Principles of Machinery Safety
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The law requires that employers institute a risk analysis by a competent person to identify all hazards on machinery in their charge. This topic considers some of the principles of machine safety to be applied to protecting personnel from the identified risks. The method uses a hierarchy of approaches, elimination or isolation of the hazard, or if this is impractical, then other measures to reduce risk. The environment created by the machine needs to be reviewed and hazards due to pollution from dust, fumes, fluids and noise will need to be considered using the same approach.

Latest Updates

02/09/2003
The need for proper Information and Training - both to users and also for people responsible for maintenance - is given by a fatality in which neglect contributed to the death of a laundry worker who overheated after being trapped in a giant washing machine for almost three hours, an inquest jury has ruled.

25/07/2003
Workers in the engineering sectors run the risk of serious or fatal injuries because guards on turning machines (lathes) are not being properly maintained, resulting in degradation of the Guard Material, says the Health and Safety Executive (HSE).

18/07/2003
The Health and Safety Executive (HSE) has issued a warning to firms buying second hand industrial machinery to ensure it is safe at all times when being 'set, used, cleaned and maintained', when they are considering the Purchase of the Machine.

11/07/2003
The Health and Safety Executive has published a research report on the evaluation of the implementation of the Use of Work Equipment Directive (89/655/EEC)(UWED) and the Amended Use of Work Equipment Directive (95/63/EC)(AUWED) in the UK, which aims to provide an Introduction to Principles of Machinery Safety.

20/12/2002
When considering Interlocks for equipment, it is particularly important to ensure that they are maintained in fully working order, people are trained to use them and they are properly supervised to ensure that they do not deliberately or accidentally bypass the safety devices, as was shown by the death of a worker when opening a soup boiler incorrectly.

Latest Updates

23/09/2002
An Introduction to Principles of Machinery Safety that shows the need for suitable provisions to protect employees working on or near machines is given by a case, R v. Eternit UK (September 2002, unreported) in which an employee was killed.

12/07/2002
The Health and Safety Executive (HSE) has published guidance aimed at reducing the risks of injury from using work equipment, as indicated in the Introduction to Principles of Machinery Safety.

15/10/2001
The HSE has published three new Useful Publications containing safety guidance on packaging machinery.

06/06/2001
When constructing guards to protect from ejected items, care must be taken in the correct selection of Guard Material as some can degrade with time. Of particular note are the translucent materials used in the guarding of CNC machines that are the subject of an HSE information sheet.

05/06/2001
An example of Distance Guards and Trip Devices is given by the particular requirement by the HSE to retrofit guards to
wood chipping machines.

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Quick View

1. Machines should only be purchased that comply with current safety regulations and should not be modified without consultation with the supplier. See Purchase of the Machine.

2. All machinery controls should be clearly identified and machinery operation should be that which is expected by the operator. Operators should have immediate access to an emergency stop button at all times and the machinery should stop safely under emergency stop. See Machinery Controls.

3. Guarding excludes personnel from the hazardous area, trip devices render the machine safe before the operator can approach the hazardous area. The appropriateness of the various types of guarding depends on the machinery to be guarded, the hazard to be guarded against, the frequency of access required and the operation of the machine. The design of guard interlocks is critical to the safety of the machine. See Guarding.

4. Where the hazard cannot be guarded, consideration should be given to devices such as holders or jigs that shroud the cutter, or holders and devices such as push sticks which distance the operator from the hazard. If all other methods of protecting the operator have been considered and are not practical, personal protective equipment can be specified. See Residual Controls.

5. Consideration should be given to the weight of the workpiece and the lift involved. Incorrect lifts should be avoided, if necessary by the provision of fixturing or other devices which allow a correct lift. See Manual Handling.

6. Danger from fumes should be eliminated by good ventilation or local exhaust ventilation (LEV). Selection of the correct fluid for the operation is required. Skin contamination should be avoided by the use of gloves or other protective equipment, so long as this does not create other dangers. See Elimination of Dust and Fumes.

7. Noise can be reduced by the use of sound absorbent paneling on guards or around the cutter or workpiece. Ear protectors can be used if other methods fail to reduce the noise sufficiently, but this will give no protection to other personnel in the workplace. See Noise.

8. Consideration needs to be given to the selection of operators and their ability to understand and carry out safety procedures. A system of authorisation of only those operators shown to be trained and fully competent on the particular machine should be in place. Training of operators, as well as being required by law, can contribute considerably to the safe operation of machinery. See The Human Factor.
1. Introduction to Principles of Machinery Safety

When, as required by law, a risk analysis has been carried out to identify the risks associated with the operation, cleaning, setting, maintenance, repair, breakdown and the removal of blockages of each machine, solutions to minimise the risks presented by these hazards will have to be proposed and implemented. The approach should be a hierarchy of solutions, first attempting to avoid or eliminate the hazard. If this is impractical, the next solution should be to exclude personnel from the hazardous area. Only if these solutions are impractical should the manager of machinery resort to solutions such as personal protective equipment (PPE).

