handle a problem, Workplace Health and Safety Queensland should be contacted on 1300 369 915. Issues and options can be discussed with an inspector or adviser.

Appendix 1 – Machinery and plant hazard list

#	Hazard	Comments
Hazards, hazardous situations and hazardous events		
1	**Mechanical hazards**	
1.1	Generated by machine parts or work-pieces, caused, for example, by:	
1.1.1	shape	
1.1.2	relative location	
1.1.3	mass and stability (potential energy of elements which may move under the effect of gravity)	
1.1.4	mass and velocity (kinetic energy of elements in controlled or uncontrolled motion)	
1.1.5	inadequacy of mechanical strength	
1.2	Accumulation of energy inside the machinery caused, for example, by:	
1.2.1	elastic elements (springs)	
1.2.2	liquids and gases under pressure	
1.2.3	the effect of vacuum	
1.3	Elementary forms of mechanical hazards	
1.3.1	crushing hazard	
1.3.2	shearing hazard	
1.3.3	cutting or severing hazard	
1.3.4	entanglement hazard	
1.3.5	drawing-in or trapping hazard	
1.3.6	impact hazard	
1.3.7	stabbing or puncture hazard	
1.3.8	friction or abrasion hazard	
1.3.9	high pressure fluid injection or ejection hazard	
2	**Electrical hazards, due to:**	
2.1	contact of people with live parts (direct contact)	
2.2	contact of people with parts which have become live under faulty conditions (indirect contact)	
2.3	approach to live parts under high voltage	
2.4	electrostatic phenomena	
2.5	thermal radiation or other phenomena such as the projection of molten particles and chemical effects from short circuits, overloads, etc.	
3	**Thermal hazards, resulting in:**	
3.1	burns and scalds by a possible contact of people with objects or materials with an extreme temperature, by flames or explosions and also by the radiation of heat sources	
3.2	health damaging effects by hot or cold work environment	

4	**Hazards generated by noise, resulting in:**	
4.1	hearing loss (deafness), other physiological disorders (e.g. loss of balance, loss of awareness)	
4.2	interference with speech communication, acoustic signals, etc.	
5	**Hazards generated by vibration**	
5.1	use of hand-held machines resulting in a variety of neurological and vascular disorders	
5.2	whole body vibration, particularly when combined with poor postures	
6	**Hazards generated by radiation**	
6.1	low frequency, radio frequency radiation, micro waves	
6.2	Infra-red, visible and ultraviolet light	
6.3	X and gamma rays	
6.4	alpha, beta rays, electron or ion beams, neutrons	
6.5	lasers	
7	**Hazards generated by materials and substances processed, used by the machinery and by its constituent materials**	
7.1	hazards from contact with or inhalation of harmful fluids, gases, mists, fumes and dusts	
7.2	fire or explosion hazard	
7.3	biological or micro-biological (viral or bacterial) hazards	
8	**Hazards generated by neglecting ergonomic principles in machinery design as, e.g. hazards from:**	
8.1	unhealthy postures or excessive effort	
8.2	inadequate consideration of hand-arm or foot-leg anatomy	
8.3	neglected use of personal protection equipment	
8.4	inadequate local lighting	
8.5	mental overload and under-load, stress	
8.6	human error, human behaviour	
8.7	inadequate design, location or identification of manual controls	
8.8	inadequate design or location of visual display units (VDU)	
9	**Combination of hazards**	
10	Unexpected start-up, unexpected over-run/over-speed (or similar malfunction) from:	
10.1	failure/disorder of the control system	
10.2	restoration of energy supply after an interruption	
10.3	external influences on electrical equipment	
10.4	other external influences (gravity, wind, etc.)	
10.5	errors in the software	
10.6	errors made by the operator (due to mismatch of machinery with human characteristics and abilities, see 8.6)	

