CHAPTER 7.5

THE USE OF SAFETY DEVICES AND SAFETY CONTROLS AT INDUSTRIAL MACHINE WORK STATIONS

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7.5.1 INTRODUCTION

This chapter is about human-factors considerations for the use of devices and methods that are designed into or installed on work stations at hazardous industrial machines for the intended purpose of preventing traumatic amputations, crushing injuries, and fatalities to industrial workers. Guidelines given here focus, in particular, on helping persons who are evaluating the relative merits of various machine safeguarding alternatives to understand how the human-factors design aspects of these devices and methods contribute to their effective use. Topics that are considered include human reliability in using machine safety devices and methods to avoid access to industrial machine dangers; inadvertent human entry into machine danger areas and machine controls that respond to these entries in such a way that dangerous machine action will not occur; and possible injuries owing to the *misuse* of machine safety devices or methods.

This chapter includes considerations of human anthropometry, information processing, physiology, and behavior as they relate to the use of safeguarding on industrial machine work stations. Discussion is devoted to the problems of why people (1) fail to use a safeguard that has been provided; (2) fail to adjust and maintain a safeguard that has been provided; and (3) improperly use or erroneously use a safeguard that has been provided.

For overviews of other human-factors aspects of industrial machine work station design (posture, lighting, noise, etc.), see Garg and Kohli (1979) or Percival (1977). The references at the end of the chapter provide more particular information on the construction and operating principles of work station safety devices.

7.5.2 MACHINE SAFETY DEVICES FROM THE HUMAN-FACTORS DESIGNER'S POINT OF VIEW

The industrial machine work station is a focus for ergonomic attention as a place where people's capabilities and limitations must be considered in order to achieve safe and productive industrial output. In the industrial workplace, processing machines (e.g., lathes, saws, spot welders, forming and punching presses, shears) and materials handling machines (e.g., robots, conveyors, coil feeders) are used to work by themselves or to work under the control of people in doing industrial production tasks. They are used because they contribute some machine attribute of speed, power, repetition, or accuracy to the task. People operate and maintain this industrial machinery in order to accomplish desired production goals.

When people work interactively with machines, exchanges occur between the human and the machine. What is to be prevented by the use of safeguarding devices or methods is any brief moment of exchange, as illustrated in Figure 7.5.1, when a person intrudes into a machine location that has become hazardous owing to a machine energy transfer at that location. Machines are hazardous because they accomplish energy transfers (mechanical, electrical, heat) too great for human tolerance. Acute, traumatic injuries, such as amputations, can result.

Injuries at industrial machines remain a persistent and costly problem of the industrial workplace. The U.S. National Institute for Occupational Safety and Health (NIOSH) estimates that in 1982 machine operators suffered 2400 amputation injuries (mostly fingers) and 24,800 fractures. More severe amputations and fatalities occur as well. Workers in other industrial occupations are also potential victims of machine injury. The National Safety Council in the United States estimated for 1983 that 10% of occupational injuries were machine related, and that half of these resulted in permanent partial disability.

Repetitive trauma disorders (Armstrong, 1981) are another injury type associated with machine work stations. These are a group of injuries to the tendons and nerves of the hands, wrists, and shoulders (e.g., tenosynovitis and carpal tunnel syndrome). These injuries are not instantaneous or acute as is the case with traumatic amputations, which are associated with unexpected events (i.e., accidents). Repetitive trauma disorders occur progressively while machine operators are performing the same "normal" task over and over again. These musculoskeletal injuries have, in some cases, been associated with two-hand palm button safeguards used at work stations. It has been found that the tendons or nerves in the wrists of some workers became permanently numb or dysfunctional after working at tasks requiring repetitive exertions with a sharply flexed wrist, such as would be the case for some installation locations for dual push button safeguards. This type of occupational injury is being diagnosed in increasing numbers as repetitive trauma becomes better understood among occupational physicians.