The Health and Safety Executive (HSE) has published guidance aimed at reducing the risks of injury from using work equipment. The leaflet, INDG229 (rev 1) Using work equipment safely (available from HSE Books, single copies free) gives practical advice on how to select, use and maintain equipment, including machinery, and it covers all situations where the Health and Safety at Work etc. Act 1974 applies.

Every year workers suffer serious and sometimes fatal accidents and this leaflet is aimed mainly at those who have responsibility (directly or indirectly) for work equipment and how it is used. Employers, managers, supervisors or organisations that hire out equipment for use in the workplace can use this guidance to understand what can be done to reduce the chances of an accident happening. Accidents not only cause human suffering, they also cost money, for example in lost working hours, insurance premiums and fines. By using safe and well-maintained equipment operated by competent staff, accidents can be prevented and these personal and financial costs can be reduced.

An example of the need for suitable provisions to protect employees working on or near machines is given by a case, R v. Eternit UK (September 2002, unreported) in which an employee was killed.

Cambridge building materials firm Eternit UK was fined £40,000 at Cambridge Crown Court following the death of employee, Ciro Dario, at the company's factory in Meldreth, as reported in Construction News (16 September, 2002).

Mr Dario, 35, died as a result of injuries sustained by contact with moving parts of the fibre cement sheet production line he was cleaning. Eternit UK pleaded guilty to breaches of the Health and Safety at Work etc. Act 1974 on 12 September and was fined £40,000 and ordered to pay legal costs of £21,153.45 to the Health and Safety Executive (HSE). The death could have been prevented by simple guarding techniques that would not have been excessively expensive.

The Health and Safety Executive has published a research report on the evaluation of the implementation of the Use of Work Equipment Directive (89/655/EEC) (UWED) and the Amendment to the Use of Work Equipment Directive (95/63/EC) (AUWED) in the UK. The report, RR 125 Evaluation of the implementation of the use of work equipment directive and the amending directive to the use of work equipment directive in the UK (available from HSE Books, price £20.00, ISBN 0 7176 2702 0, or online at www.hse.gov.uk/research/rrhtm/), evaluates the implementation of the Amending Directive (95/63/EC) to the Use of Work Equipment Directive (89/655/EEC) in Great Britain as enacted by the Provision and Use of Work Equipment Regulations 1998 (S.I. 1998, No. 2306) (PUWER) and the Lifting Operations and Lifting Equipment Regulations 1998 (S.I. 1998, No. 2307) (LOLER). The evaluation describes how organisations responded to the regulations, the costs and benefits, compliance problems and areas where improvement could be made to the regulations and approved codes of practices (ACoPs).

Among the key findings are that duty holders believe that the regulations have led to safety improvements, such as safer equipment, improved working practices and a more competent workforce. The regulations are also generally believed to be an improvement on previous industry-specific regulations and offer many advantages such as flexibility and practicality. Duty holders, including small and medium sized enterprises (SMEs), have on the whole reported that they do not believe that the costs of compliance with PUWER and LOLER have caused concern. The costs of this legislation were examined across a number of sectors, including construction, local authorities, agriculture, health care and social services. The review highlighted a number of areas where the regulations, or ACoP, could be improved.

These areas included:
1. The need for more basic English and clearer Guidance to enable SMEs to better understand the regulations
2. The need for the ACoPs to contain indexes
3. The need for more industry specific guidance and practical examples
4. The need for greater clarity and consistency surrounding terminology such as 'competent person' and 'thorough examination.'
2. Elimination of the Hazard

2.1 Purchase of the Machine

The Supply of Machinery (Safety) Regulations 1992 (S.I. 1992, No. 3073) as amended require a supplier of machinery to make sure it complies with essential health and safety requirements and ensure that it is safe when used for the purposes for which it was designed. Machinery which the manufacturer claims conforms to these regulations carries a CE mark.

An employer responsible for the safe operation of a machine should ensure that any machine coming into the workplace conforms with the above regulations. They should also ensure that any machine brought onto their site, say by a contractor, also conforms with these regulations. Through these regulations the onus is put on the supplier to supply a machine which is safe; however the employer must still ensure that the machine is safe before it is put into use. To ensure that the safety built into the design of the machine is not compromised the manager responsible for the operation and maintenance of the machine should ensure that:

1. No modification of the machinery is carried out without full consultation with the supplier as to the safety implications of the modification
2. The machinery is operated in the way intended by the supplier as detailed in the instructions for use

The Health and Safety Executive (HSE) has issued a warning to firms buying second hand industrial machinery to ensure it is safe at all times when being 'set, used, cleaned and maintained', when they are considering the purchase of the machinery. Buyers and sellers of machinery are warned that 'sold as seen' is no protection from liabilities under health and safety laws.

The warning follows an HSE prosecution of both the supplier of the second-hand machinery and the buyer following an incident when an experienced machine operator sustained serious hand injuries which have left him partly disabled. The machine had been supplied 'as seen, as is', having come from a previous user who had had it in storage for some years. No changes were made to the machine by the supplier before delivery and no documentation other than an invoice stating 'free from any damage other than normal wear and tear' and machine manuals were provided to the user. The supplier did not obtain any written undertaking from the user in relation to ensuring safety before use.