11	Impossibility of stopping the machine in the best possible conditions	
12	Variations in the rotational speed of tools	
13	Failure of the power supply	
14	Failure of the control circuit	
15	Errors of fitting	
16	Break-up during operation	
17	Falling or ejected objects or fluids	
18	Loss of stability / overturning of machinery	
19	Slip, trip and fall of people (related to machinery)	
Additional hazards, hazardous situations and hazardous events due to mobility		
20	Mechanical hazards	
21	Linked to the working position (including driving station) on the machine	
22	Due to the control system	
23	From handling the machine (lack of stability)	
24	Due to the power source and to the transmission of power	
25	Lack or inadequacy of visual or acoustic warning means	
26	Insufficient instructions for the driver/operator	
Additional hazards, hazardous situations and hazardous events due to lifting		
27	Mechanical hazards and hazardous events	
28	Electrical hazard	
28.1	from lightning	
29	Hazards generated by neglecting ergonomic principles	
Additional Hazards, hazardous situations and hazardous events due to underground work		
30	Mechanical hazards and hazardous events:	
31	Restricted movement of people	
32	Fire and explosion	
33	Emission of dust, gases etc.	
Additional hazards, hazardous situations and hazardous events due to the lifting or moving of people		
34	Mechanical hazards and hazardous events	
35	Falling of person from carrier	
36	Falling or overturning of person carrier	
37	Human error, human behaviour	

Appendix 2 - Dictionary of defined terms

Abrasion areas	Abrasion areas involve 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 abrasion areas include the periphery of an abrasive wheel, belt sanding machine, material running onto a reel or shaft, a conveyor belt and its drums or pulleys, and fast-moving ropes or belts.
Consequence	The outcome of an event or situation expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain.
Cutting areas	Cutting areas may involve rotating, reciprocating, or transverse motion. The danger of cutting action exists at the point of operation where finger, arm and body injuries can occur and where flying chips or scrap material can strike the head, particularly in the area of the eyes or face. Such hazards are present at the point of operation in cutting wood, metal, or other materials. Examples of mechanisms involving cutting hazards include all kinds of cutting tools, band and circular saws, boring or drilling machines, planing and tenoning machines, milling machines, water jet cutting, high energy laser or edges of moving sheet material. The cutting effect may be aggravated by the body being unable to move away from the cutter.
Danger	a state or condition in which personal injury is reasonably foreseeable.
Entanglement areas	Entanglement areas occurs through bodily contact through: • contact with a single rotating surface, e.g. couplings, spindles, chucks, lead screws, mandrels, bars, or rotating work-pieces • catching on projections or in gaps, 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 • by catching between two parts such as between counter-rotating parts (e.g. gear wheels, rolling mills), rotating and tangentially moving parts (e.g. a chain and chain wheel, a power transmission belt and its pulley) or rotating and fixed parts (e.g. revolving mixer and mincing mechanisms in casings having unprotected openings) • catching in materials in motion, e.g. centrifuges, tumble driers or dough mixers.
Fixed guards	Permanent stationary guard that prevents access to the dangerous parts of machinery by enclosure or by providing a rigid barrier. May also totally enclose a machine. Fixed guards offer protection only when properly fixed in position, and should not incorporate any means of retention that creates the impression of the guard being securely fixed, when they are not so fixed. Fixed guards must be designed to require a tool for removal and replacement.