The mutilation and suffering that are consequences of occupational injury can ruin individual lives and are morally deplorable. However, occupational injury can also be costly to business. Worker

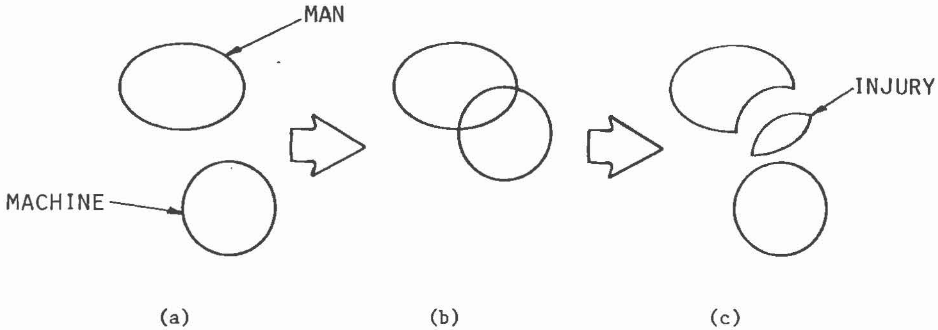

Fig. 7.5.1. The functional states of a dangerous, human–machine energy exchange: (*a*) before work begins; (*b*) a dangerous intrusion into the machine work space; (*c*) injury is sustained.

compensation insurance payments in the United States have increased at a rapid rate. For example, estimated compensation insurance payments in 1978 of $17 billion constituted annual increases of 27 and 20% over 1976 levels. The average cost per $100 of payroll jumped to $1.85 for 1978 compared with $1.73 for 1977. Industrial machine injury can be enormously costly to third parties involved in some aspect of the design of a machine, if a liability lawsuit is pursued by an injured worker as a means of restitution for injury. Awards of several hundred thousand dollars are not uncommon. Finally, consider that safeguarding based on human factors represents an investment not only in the well-being of people who operate and maintain industrial machines, but also in the productive management of the business.

7.5.3 THE PRIMARY REASON FOR USING MACHINE SAFETY EQUIPMENT

When working near or with industrial machines, humans are at risk of acute, traumatic injury from the zone in which the machine tooling does its work (often called the point of operation); workpiece hazards such as chips, sparks, or hot metal; and the components by which power is transmitted to the tooling to perform work (gears, shafts, hydraulic lines, electrical elements). Some of these hazards are illustrated in Figures 7.5.2 and 7.5.3.

7.5.4 HUMAN WORK TASKS AND THE USE OF MACHINE SAFEGUARDING

In the course of doing tasks near machines, workers make various reaching movements that could result in their being in a danger zone (see Figure 7.5.4).

Task design plays a role in the expected hazard exposure. For instance, if one of the tasks to be performed is direct hand placement of work between a machine's tooling or dies, this would involve normal and frequent exposure to a machine hazard. This normal and frequent exposure should lead to the selection of a highly reliable safeguard. In this use of the term "reliable," one would consider the human factors that affect the probability that the safeguard would be in place and functional when the human works at the machine. On the other hand, if the task were designed so that feeding of workpieces does not require a worker's hands to enter the tooling, then a different human-factors

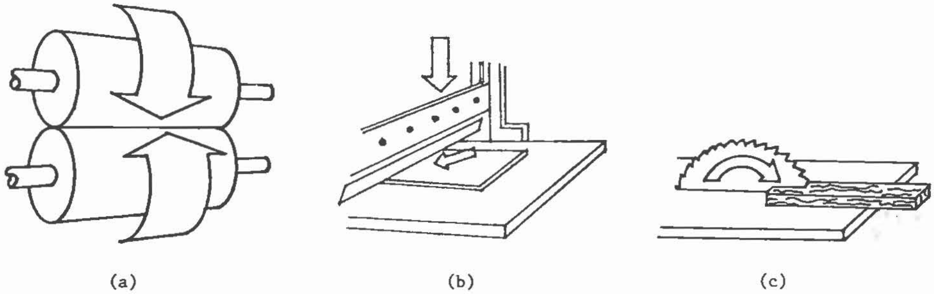

Fig. 7.5.2. Machine dangers due to (*a*) in-running nip point, (*b*) shearing mechanism, and (*c*) cutting mechanism.

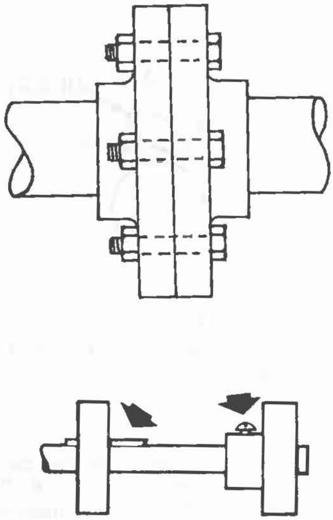

Fig. 7.5.3. Projections that could injure if touched when the shaft rotates at high speed.

evaluation of the work station would be in order. The latter analysis should take into account the unplanned or spontaneous human actions that might lead to an exposure to danger. Some of the tasks associated with industrial machines are discussed in the following sections.