The user carried out an extensive overhaul returning the machine to almost original condition, but making no changes to its design or safety features. An experienced machine operator was appointed by the user to be trained on the machine by experienced members of staff with previous knowledge of the machine. When cleaning by hand with a cloth the powered rotating gravure and pressure rollers, his hand was drawn in between them, sustaining serious crush injuries.

2.2 Machinery Controls

2.2.1 Elimination of Accidental or Incorrect Operation

All controls should be clearly identified as to their function and colour coded appropriately e.g. green for initiate, red for stop. The operation of the controls should be conventional so that the operator does not accidentally push the wrong button, push a lever in the wrong direction, or turn a handle the wrong way.

Convention is that:

1. Levers, move in the same direction that the machinery travels
2. Handwheels turn clockwise for movement away from the operator, to the right or upwards

All controls that initiate any potentially hazardous movement of the machine, for example the start up of the spindle, the movement of axes, the operation of clamps, should be positioned so that accidental operation cannot occur.

This involves such things as:

1. Fully shrouding floor switches (see the illustration below)
2. Ensuring that all start or initiation buttons have a full height collar

If the moving parts of the machinery are not able to be viewed by the operator from their operating position, they should check around the machine before starting it and audible and visual warning signals should be given by the machinery before it starts up. This warning should sound/light up early enough to allow sufficient time for anyone to leave the vicinity of the machinery before movement commences.

2.2.2 Emergency Stop Controls

It is important that the operator has easy and immediate access to an emergency stop button, that will render the machine safe, at all points to which they may move during the operation of the machine. It is particularly important to review accessories that have been added to the machine or that involve the operator moving some distance from their main operating position to ensure that there is an emergency stop available at these points and that the emergency stop not only stops the accessory from working but also renders the main machine safe.

Emergency stop buttons should be red mushroom headed and when depressed should lock in to eliminate any chance of the machinery restarting after the operators hand leaves the button. The control circuitry should be arranged so that the machine does not restart when the emergency stop button is released.

2.2.3 Safety under Emergency Stop

Particular consideration should be given to the effect of an emergency stop on the machine. The withdrawal of all power from a machine may not render it safe. For example some machines have heavy masses that move vertically and loss of power may allow this mass to drop, spindles or traversing masses may have a high degree of inertia and withdrawal of power may allow these to run on creating a dangerous situation. In these circumstances the control system should be designed to shut the machine down safely, bringing all hazardous movements to a halt.
3. Exclusion from the Hazard

Though the first line of action to reduce risks on the machinery is to eliminate the hazard this is not often possible. In these circumstances the course of action is to exclude personnel from the hazard. This is often achieved by the use of guarding.

3.1 Guarding

3.1.1 Fixed Guarding

The safest form of guarding is fixed guarding where personnel are permanently excluded from hazardous parts of the machinery by use of guards that are permanently attached to the equipment. An example of this would be covers over gearboxes which exclude operator limbs from this dangerous area of the machine.

3.1.2 Adjustable Guards

This is properly a variant on the fixed guarding in that the operator is not expected to gain access through the guards and the guards are not expected to be moved during operation of the machine. However to allow the machinery to accommodate a variety of sizes of workpieces or cutters, the guarding is provided with some adjustments which should be set up prior to the particular operation of the machine.

It is important that guarding of this type is set by a responsible person and that the guarding cannot be adjusted by the operator without the use of a tool; e.g. Wing nuts should not be used to fix the guard in position or be the means of adjusting the guard.

3.1.3 Interlocked Guards

It is often necessary for the operator or other personnel to access potentially dangerous areas of the machine, for example they will often need access to areas under the cutter for loading and unloading the workpiece. Interlocked guards ensure that the dangerous parts of the machinery are in a safe condition before the guards can be opened and the operator can gain access to the potentially dangerous area. The interlock can be electrical, mechanical, hydraulic, pneumatic or a combination of any of these.

3.1.4 Automatic Guards

These are guards which are operated within the sequence of the machine, automatically closing to exclude the operator from a dangerous area when the area is a potential hazard and opening to allow operator access for loading and unloading when the sequence has finished the hazardous operation. If fitting automatic guards, ensure that a new hazard is not introduced through the action of the guard potentially trapping and crushing the operator.

The following section gives details of common methods of safeguarding automatic guards.

Automatic guards are usually equipped with sensors or trip devices on their leading edge to stop their motion if they encounter any obstruction and/or are operated by actuators that can be stopped by finger pressure such as low pressure air systems. Further safety can be achieved by using two controls for guard operation and placing these a minimum of 600mm apart so that the operator's hands are clear of the guard when it closes. Note unless the controls are some distance from the guard, this does not ensure head, legs etc. are clear of the guard. Also this method does not safeguard other personnel and so the sensors and low pressure operating system should still be incorporated.