Flying particles	The body may be penetrated by flying objects, ejection of parts of machinery (e.g. flying shuttle of a loom) or ejection of material (e.g. molten metal ejection from a die-casting machine, sparks generated in a welding process). Injection of fluids through the skin can cause tissue damage similar to crushing and can be considered in this category. Examples are compressed air jets, diesel fuel injectors, paint sprayers and high pressure hydraulic systems.
Guard	A physical barrier that prevents or reduces access to a danger point or area.
Hazard	Something with the potential to cause harm.
Impact and crushing areas	Impact and crushing areas occur when one part of machinery moves against another with a part of the body in between eg the ram of a forging hammer, counterweights or the tools of power presses. The traversing motion of a machinery part eg the table of a machine tool and a fixed structure not being part of the machinery may also create this type of a hazard, as may a scissor hoist or table.
In-running nip point	In-running nip points occur on the rotating parts of machinery. There are three types: • parts rotating in opposite directions and parallel to each other, typically where material may be fed into a rolling mill, or where there are intermeshing gears • between rotating and tangentially moving parts, for example chain and sprocket, rack and pinion • between rotating and fixed parts which create a shearing, crushing or abrading action, as in spoked handwheels, flywheels and screw conveyors.
Interlocking guard	Physical barrier which is interconnected with the power or control system of the machine. The interlock prevents the machinery from operating unless the guard is closed. Interconnections are usually either mechanical, electrical, hydraulic or pneumatic, and 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.
Lock-out/tag-out	Procedure which can include various types of locks, keys and danger tags eg. applying a lock to the isolation switch, as well as a danger tag with the maintenance person's name on it.
Presence-sensing guard	There are two types: • laser guards—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. If the light field is broken, the machine stops and will not cycle.

This device must be used only on machines which can be stopped before the worker can reach the danger area
- light beams—used in laser guarding of machinery. May be a scanning beam or beams, or a number of fixed beams. The light may be visible or invisible, e.g. infra-red, and may be continuous or modulated.

Risk — The likelihood that death, injury or illness might result because of the hazard.

Risk assessment — The process used to determine risk management priorities by evaluating and comparing the level of risk against predetermined standards, target risk levels or other criteria.

Risk priority — The level of importance placed on a risk where the higher the risk score the higher the priority of controlling the risk.

Safeguarding — A means of preventing people from coming in contact with any hazardous parts of a machine.

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

Shear points — Shearing action involves applying power to a slide or knife in order to trim or shear metal or other materials. Shear points occur where stock is actually inserted, held, and withdrawn. Parts of the body may be sheared in the following ways:

- between two machine parts, 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
- between a machine part and a work-piece, e.g. transfer mechanisms, the tool of a broaching machine.

Stabbing points — Stabbing points involve moving parts of machinery or piece of material:

- flying objects, ejection of parts of machinery or ejection of material, e.g. timber ejected from a bench saw
- rapidly moving parts of machinery or pieces of material, e.g. sewing machines, drilling machines.

Appendix 3- Risk Assessment Form

Type of machine: .....

Identification: .....

Hazard: .....

- On the following chart, circle the most likely harm to a person if the risk happens (along the top).
- Next, circle how often it *could* happen (down the left hand side).
- The risk priority (score) is the number where the two intersect.

Risk Assessment Priority Chart

Likelihood: How likely *could* happen?	**Consequences:** How *severely* could it hurt someone?			
	EXTREME death, permanent disablement	**MAJOR serious bodily injury**	**MODERATE casualty treatment**	**MINOR first aid only, no lost time**
Very likely Could happen frequently	1	2	3	4
Likely Could happen occasionally	2	3	4	5
Possible Could happen but rarely	3	4	5	6
Unlikely Could happen, probably never will	4	5	6	7

What is the risk priority? (score 1 - 7 from the above chart)

- If you score a 1, 2 or 3 – do something *now* – consider all applicable control measures.
- If you score 4 or 5 – do something as soon as possible.
- If you score 6 or 7 – does not need immediate attention.

Choose control measures from the highest possible level in the following list:

Level 1: Eliminate the hazard	**Level 2: Prevent or minimise the risk by one or a combination of:**	**Level 3: When exposure to the risk is not or cannot be minimised by other means:**
	• **Substitute** a less hazardous machine • **Modify** the design of the machine • **Isolate** the machinery • **Introduce** engineering controls, e.g. guarding	Introduce administrative controls, and use appropriate personal protective equipment

Control measures – action to take:

Now: .....

.....

.....

Later (date and action): .....

.....

.....

In many cases, guarding is the best form of control to manage exposure to risks involving the use of machinery, particularly in many smaller businesses.

This Risk Assessment Form can be used to prioritise the risks identified in a workplace.