7.5.4.1 Normal Operation Tasks

The machine is processing or handling materials as it was designed to function and the machine operator, feeder, tender, or supervisor is providing input (e.g., manual actuation of switches, manual parts handling, and visual quality surveillance) needed to accomplish the production task.

7.5.4.2 Cleaning and Clearing Tasks

If the machine's operation results in a buildup of scrap or if material becomes caught in the machine, human intervention is necessary to correct the machine feeding process. This is a particularly important area of human–machine interaction where consideration of human task performance can be beneficial.

7.5.4.3 Maintenance Tasks

Achieving safe performance of infrequent or random tasks necessary to keep a machine, process, or system in a state of repair or efficiency presents special human-factors problems. This is because normal

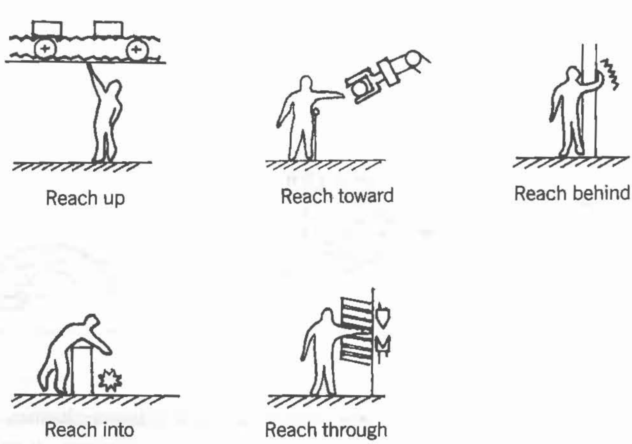

Fig. 7.5.4. Various reaching tasks that might be toward a danger point.

safety methods may not be usable and other safety equipment and procedures are temporarily brought into use. Examples of such tasks would be inspecting, lubricating, repairing, setting up, replacing worn or damaged tooling, or troubleshooting a machine control malfunction that would require close observation of machine action. Motivation, training, and supervision gain increased importance as modes of protection against traumatic injury. Accessibility and postural stability of the human body for the site where maintenance work is to be done should lead to anthropometric evaluation of how these factors could lead to traumatic injury. Stress that leads to risk taking may be associated with efforts to minimize downtime cost and to demonstrate to peers that one is capable of making the repair.

7.5.4.4 Tasks of Other Workers and Bystanders

Persons who do not work with a machine still may be at risk. Access to danger may exist along aisleways on the work floor and at the back or sides of the equipment. Unexpected motion by projecting workpieces can cause injury. This has been the case in injuries at automatic screw machines where passersby have been struck by projecting bar stock which bends out into aisleways while rotating at high speed. Unexpected start-up of automated equipment or of robots could injure passersby who take shortcuts through the machine's working zone.

7.5.5 STANDARDS

7.5.5.1 Regulatory

In the United States, the Occupational Safety and Health Administration (OSHA) has a general, performance-type requirement (General Industry Standard 1910.212) for safeguarding all machines. The standard states in part:

> *One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks. Examples of guarding methods are—barrier guards, two-hand tripping devices, electronic safety devices, etc.*

For 1978 to 1981 this standard was the third most often cited violation (10,811 times) in workplace inspection reports by federal safety compliance officers. Other requirements for individual machine categories (mechanical power presses, grinding machines, forging machines, etc.) are also included in Subpart 0 of the General Industry Standards.

7.5.5.2 Voluntary

The consensus, voluntary standards issued by the American National Standards Institute (ANSI) are a source of other suggestions for alternative safeguarding approaches that could be tried on various metalworking, plastics processing, woodworking, and paper processing machines, among others. These voluntary standards may be utilized for specific information and guidance for meeting the performance requirements of the OSHA standards.

Be aware that standards are often only a minimum requirement, and that known risks not covered by standards should be considered. Up-to-date risk information may be found in research articles, patents, technical reports, and industry and trade publications.

7.5.6 VARIOUS SAFEGUARDING METHODS

Comparisons between methods of safeguarding are fruitful only in the context of a particular work station where they are to be used. The most positive means for keeping people away from a danger point (e.g., barriers that do not permit contact with the danger point) is the preferred method of safeguarding. Human factors associated with the use of a particular safeguard to a machine are discussed here in relation to how effective that alternative will be in its primary purpose of preventing injury.

7.5.6.1 Safe Opening

A $\frac{1}{4}$ inch or less opening, as shown in Figure 7.5.5, will not permit any part of a worker's body to contact a danger point. Tooling that closes through a small distance is an example of one way to eliminate a hazard by the design of the process.