3.1.5 Distance Guards and Trip Devices

These work by keeping personnel at such a distance from the hazard that they cannot reach into it and cause themselves injury. It is usually in the form of a fixed barrier some distance from the machinery and could be used to exclude personnel other than the operator from approaching the sides or the rear of the machine.
Serving the same purpose as the distance guards are trip devices that ensure that the machinery is shut down if personnel move close to a hazard, the trip device shutting the machinery down before the person comes close enough to be injured by the machinery.

There are many types of trip device. Examples are pressure sensitive floor mats, trip wires stretched around machinery, and photo electric guards discussed below.

A particular example of a trip device being used to exclude the operator from the hazard is given in wood chipping machines. These machines had caused a large number of amputations, since it was possible - under the original design - for the user to become tangled in the crushing and chipping wheels, causing severe injury to the arm. As a result, in October 2000, the HSE published Agriculture Information Sheet AIS 38 Power-fed mobile wood chippers - operator protection at infeed chutes (available from HSE Books, single copies free). There are two particular requirements necessary to be retrofitted to these machines - the first is to ensure that the infeed tube is long enough to prevent the operator becoming entangled. However the other - more relevant here - is to fit a protection device, in the form of a trip bar, fitted around the edge of the chute in such a way that the user of the machine can operate it in the event of becoming entangled and drawn in to the rollers. The trip would then stop the rollers and operating a separate reset unit that is outside the danger area, physically distant from the trip device, is the only means to restart them.

3.1.6 Photo Electric Guarding

Photo electric guarding forms a curtain, usually of infra red signals, across the access to the dangerous parts of the machine. If the signal is broken the machinery is inhibited from starting its operation or the operation is stopped.

Photo electric guarding has the twin advantages of no moving parts and a lack of any structure between the operator and the machine allowing good access for loading and unloading and good vision of the operation. It does not, however, guard against projectiles coming from the machine and cannot be used where swarf or other particles would, during normal operation, break the signal as frequent nuisance tripping of the safety system would occur.

3.2 Design and Selection of Guards

The selection of the type of guard will depend on the machinery to be guarded, the hazard to be guarded against, the frequency of access required and the operation of the machine, e.g. whether the machine is being used for a very rapid cycle of work and/or large batches of components or whether the machine is being used to produce one off components.

The table shows the appropriate guard for a variety of machine use.

<table>
<thead>
<tr>
<th>Infrequent access</th>
<th>Frequent access</th>
<th>One off/small batches</th>
<th>Large batches</th>
</tr>
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<tbody>
<tr>
<td>Fixed guarding</td>
<td>Interlocked guarding</td>
<td>Interlocked guarding</td>
<td>Interlocked guarding</td>
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<tr>
<td>Distance guarding</td>
<td>Automatic guarding</td>
<td>Adjustable guarding</td>
<td>Automatic guarding</td>
</tr>
<tr>
<td></td>
<td>Photo electric guarding</td>
<td>Photo electric guarding</td>
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3.2.1 Guard Material

The material of the guard will depend on such factors as durability, strength, stiffness and the need for visibility through the guard.

The material for the guard needs careful choice. Good visibility is achieved by material such as perspex. However if the debris from the machine is abrasive the perspex can soon be scratched and the transparency will be lost. Perspex can also crack easily. Using wire mesh guards may not exclude flying debris and fingers can be poked through them,
potentially reaching dangerous areas.

One particular consideration when selecting an appropriate guard material is how rapid it degrades with time - including any accelerating factors such as heat or UV light. This issue is dealt with for CNC (computer numeric control) machines in an HSE information leaflet, however although written for these machines, the principles and guidance applies to all transparent guard materials.

The engineering information leaflet, CNC Turning Machines - controlling risks from ejected parts (EIS33, available from HSE Books, free), draws on research that shows clear evidence that polycarbonate, the material most commonly used to manufacture vision panels on CNC turning machines - as well as many others - degrades significantly over time, thus increasing the likelihood of incidents and injuries.

Workers in the engineering sectors run the risk of serious or fatal injuries because guards on turning machines (lathes) are not being properly maintained, resulting in degradation of the guard material, says the Health and Safety Executive (HSE). This follows a survey of CNC turning machines carried out by HSE inspectors during 2002/03. They looked at the condition of machine guards, including vision panels, which are fitted into guard doors to allow operators to view the machining process.

Inspectors found evidence of cracked or damaged panels. These parts can also deteriorate over time due to the effects of metalworking fluid and lose a substantial amount of their impact resistance. These safety-critical parts of the machine need to be properly maintained. At about two thirds of the visits, inspectors also found that users had not assessed the arrangements needed to maintain the machine so that it was safe to use.

The survey follows on from guidance issued by the HSE, Engineering Information Sheet (EIS) 33 CNC Turning machines - controlling risks from ejected parts (available free from HSE Books, or online at www.hse.gov.uk/pubns/eis33.pdf), which warned about the hazard of parts being ejected from machines and the need to ensure that vision panels are properly constructed and maintained.