Appendix 4 – Risk Assessment Template

Identify risks			Assess risks			Control risks	Implement controls	Monitor and review controls
Description of hazard	Example(s) of related hazardous situation(s)	Associated activity	Related danger zone	Score	Action	Control measures	Method for implementing	Methods for reviewing and monitoring

Appendix 5 - Australian Standards

Australian Standards are the accepted standards for safeguarding machinery, plant and other issues. They are developed, published and distributed by Standards Australia. Contact details for Standards Australia are:

Standards Australia Limited
286 Sussex Street, Sydney, NSW, 2000
GPO Box 5420, Sydney, NSW, 2001
Telephone: +61 2 8206 6000

Email: mail@standards.org.au
Website: www.standards.org.au

Some of the most useful standards available from Standards Australia relating to machine guarding are listed below. These standards were current at the time of printing. Please contact Standards Australia to ensure that these standards are still current.

Title	Description
AS 4024.1 - 1996 *Safeguarding of machinery - General principles*	Sets out the general underlying principles for machine guarding and provides means for identifying hazards and risks arising from the use of machinery during all phases of machine life. Methods for eliminating or reducing these hazards and risks, for safeguarding machines, and for safe working practices are described. Guidelines for assessing the safety measures needed in particular circumstances are provided. It does not provide guidance for safeguarding any particular machine.
AS 4024.2 – 1998 *Safeguarding of machinery – Installation & commissioning requirements for electro-sensitive systems – Optoelectronic devices*	Specifies requirements for the installation and commissioning of optoelectronic devices which are to be used for machinery safety applications.
AS 4024.3 – 1998 *Safeguarding of machinery – Manufacturing and testing requirements for electro-sensitive systems – Optoelectronic devices*	Specifies requirements for the manufacture and testing of optoelectronics protective devices which are specifically used for machinery safety applications.
AS 4024.4 – 1998 *Safeguarding of machinery – Installation and commissioning requirements for electro-sensitive systems – Pressure-sensitive devices*	Specifies requirements for the installation and commissioning of pressure-sensitive mats, floors, edges and bars which are to be used for machinery safety applications.

Title	Description
AS 4024.5 – 1998 *Safeguarding of machinery – Manufacturing and testing requirements for electro-sensitive systems – Pressure-sensitive devices*	Specifies requirements for the manufacture and testing of pressure-sensitive mats, floors, edges and bars which are to be used for machinery safety applications.
AS 1219 - 1994 *Power presses - Safety requirements*	Specifies safety requirements for the design, construction, operation and maintenance of power stamping presses and brake presses. Incorporates details for safeguarding power presses, die design and die setting. Provides recommendations for operation, maintenance and inspection of presses, and the training and supervision of operators.
AS 1473 - 1991 *Guarding and safe use of woodworking machinery*	Specifies minimum requirements for the guarding and safe use of powered machines which cut or abrade wood, wood products and like materials, to be observed by employers, trainers, employees, designers, makers and suppliers of woodworking machinery and other people having an interest in woodworking machine operations. Chainsaws, and machinery used in the milling of raw sawlogs, together with debarkers and log peelers are not covered.
AS 1473.1-2000 *Wood processing machinery* – Primary timber milling machinery	Specifies safety requirements for the design, manufacture, guarding and use of milling equipment used for the primary milling of saw logs into green sawn timber products.
AS 1473.2 – 2001 *Woodprocessing machinery – Safety – Finishing machinery – Common requirements*	Specifies requirements which are common to all classes of wood for the design, manufacture, guarding and use of machines for the manufacture of components for furniture joinery and the like. The standard does not apply to machines used for the primary milling of
AS 1473.3 – 2001 *Woodprocessing machinery – Safety – Finishing machinery – Circular sawing machines*	Specifies safety requirements for the design, manufacture, safeguarding and use of circular sawing machines used in the manufacture of components for furniture, joinery and the like. To be used in conjunction with AS 1473.2, which contains general safety requirements.
AS 1473.4 – 2001 *Woodprocessing machinery – Safety – Finishing machinery – Bandsawing machines*	Specifies safety requirements for the design, manufacture, safeguarding and use of bandsawing machines used in the manufacture of components for joinery, furniture and the like. To be used in conjunction with AS 1473.2, which contains general requirements.
AS 1473.5 – 2001 *Woodprocessing machinery – Safety – Finishing machinery – Moulding machines and routers with rotating tool*	Specifies the safety requirements for the design, manufacture, safeguarding and use of moulding and routing machines used in the manufacture of components for joinery, furniture and the like. To be read in conjunction with AS 1473.2, which contains general requirements.