7.5.6.2 Positively Fixed Barriers or Enclosures

These guards are designed to prevent contact with hazards by placing a stationary obstruction between workers and hazards.

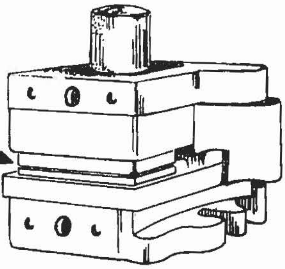

Fig. 7.5.5. Safe die opening.

Opening dimensions at different distances from the hazard are given in Figures 7.5.6 and 7.5.7. Fasteners for fixed barriers should be of a type not easily removed, and the material from which the barrier is made should be substantial. Properly maintained barriers are a highly effective safeguard because they do not permit exposure of body parts to dangerous machine actions (Courtney, 1984).

7.5.6.3 Adjustable Barriers

If nonuniformity is present in how the workpiece is presented to a machine, then a variably sized opening adjusts so that the workpiece itself prevents the worker from contacting a danger point. Such barriers may be either manually adjustable or self-adjusting (see Figure 7.5.8).

7.5.6.4 Interlocked Barriers

The goal of an interlocked barrier is to ensure that energy is removed before entry to a hazard area can occur. How frequently the gate is used will indicate how it should function. Two conditions of frequency of use should be considered with interlocked gates. For frequent entry, (Figure 7.5.9), as

Distance of Opening From Point of Operation Hazard, *b* (Inches)	Maximum Width of Opening, *a* (Inches)
$\frac{1}{2}$–$1\frac{1}{2}$	$\frac{1}{4}$
$1\frac{1}{2}$–$2\frac{1}{2}$	$\frac{3}{8}$
$2\frac{1}{2}$–$3\frac{1}{2}$	$\frac{1}{2}$
$3\frac{1}{2}$–$5\frac{1}{2}$	$\frac{5}{8}$
$5\frac{1}{2}$–$6\frac{1}{2}$	$\frac{3}{4}$
$6\frac{1}{2}$–$7\frac{1}{2}$	$\frac{7}{8}$
$7\frac{1}{2}$–$12\frac{1}{2}$	$1\frac{1}{4}$
$12\frac{1}{2}$–$15\frac{1}{2}$	$1\frac{1}{2}$
$15\frac{1}{2}$–$17\frac{1}{2}$	$1\frac{7}{8}$
$17\frac{1}{2}$–$31\frac{1}{2}$	$2\frac{1}{8}$

Fig. 7.5.6. Safe openings between parallel barriers.

Distance of Opening From Nearest Point of Operation Hazard, *b* (Inches)	Maximum Dimension of Opening, *a* (Inches)
$< 1\frac{1}{2}$	$\frac{1}{4}$
$1\frac{1}{2}$–$2\frac{1}{2}$	$\frac{3}{8}$
$2\frac{1}{2}$–4	$\frac{1}{2}$
4–15	2

Fig. 7.5.7. Safe square openings.

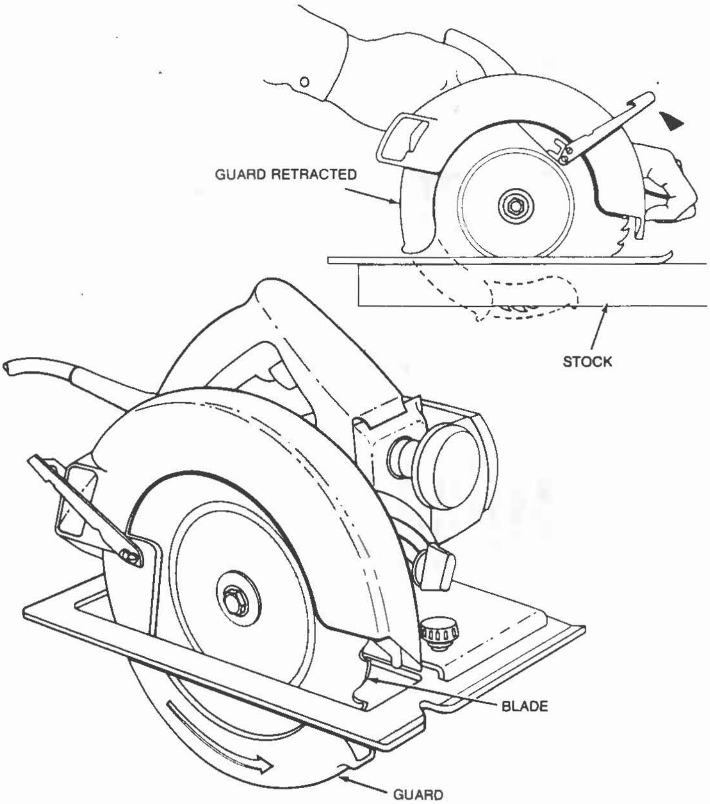

Fig. 7.5.8. An adjustable guard that opens against spring action to accommodate the workpiece.