3.2.2 Ease of Use

Guards should be designed to impose the minimum of constraint upon the normal operation of the machine. If this is not achieved there will be a high level of temptation for the operator to use the machinery without the guard or to modify the guard to avoid the constraint. Both actions could of course compromise their safety.

3.2.3 Guard Security

However well designed the guards are they may introduce some impediment to the ease of use of the machinery, thus the temptation to operate the machine without guarding or with modified guarding will still be present. It is important therefore, to consider how easily the guarding system can be removed or defeated. Fixed guards for example can be welded in place in preference to attaching with removable fixings.

Interlocked guarding presents particular problems as, unless the control circuitry is carefully designed with safety in mind, the sensors that indicate that guards are closed can be easily fooled by a determined operator.

3.2.4 Interlocks

If interlocking guarding is specified the design of the interlocks is critical. If the system is electrical, pneumatic or hydraulic it will probably rely on sensors such as pressure switches or limit switches to indicate to the control system the position of the guard. When the guard is in its position to exclude the operator from the dangerous area, the operation will then be allowed to commence. It is possible under certain circumstances that the control system can be fooled into believing that the hazardous area is secure when it is, in fact, still open to access.

1. To increase production or for ease of working the operator may try to fool the sensor into believing the guard is closed, for example by taping a limit switch closed

2. The sensor may fail or stick giving a false signal to the machine

For these reasons it is important that control circuits are designed to eliminate the sort of problems highlighted above.
The following section gives some methods that are in common use.

To ensure that the indication to the control system of the position of the guard does not rely on only one sensor signal, two sensors can placed so that one is operated when the guard is open, giving a guard open signal until the guard is fully closed, whereupon it gives a guard closed signal to the control system. The other sensor is only operated when the guard is fully closed, also giving a guard open signal whilst it is not operated and a guard closed signal when it is operated. The control system would then check with each of the sensor signals that the guard is not open and is closed. Thus the malfunction of one of the sensors would not be enough to give a permissive signal to the machine and the machine would not operate in an unsafe condition.

The assurance of operator safety comes from the assumption that it is very unlikely that both switches will fail on the same machine cycle. However the machine can function with one of the switches faulty and in time this does leave the possibility of the failure of the second switch which could expose the operator to an unguarded hazard. The long term safety of a system such as this can only be ensured by regular checking that both switches are functioning correctly and/or the use of circuitry such as that described in the proceeding paragraph, to automatically check all safety switches in each cycle of the machine.

The control system can be designed to check for operation of the sensors on each cycle of the machine and to stop the machine if sensor operation is not detected on each cycle. This makes it difficult for an operator to tape up a switch to fool the control circuits.

The signal from sensors should be designed so that if the sensor fails the machine is put to a safe condition, i.e. all sensors should operate in a positive mode to allow machine operation. Positive mode means that the switch actuator is released to work, i.e. it cannot be defeated by pushing in by hand.

When considering interlocks for equipment, it is particularly important to ensure that they are maintained in fully working order, people are trained to use them and they are properly supervised to ensure that they do not deliberately or accidentally bypass the safety devices. A factory worker from Deptford, an employee of the New Covent Garden Soup Company, died after half a tonne of red-hot spinach soup exploded, as reported by This is Local London (16 December 2002). Zachariah Conteh, aged 34, suffered severe burns after prising open the lid of a pressure-cooker containing the Thai broth. Mr Conteh had been about to add extra ingredients to the soup, which was bubbling at about 105 degrees, West London Coroner's Court heard. A safety system that should have warned him of the danger of opening the hatch was broken, and the soup sprayed in his face. He was rushed to a specialist burns unit at Broomfield Hospital in Chelmsford, but died a month later. Colleague Abdullah Saleh, 42, was also hit by the blast and spent three weeks in hospital after the incident, on July 5 2001. The jury returned a verdict of accidental death on December 4 2002.

An investigation by the Health and Safety Executive (HSE) showed the soup had sprayed 30 feet into the air when the vat was opened. Engineering expert Dr Marc Loyez inspected the vat and concluded the top must have been opened by Mr Conteh. He said: "The security system relied on a pressure transducer to tell it what the pressure in the vessel was. I found this had failed and did not work "It is possible Mr Conteh could have opened the lid before the proper time as a result of carelessness or workplace bravado." HSE expert Anthony Lees queried how Mr Conteh could have opened the vat under such high pressure. He said: "The steam, the noise and the difficulty would have prompted anyone trying to open it to desist."

### 3.2.5 Check Before Use

It is good practice in designing a safe working system to ensure that a competent person, i.e. a person that has been trained on what to look for to ensure correct operation, checks guarding and interlocks before the operation of a machine at the beginning of a shift.

A pre-operating check should consist of a check:

1. Around the machine for evidence of damage e.g. by collision with vehicles or components being carried by overhead crane
2. That conduits containing cables are undamaged
3. That all guards are in place on the machine and that none are cracked or damaged in any way
4. That any fixturing is correctly located and clamped to the machine table
When the machine is switched on, but before commencing work, further checks should be carried out:

1. All the emergency stop buttons stop the spindle motion and any other motions on the machine including those of auxiliary attachments
2. Each of the emergency stop buttons should remain depressed when operated
3. All the safety interlock switches and trip switches are operational
4. Any power clamping fully clamps the workpiece and, if the power is removed from the machine, the workpiece remains clamped

These checks should be supplemented by checks specific to the piece of machinery being considered.