Title	Description
DR 01145 *Wood processing machinery – Safety – Pt 6: Finishing machinery – Surface planers and thicknessing*	Proposes the safety requirements for the design, manufacture, safeguarding and use of surface planers and thicknessers, used in the manufacture of components for furniture, joinery and the like. To be read in conjunction with AS 1473.2, which contains general requirements.
AS/NZS 1677.1 – 1998 *Refrigerating systems – Refrigerant classification*	Specifies a simple means of referring to common refrigerants instead of using the chemical name, formula, or trade name. It also establishes a uniform system to be used in assigning the proper reference number and classification to refrigerants. The system for refrigerants classification is defined and physical data of common refrigerants listed.
AS/NZS 1677.2 – 1998 *Refrigerating systems – Safety requirements for fixed applications*	Specifies requirements for the safety aspects, in terms of the design, construction, installation and inspection of refrigerating appliances, systems and ancillary equipment intended for use or installation in institutional, public assembly, residential, commercial and industrial occupancies. It applies to new refrigerating systems, to extensions and modifications of existing systems and to used systems on being reinstalled and operated at another site. It also applies in the case of the conversion of a system for use with another refrigerant.
AS 1680.1 – 1990 Interior lighting – General principles and recommendations	Specifies general principles and recommendations for the lighting of interiors of buildings. Primarily relates to interiors in which work is undertaken and takes into account both electric lighting and daylight.
AS 1755 – 2000 *Conveyors - Safety requirements*	Specifies minimum safety requirements for the design, construction, installation and guarding of conveyors and conveyor systems, both above ground and underground. It does not apply to platform elevators, moving stairways or conveyors specifically designed for the conveyance of people. Provides recommendations for inspection, maintenance, marking and identification, and the training of operators.
AS 1788.1 - 1987 *Abrasive wheels - Design, construction and safeguarding*	Specifies requirements for the design and construction of abrasive wheels and the manufacture and installation of abrasive wheels and ancillary equipment. Particular requirements are given for the construction of guards for all equipment fitted with abrasive wheels and for the construction of flanges for use with abrasive wheels. Includes sections covering standard (normal) maximum operating speeds for all types of wheels. Extensively illustrated.
AS 1788.2 - 1987 *Abrasive wheels - Selection, care and use*	Specifies requirements for the application and operation of abrasive wheels. Includes sections on the storage, handling and mounting of abrasive wheels, as well as conditions for using special operating speeds. Illustrations of suitable guards and guarding details are included.