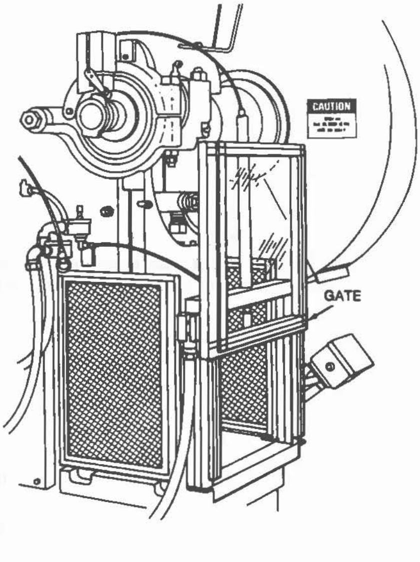

Fig. 7.5.9. A powered, interlocked gate that must close before dangerous machine motion can begin. The gate is made of clear plastic for viewing the working area.

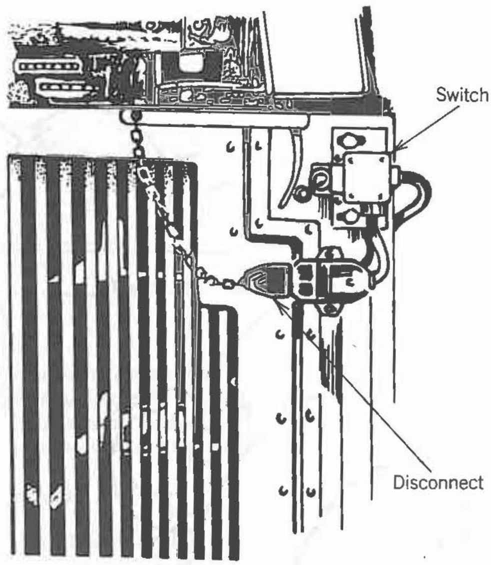

Fig. 7.5.10. An interlocked, sliding door intended for maintenance and servicing tasks.

with manual feeding, gates should either have a latch that holds the gate closed until the dangerous machine action is finished or have a means for stopping machine operation if the gate is opened during machine processing. Precautions should be taken to avoid the use of switching mechanisms and switch configurations that are easily overridden with screwdrivers, pencils, or adhesive tape, or broken so as to make the worker's feeding task more convenient. For infrequent entry, as with cleaning and maintenance tasks (Figure 7.5.10), switch arrangements controlling the machine's power service should be devised to prevent easy override of the switch or closure of the switch by means other than replacement of the barrier. Redundant electrical or other types of additional detection interlock should be considered in high risk situations. Equipment overrun or coasting hazards should also be protected against with interlocks that detect whether such energy sources are completely eliminated before a gate can be opened to permit entry for maintenance and servicing tasks. Visual or auditory warnings if energy remains present with the interlock open (flywheel turning, electrical power on, hydraulic pressure available) are advisable with interlocked barriers. Indications as to the status of the interlock and of machine energy sources when the interlock is open should be given consideration. Easy visual supervision assures the intended use of interlocks.

7.5.6.5 Safe Distance by Presence-Sensing Controls

Noncontact sensing devices can be used to generate an electromagnetic or other form of detection field that is sensitive to hand or body intrusion within a machine hazard zone (Figure 7.5.11). Circuitry connected to the sensor initiates control signals to stop the machine or prevent machine action if such an unsafe intrusion occurs.

In some countries it is also possible to use a presence-sensing device to initiate a machine cycle as well as to act as a safeguard. This mode of operation is governed by very specific regulations. At the date of this chapter, this mode of operation (presence-sensing device initiation) was under study by OSHA, which previously has prohibited its use under any circumstance for mechanical power presses. In a case study comparison, Salvendy, Shodja, Sharit, and Etherton (1983) reported no significant difference in stress measurements in one group of workers between using photo-electronic presence sensing protection and two-hand control device protection.

Other detection principles such as infrared, ultrasonic, and capacitance sensing are available, but care must be taken that the signals processed from the transducer are accurate and precise indicators of human proximity to danger, at any given exposure period and for all persons who may be exposed.