It is important that personnel do not put themselves into danger when carrying out these checks. A risk assessment of the checks should be carried out before being implemented and the procedure modified if risks are identified.
4. Controlling or Reducing the Risk from the Hazard

In some cases it will not be possible to exclude the operator and other personnel from the hazardous area. In these circumstances the manager of the machinery must take steps to control or reduce the risk from the hazard.

Though a safe system of working should be specified for all machinery, it is particularly important that if the operator and other personnel cannot be excluded from the hazard that the safe system of working clearly indicates how the operator is to avoid the hazard or reduce the risk.

4.1 Residual Controls

4.1.1 Jigs, Holders and Push Sticks

The type of hazard where the operator cannot be completely excluded by guarding or other means often occurs where the operator has to feed the workpiece into a cutter under manual control, thus bringing hands and arms at risk from the cutter. A number of methods are available to reduce the hazard in these circumstances.

1. Specially designed holders or jigs to hold the workpiece may be designed that shield the operator's hands or distance their hands and arms from the cutter

2. Jigs or tools may be designed to completely shroud the cutter when the cutter is in operation thus excluding the operator's hands and limbs from the hazard (see the illustration below)

3. It may be possible to use push sticks to feed the workpiece into the cutter, as for example in circular saw work, thus again distancing the operator's hands from the cutter

4.1.2 Two Handed Control

For some hazards, for example the risk of trapping and crushing the operators hands under workpiece clamps, it is not practical to use any form of guarding. In these sorts of circumstances it is possible to ensure that the operator's hands are not at risk by designing the control system so that the initiation of the clamping can only take place when the two controls are activated. If these two controls are placed a minimum of 600mm apart then the operator will have to use two hands to initiate the clamping sequence.

It must be noted however that this protects only the operators hands and does not protect anyone but the operator from the risks from the clamp movement.

4.1.3 Personal Protection

If all other methods such as eliminating the hazard, guarding the operator access to the hazard or distancing the operator from the hazard have all been considered and they do not eliminate the risk then as a last resort personal protective equipment can be specified to be worn by the operator. Items such as goggles will protect the operator from hazards such as broken tool particles or swarf. Personal protective equipment such as gloves can protect the operator's hands from sharp edges of workpieces. However the use of PPE should be looked at to ensure that it does not introduce other risks. For example, if the operator can get a gloved hand close to a rotating spindle or cutter there may well be a risk of entanglement of the glove thus putting the operators hand at risk and the use of this item of PPE will not be appropriate.

4.2 Maintenance, Inspection and Testing

Maintenance is required to ensure that equipment does not deteriorate in such a manner that it causes a hazard to personnel. The Provision and Use of Work Equipment Regulations 1998 (S.I. 1998, No. 2306) require that work equipment is maintained so that it remains safe. The Regulations also require that equipment can be maintained safely.

Inspection and testing of work equipment is required by law where a safety risk could come from incorrect installation or re-installation of the work equipment. Regular inspection is also required if deterioration of the work equipment could lead to risks to personnel.
5. Manual Handling

The loading and unloading of workpieces is the cause of much injury and ill health. If manual handling can be avoided it should be. If not then a risk assessment must be carried out to assess the risk of injury. Consideration should be given to the weight of the workpiece and the lift involved, bearing in mind that the operator may be called upon to do this frequently during a complete shift. If a manual lift is required, it should be well within the operator’s capability and the lift involved should not be so awkward as to involve the operator in incorrect lifting movements such as bending or twisting.

Consideration should be given to fixturing that can be withdrawn from the cutting area and allow easy access for loading and unloading of workpieces. Gloves can be used to eliminate the risk if cuts from swarf or sharp edges on the workpiece but only if there is no chance of the operator’s gloved hand coming into contact with any rotating machinery.
6. The Machine Environment

6.1 Elimination of Dust and Fumes

The elimination of the hazard from dust and fumes follows the general principles of machine safety, that is to say the first consideration should be whether the hazard can be eliminated. This could be achieved by eliminating the operation, substituting the operation for one that does not create dust and fumes or by changing the material being machined to a material that does not give off dust or fumes when being machined. In some cases a wet machining process rather than a dry machining process may eliminate the hazards of dust.

The next level of hazard reduction is to attempt to isolate the dust or fumes at the point that they are created. This may involve close-fitting dust proof guarding around the cutter or may involve the whole machine being housed in a dust or fume proof box. Local exhaust ventilation (LEV) may be used to extract the dust or fumes from the area of the cutting point or may be used in conjunction with the enclosures described above to remove all of the dust or fumes either to the outside of the workplace if this is safe or to a collection point remote from the workplace.