Title	Description
AS 1893 – 1977 *Code of practice for the guarding & safe use of metal & paper cutting guillotines*	Outlines the general requirements for guarding, with specific requirements for the guarding of different types of machines. Fixed, interlocked, automatic and electronic guards are included.
AS/NZS 2211.1 – 2004 *Safety of laser products - Equipment classification, requirements and user's guide (IEC 608825-1:2001, MOD)*	Specifies requirements and procedures designed to protect people from laser radiation. Intended for application both by users and manufacturers of laser products. It specifies safe working levels of optical radiation, classifies lasers according to their degree of hazard and sets out detailed protective and control measures appropriate to each class. A statement on the effect of laser radiation on biological tissues is given in an appendix, and other appendices cover maximum permissible exposures, calculations, a medical surveillance chart, and the design of warning labels and signs. It is based on, but not equivalent to, IEC 825-1:1993.
AS/NZS 2211.4 – 2002 *Safety of laser products - Laser guards*	Provides requirements for laser guards, permanent and temporary, which enclose the process zone of a laser processing machine, and specifications for proprietary laser guards. This standard is identical with and has been reproduced from IEC 60825-4:1997.
AS/NZS 2211.6 – 2002 *Safety of laser products - Safety of products with optical sources, exclusively used for visible information transmission to the human eye*	Provides an adapted hazard categorisation scheme and specific guidance for the safe use of visible optical sources that are used exclusively for transmission of information to the human eye. This standard is identical with and has been reproduced from IEC TS 60825-6:1999.
AS 2359.9-1995 *Powered industrial trucks - High-lift rider trucks - Overhead guards - Specification and testing*	Specifies the requirements and testing for overhead guards designed to protect the operator from falling objects, but not from the impact of a falling load. This standard is technically equivalent with and reproduced from ISO 6055:1979, including Erratum:1980.
AS 2397 – 1993 *Safe use of lasers in the building and construction industry*	Sets out safety requirements for the use of lasers in the building and construction industry. Provision has been made for the use of Class 3B (Restricted) lasers where the level of illumination is appropriate. It is intended for use as a reference by people concerned with the use of lasers for alignment, levelling, control and survey tasks in the building and construction industry, and supplements the requirements of AS 2211 relevant to work in that industry. It does not cover the design and manufacture of lasers, nor the use of lasers in other applications.
AS 2939 – 1987 *Industrial robot systems - Safe design and usage*	Specifies requirements for the design, construction, safeguarding and installation of industrial robot systems. In addition, requirements are given for the training of personnel. Recommendations for the safe programming, maintenance and operation of industrial robots are also included. The standard is extensively illustrated.

Title	Description
AS 2661 – 1983 *Vapour degreasing plant - Design, installation and operation - Safety requirements*	Sets out safety requirements for the design, construction and installation of vapour degreasing plant with or without ultrasonic agitation. Provides also recommended methods for the safe operation of such plant and prescribes the inspection and maintenance procedures relevant to the safety of people. Appendices cover a recommended method for plant cleaning, and first aid in emergencies. It does not cover surface treatment processes or aqueous or alkaline degreasing.
AS 2958.0 – 2000 *Earth-moving machinery - Safety - General introduction and listing*	Provides the introduction to and listing of Australia Standards grouped under the subject heading 'Safety'.
AS 2958.1 – 1995 *Earth-moving machinery - Safety - Wheeled machines - Brakes*	Sets out the minimum performance criteria for service brake systems, secondary brake systems and parking brake systems for operator-controlled, self-propelled earth-moving machines. Applies to rubber-tyred backhoe loaders, dumpers, excavators, graders, loaders, and tractors or tractor scrapers. It includes an appendix setting out requirements for in-service testing.
AS 2958.2 – 1988 *Earth-moving machinery - Safety - Guards and shields - Definitions and specifications*	Gives definitions and specifies characteristics of different guards and shields to protect personnel from accidental hazards due to mechanical, thermal, chemical or electrical causes. Covers both rubber-tyred and track-type off-highway earth-moving machinery, but not ROPS, FOPS and cabs.
AS 2958.3 – 1992 *Earth-moving machinery - Safety - Roller compactors - Brake systems*	Specifies requirements for brake systems that are fitted to self-propelled ride-on roller compactors.
AS 3710 – 1989 *Vibration and shock - Balancing machines - Enclosures and other safety measures*	Specifies requirements for enclosures and other safety measures used to minimise hazards associated with the operation of balancing machines under a variety of rotor and balancing conditions. It defines different classes of protection that enclosures and other protective features provide and describes the limits of applicability for each class of protection.
AS 3877 – 1991 *Manipulating industrial robots - Vocabulary*	Defines terms relevant to manipulating industrial robots operated in a manufacturing environment. It is identical with and has been reproduced from ISO/TR 8373:1988.
AS 3984 – 1991 *Manipulating industrial robots - Performance criteria and related test methods*	Describes methods of specifying and testing the performance characteristics of manipulating industrial robots. This standard is identical with and has been reproduced from ISO 9283:1990.