7.5.6.6 Safe Distance by Hand Contact Push Buttons

Keeping both hands away from a point of hazard by using them to depress dual palm buttons in order to start machine action is another method of injury prevention (Figure 7.5.12).

The remote location where the dual palm buttons are placed is determined by both machine and

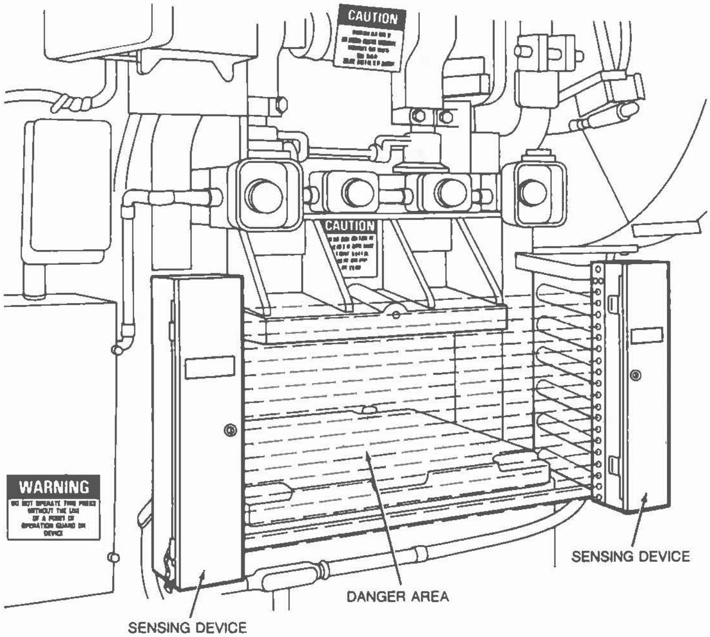

Fig. 7.5.11. A photo-optical sensor intended to issue a stop command should a human hand penetrate the planar sensing field.

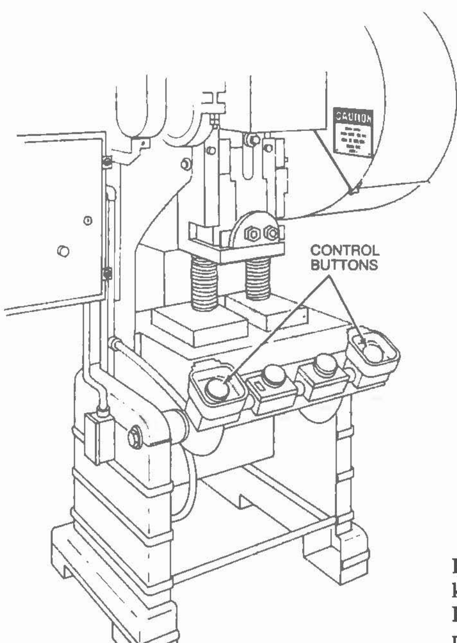

Fig. 7.5.12. Dual palm buttons can be a means of keeping hands at a safe distance from a danger point. Placing the buttons in a high location could cause postures, hand forces, and wrist deviations implicated in repetitive trauma disorders.

human performance factors. Machines do not stop instantaneously, but have a certain brake time. The worker should not be able to reach from the dual palm buttons to a danger point before motion has stopped or the hazard is under control. The human parameter used for average reach speed has generally been either 1.6 or 2.5 m/sec, depending on whether the hazardous reach is considered to have begun with the hand stopped or with the hand already in motion. These values have not always been replicable across variations in reach task imposed by different safety researchers. Musculoskeletal stress caused by location of dual button safety devices should also be considered. The convenience of fixing the buttons above the machine's dies or tooling could create stressful, repetitive reaching tasks. Two-hand control devices have been found to require more muscle effort (4.7 times higher EMG energy) when located above shoulder height than when located in a lower position (Nemeth, 1982).

7.5.6.7 Pullouts and Restraints

These safeguards are attachments to the person's hands, and are either linked to the machine so that the machine pulls the person's hands away from the hazard prior to a dangerous closure or are linked to a fixed point so that movements toward the danger point are stopped short (Figure 7.5.13). Such devices are permitted under current safety regulations in the United States, but their use must be carefully supervised. Human-factors problems may arise owing to inadequate cord adjustment for different size operators using the same device and owing to catch points in the machine tooling that could hold the strap in the tooling when a pullout action begins on the wrist.