If dust is present on the machinery or surrounding area it is important that the housekeeping in the area and the cleaning of the machine is considered in any risk assessment, especially if the dust is hazardous. For example, some wood dust is carcinogenic, and the protection of anyone involved in cleaning the area around the machine and the machine itself will need to be considered. Regular cleaning of the area and the machine will need to carried out if personnel in the vicinity of the machine are not to be put at risk by dust lying on and around the machine. After the work has been completed or at the end of the shift the area must be cleaned with brushes or vacuum cleaners ensuring that the cleaning staff are protected.

If none of the above is considered reasonably practicable then personal protective equipment (PPE) such as goggles and face masks can be provided. PPE includes dust masks to prevent the inhalation of dust and respiratory equipment if there is a risk of inhalation of toxic fumes. Other equipment such as gloves may be required if the dust is an irritant to skin.

6.2 Contact with Fluids

Cutting and cooling fluids are used on many machines. To avoid any hazard from the fluid, the correct fluid for the job in hand should be selected and used. A supplier or manufacturer of cutting and cooling fluids should be able to recommend on selection of coolants and what precautions should be in place in respect to their use. Fluids when heated by the cutting action can give off fumes which can cause irritation of the eyes, nose and throat. It is, therefore, necessary to ensure that the workplace is properly ventilated and, where possible, suitable exhaust ventilation should be fitted in close proximity to the machining area to remove all fumes. See Elimination of Dust and Fumes for a fuller discussion of the precautions.

Contamination of the skin with fluids can be avoided if gloves are worn; however this does introduce the risk of the entanglement of clothing. If there is a risk of the operator getting a gloved hand close to rotating machinery this should not be the solution. Some form of protection for the skin such as a barrier cream could then be tried. An industrial vacuum cleaner may also remove much of the fluid before the operator handles the workpiece.

Inspection of the fluid should be carried out on a regular basis as the fluids do deteriorate with use and over a period of time as they are exposed to air.

6.3 Noise

If normal speech cannot be heard two metres away anywhere in the workplace, the noise level is likely to be 85dB(A) or above and may be a hazard and a full noise risk assessment should be conducted.

If high noise levels are present, the first thing to check would be that the machinery is operating correctly and that all other conditions are correct e.g. the workpiece and tool are both adequately clamped. If noise still persists and some form of noise reduction is required one or more of the following may be appropriate:

1. Sound absorbent paneling lining the guarding or around the workpiece
2. The machinery may need to be moved to a separate room or area
3. Using rubber buffers or cushions to reduce metal to metal impacts
4. The addition of exhaust silencers in pneumatic systems
5. Installation of noise absorbent panels in the workplace

In addition ear protectors can be used but this will give no protection to the other personnel in the workplace.

6.4 Vibration

Vibration can be a particularly serious problem leading to diseases known as hand-arm vibration syndrome (HAVS) of which the most widely known is vibration white finger (VWF). These conditions are particularly prevalent amongst operators of hand tools and the discussion of precautions for these employees is therefore shown elsewhere.

See also Vibration

Vibration hazards do occur on fixed machinery, examples would be the hand feeding of metal sheets into a punch press and the use of a pedestal grinding machine.

The first approach to such a hazard is to see whether the causes of the vibration can be eliminated. Heavy and prolonged vibration can sometimes occur, for example on the pedestal grinding machine, because considerable amounts of material are being removed. In this situation rough machining on say a milling machine prior to finishing on the grinder may eliminate the problem. Automating the feeding of sheet into a punch press would remove the transmission of vibration to the operator and a redesign of the tooling may reduce the vibration.

Vibration may be occurring because of an imbalance in the tool, e.g. a grinding wheel worn out of true will transmit vibration to the workpiece and the operator and frequent redressing would eliminate this problem.

The HSE has now published a CD-ROM 'The Successful Management of Hand Arm Vibration' £95.00, 2000 from HSE Books.
7. The Human Factor

A summary of the personnel requirements for safe machinery operation are given below.

7.1 Selection of Operators

The selection of operators for operating machinery needs to be carried out with care. It is the management's responsibility to provide a safe working environment. However, it is the employee's responsibility to adopt the safe working practices specified by their employer and to ensure that they do nothing to endanger their fellow employees. Operators of machinery should therefore have the ability and the will to do the job in a responsible manner.

If operators are employed who have a poor command of the English language, special efforts will have to be made to ensure that all safety instruction is understood by them. These can include: preparation of safety instructions in their native language; pictorial presentation of correct and incorrect procedures; practical demonstrations of safe working. The same applies for practical demonstrations to people with impaired hearing. Ensure that verbal instructions are kept to the minimum and that they are given in a manner which enables lip reading and/or the use of sign language. The blind should be given instructions on tape or in Braille or Moon to reinforce what cannot be seen.

7.1.1 Supervision

Where personnel safety is dependent upon personnel correctly following the procedures laid down for safe working, close supervisory control is essential. The supervisory role is to ensure that personnel already trained in safe working on machinery are carrying out the procedure in the prescribed manner.

7.2 Information and Training

Suitable training and instruction, as well as being required by law, can help minimise risk of injury to employees and other persons using the workplace.