Title	Description
AS 3985.1 – 1991 *Manipulating industrial robots - Mechanical interfaces - Circular (form A)*	Defines the main dimensions, designation and marking for the circular mechanical interface (form A). This standard is identical with and has been reproduced from ISO 9409-1:1988.
AS 3986 – 1991 *Manipulating industrial robots - Coordinate systems and motions*	Defines and specifies three robot coordinate systems. This standard is identical with and has been reproduced from ISO 9787:1990.
AS 3987 – 1991 *Manipulating industrial robots - Presentation of characteristics*	Specifies requirements for how characteristics of robots shall be presented by the manufacturer. This standard is identical with and has been reproduced from ISO 9946:1991.
AS/NZS 4486.1 – 1997 *Playgrounds and playground equipment - Development, installation, inspection, maintenance and operation*	Specifies requirements for the development, installation, inspection, maintenance and operation of playgrounds and playground equipment to ensure a continuing level of function and safety. It also contains requirements for information to be supplied by the manufacturer.
AS 61508.1 – 1999 *Functional safety of electrical/ electronic/programmable electronic safety-related systems - General requirements*	Specifies general requirements for a generic approach for all safety lifecycle activities used in electrical/electronic/programmable electronic devices used in safety-related applications. The standard is identical with and has been reproduced from IEC 61508-1:1998.
AS 61508.2 – 2001 *Functional safety of electrical/ electronic/programmable electronic safety-related systems - Requirements for electrical/ electronic/programmable electronic safety-related systems*	Specifies the safety lifecycle activities in systems comprised of electrical/electronic/ programmable electronic devices with the requirements for techniques and measures that are graded against safety integrity levels, for the avoidance and control of faults and failures.
AS 61508.3 – 1999 *Functional safety of electrical/ electronic/programmable electronic safety-related systems - Software requirements*	Specifies software requirements for a generic approach for all safety lifecycle activities when applied to safety-related software. The standard is identical with and has been reproduced from IEC 61508-3:1998.
AS 61508.4 – 1999 *Functional safety of electrical/ electronic/programmable electronic safety-related systems - Definition and abbreviations*	Provides the definitions and abbreviations used in other parts of this series of standards. The standard is identical with and has been reproduced from IEC 61508-4:1998.

Title	Description
AS 61508.5 – 1999 *Functional safety of electrical/ electronic/programmable electronic safety-related systems - Examples of methods for the determination of safety integrity levels*	Provides information on the concepts and relationship of risk to safety integrity together with methods of determining safety integrity levels. The standard is identical with and has been reproduced from IEC 61508-5:1998.
AS 61508.6 – 2001 *Functional safety of electrical/ electronic/programmable electronic safety-related systems - Guidelines on the application of AS 61508.2 and AS 61508.3*	Specifies the safety lifecycle activities in systems comprised of electrical/electronic/programmable electronic devices with guidelines on the applications, calculations and methodologies as outlined in part 2 and part 3 of this standard.
AS 61508.7 – 2001 *Functional safety of electrical/ electronic/programmable electronic safety-related systems*	Specifies the safety lifecycle activities in systems comprised of electrical/electronic/programmable electronic devices with an overview of various safety techniques and measures as outlined in part 2 and in part 3 of this standard.
AS/NZS2865:2001 *Safe working in a confined space*	Sets out the particular requirements and procedures to ensure the health and safety of any people required to enter or work in a confined space.
HB 6 – 1999 *Design standards for mechanical engineering students*	This handbook contains edited extracts from current Australian and British Standards that are of interest to students undertaking studies in mechanical engineering design. It includes extracts of standards concerning drives, structural design, mechanical handling equipment, and safety of machinery, and is intended to be used solely for the purpose of student instruction.

Australian Standards are available from:
Standards Australia, 55 Little Edward Street, Spring Hill.

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