7.5.6.8 Awareness Devices

By touch or other human sensory channel, an indication is given that the danger is being approached. These devices include chains hung in front of a hazard that will be brushed against if reaching toward the danger, warning lights that indicate that the power supply to the machine is on, or sirens that signal that a dangerous condition has been created on the machine.

Because they neither stop a person from reaching to a danger point nor initiate a control to deenergize

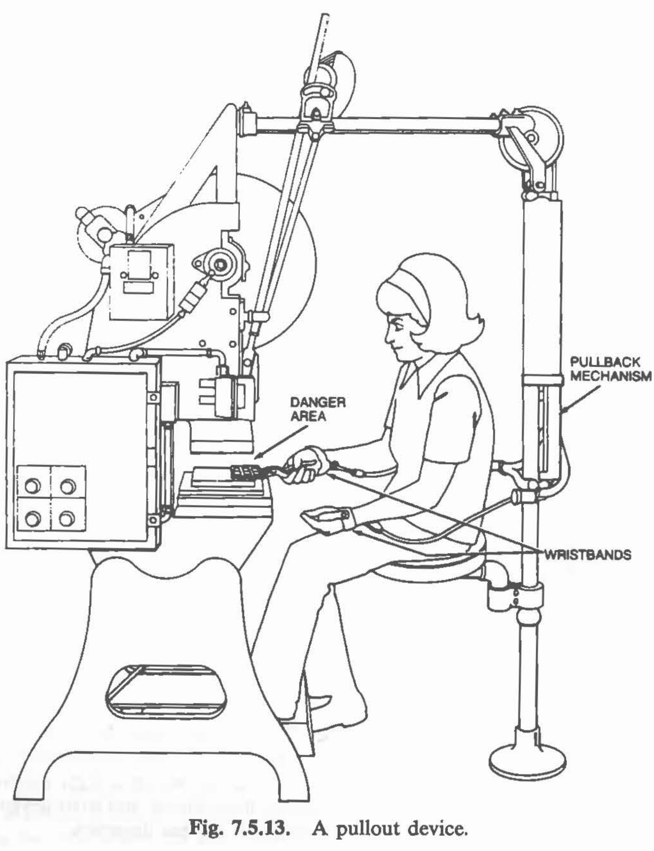

Fig. 7.5.13. A pullout device.

the danger if a danger point is approached, awareness devices are not considered effective primary safeguards. They can, however, provide supplementary information to improve the effectiveness of primary protective devices.

7.5.6.9 Floor Mats

By stepping on a pressure-sensitive floor mat, a person initiates a machine control signal to bring the hazardous machine elements to a safe state.

7.5.6.10 Lockout

To cut off the external power supply to a machine, to block or relieve internal energy sources, and to ensure that these sources remain off are the goals of any lockout method. A study of the various energy sources available is part of this method. Padlocks are one way to achieve external power lockout. One human factor in machine shutdown conditions is that communication between workers may break down. Unless a worker is in control of the restart switch or valve, there is a chance that another worker can accomplish a restart with the co-worker in a danger zone. The method for restart can be made less susceptible to inadvertent human action by requiring special keys and/or use of two or more types of switches.

Special cases within the domain of lockout are situations during machine setup or maintenance when power may be present with a human in or near what would normally be a danger zone. Training, energy reduction, and special supervision are among the considerations that must be carefully reviewed in such cases.

7.5.6.11 Emergency Stop

In case the precautions of separation and responsive control are violated, the elimination of machine power should be readily possible. This can be done with emergency stop buttons or with trip wires (see Figure 7.5.14) or bars near the danger point. Use of these emergency stop devices may lead to a subsequent removal of safeguards. For this reason consideration should be given to a safe restart sequence which assures that safeguards are back in place. When emergency stop buttons are used on control panels with many other control buttons, the color, shape, and location of the emergency stop button should be such as to avoid confusion about use of the button when needed.

7.5.7 HUMAN-FACTORS CONCERNS WITH MACHINE SAFEGUARDS

Lack of human-factors engineering of safety devices and methods plays a part in injuries at machines even when a first glance might make human factors seem unimportant. In many cases, injuries at machine work stations have not been prevented because although safeguarding was provided, it was not used. When a safeguard is installed it may satisfy the minimum requirement of a safety standard (e.g., an intended purpose to separate the person from the risk), and yet not be effective because it is ill-conceived from a human-factors point of view (e.g., difficult actually to use). An example of this would be a sweep-type device, which is intended to sweep across the opening between a person and a danger point when a machine such as a mechanical power press is closing its dies. The problem with such devices is that they may be a cause of injury if they sweep rapidly. This type of device as a single safeguard on mechanical power presses has not been accepted by OSHA since 1974.