The need for proper information and training - both to users and also for people responsible for maintenance - is given by a fatality in which neglect contributed to the death of a laundry worker who overheated after being trapped in a giant washing machine for almost three hours, an inquest jury has ruled.

Paul Clegg, 23, died from heat exhaustion on 21 March 2003 after getting inside the 13-metre long drum of the machine to clear a blockage. Attempts to get Mr Clegg out of the machine at the Sunlight Textile Services laundry in Bournemouth failed and firefighters had to cut a large hole in the side of the appliance. The Bournemouth inquest heard that no-one on duty at the time had been given training to deal with blockages. Fire station commander Tim Spring said his crew arrived at about 09.38 and Mr Clegg was still conscious. Mr Spring said: 'I asked on three or four occasions if there was an access panel on the machine. They said there was not.' In fact there was an access panel but David Lewis, the company engineer on duty at the time, admitted under questioning that he had not read the machine manual. It took nearly two hours to remove Mr Clegg, compared to an estimated 15 minutes had the firefighters been told about the access panel. In January 1997 the firm was fined £3,000 after a teenage employee removing a blockage was lucky to survive an electric shock.

7.2.1 Training for Persons Directly Involved

Training and instruction should be provided for all those who use machinery and for direct supervisory staff. This will also apply to the selection, care, storage and use of PPE.

7.2.2 Instruction for Other Personnel on Site

All other persons working on the site, including contractors, should be aware of the hazards present in the vicinity of any machinery, and the safely and hygiene rules to be observed and procedures to be followed. This will include emergency procedures and prohibition of persons using machinery, unless trained and authorised.
8. Useful Publications

Heath and Safety Executive publications:

*Buying New Machinery* INDG271 04/98 C200.


*Manual Handling* INDG 146(L) s/93.

*Keep the Noise Down* ISBN 0 7176 1480 8.

The Health and Safety Executive (HSE) has published new guidance leaflets on safeguarding three common types of packaging machinery, Food Information Sheets No. 26 Packaging Machinery: Safeguarding thermoform, fill & seal machines, No. 27 Packaging Machinery: Safeguarding palletisers and depalletisers and No. 28 Packaging Machinery: Safeguarding pre-formed rigid container packaging machines (all available from HSE Books, single copies free). This follows the publication of European CEN ‘C’ standards for these three classes of machine. The majority of packaging machines are used in the food and drink industries. In these industries 7% of injuries are caused by machinery with about half these injuries caused by packaging machines and conveyors.

The new guidance:

1. Analyses where most accidents occur
2. Indicates why these accidents occur
3. Gives guidance on how the accidents can be prevented
4. Gives advice on safe systems of work and what standards of maintenance are needed
5. Provides sources of further advice
Key Questions

- What assurance is there that new machinery is safe?
  See Purchase of the Machine.

- In what situation should each different type of guard be used?
  See Guarding.

- What steps can be taken to ensure that guard interlocking is protected from failure?
  See Interlocks.

- If guarding is impractical what alternative safety measures should be considered?
  See Controlling or Reducing the Risk from the Hazard.

- What steps can be taken to reduce noise in the work place?
  See Noise.
Principles of Machine Safety applied to Drilling Machines in a Fitting Shop

Q. Our company's main activity is fitting mechanical components together. This does not involve much machinery, only hand tools and some bench and radial drilling machines. The drilling machines are quite old and we feel that the safety provisions on them are probably inadequate. What is the best way to approach the task of ensuring that our responsibilities with regard to these machines are carried out?

A. Drilling machines used to support a fitting shop are mainly used to machine 'one off' or small batches of components. This can present problems in achieving safety due to the variety of different size components and tools being used.

The employer should carry out a risk assessment of each of the drilling machines in the workplace looking at the operations performed over a sample period, the sample period being chosen so that the full range of typical operations is assessed. The risk assessment should also include all other activities carried out on the machines such as setting, maintenance and cleaning.

All possible hazards should be listed. The mechanical hazards most likely to feature on all machines are the risk of:

1. Puncture wounds including eye injuries, from the tool or from flying swarf
2. Entanglement of limbs, fingers, hair or jewellery around the rotating tool or rotating elements of the machine

The response to risks of this nature is often to guard the hazardous areas of the machine. A variety of guarding methods could be employed, the most common being adjustable guards around the spindle.

In some circumstances close guarding of the spindle is impractical and often, particularly on radial drills, a trip device consisting of a vertical probe adjacent to the tool is used to protect the operator from injury, by stopping the machine, if they become entangled around the tool or spindle.

This solution does not however give any protection in any other respect such as the hazard from particles of a broken drill or flying swarf. Other precautions, such as safety goggles which should be worn in any case, will be needed.

It should be noted that recent advice from the Health and Safety Executive (HSE Press Release E208:98, 21 September 1998) has warned against the use of 'flag' type guards on drilling machines as they are inadequate to prevent all access to the rotating parts of the drill.

Guards that are inadequate in this respect should not be used, and if already fitted to a machine, should be replaced. See Guarding.