No single, universally satisfactory safeguard has been found that will protect all workers at all times from a machine hazard. Safeguards used in the industrial workplace must be used by people who vary by sex, nationality, size, strength, and age. These safeguards must be used on machines that are old, reworked, and infrequently used, as well as on relatively new machines operating with state-of-the-art control.

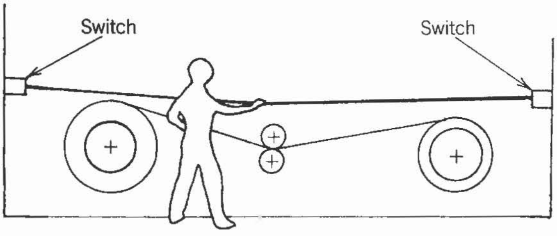

Fig. 7.5.14. Emergency stop trip wire—it may be possible to pull the wire in such a way that one switch would not detect the emergency condition.

Dissimilar tasks are performed, ranging from repetitive machine loading to occasional clearing of scrap and troubleshooting. Conflicts between the use of safeguards and performance of production tasks in the industrial work environment should be minimized. It would be best if a machine hazard could be eliminated in the design of the process. If this cannot be done, then the human's acceptance and use of a safety device becomes a design criterion. One should avoid safety devices that are satisfactory from an engineering production point of view, but that usually are improperly used by workers.

As machine systems in the workplace evolve and become more sophisticated, the need to provide adequate safeguarding does not diminish. Injuries occur even at machines that have been designed with the intent that human interaction would not normally be needed in their day-to-day operation. Although modern technology permits more machine elements to work autonomously under programmed, microelectronic control, the human presence cannot be discounted. Humans remain proficient and essential in nonroutine machine tasks such as troubleshooting, setup, and adjustment. To do these tasks, workers are required to access machine work zones where an inadvertent startup could be traumatic, such as entry into a robot work envelope to clear a stuck part, or troubleshooting a problem in an automated storage system.

The hazards of stress, fatigue, and cumulative trauma caused by repetitive, lengthy work periods are other elements to be considered in the use of guards and devices for industrial work stations. Motion economy principles, such as the avoidance of excessive reaches, should be used during the study of a safeguard application. It is possible that safety devices will interfere with normal, efficient motion patterns. When such is the case the surcharge imposed by necessary safeguarding must be accounted for in the production standards for the task.

7.5.8 HUMAN-FACTORS ITEMS ASSOCIATED WITH SAFEGUARD USE TRAINING

Untrained and unskilled workers may make dangerous reaching movements that a person familiar with the equipment would not make. However, training is not by itself a total assurance against inadvertent approach to a hazard because mental slips are made by trained workers who momentarily become distracted.

Convenience. Individual preferences, comfort, habit, and job satisfaction can play a role in how a worker uses a safety device provided. The convenience of using a safeguard affects whether people use the safeguard as intended.

No Added Hazard. The misuse of a safety device or an unexpected performance characteristic should be considered. If a gate closes under power, is it creating its own pinching hazard? Can pullout devices catch on a protrusion in the tooling and cause the arm to be jerked back while the hand is caught in the die?

Incentive Production. When work is done on an incentive basis, the worker may be prone to override or remove any safety device that interferes with work or that repeatedly stops work.

Fail-Safe. An ergonomist may not determine the functional control of equipment, but in the process of reviewing how people will use the equipment, it is worthwhile to consider what actions people take if the equipment fails and whether these actions are compatible with fail-safe design. For instance, if a machine can be rather simply restarted after a shutdown due to failure of a safety circuit, it may then be the case that the machine will indeed be restarted and operated with no safety device.

Ease of Maintenance. A safety device that is hard to get parts for, difficult to replace, or otherwise hard to maintain is a candidate for misuse or sabotage.

Verifiability. One technique that has been found useful is painting guards a bright color, such as yellow, making it easy for supervisors to spot guards that are not in place. Pilot lights may also provide indications of safeguard status. When redundant safeguards are used there may be a tendency to assume that all safeguards are operational. Verification that each device is operational is important.

Method of Loading and Unloading. The worker may want to reach into and remove work from a machine before the process is complete. Possible unloading methods to reduce risk include air jet blowouts, mechanical hands, gravity, hand tools, robots, and sliding bolsters. (See Figures 7.5.15 and 7.5.16 for two solutions.)

Error and Inadvertent Use. If an installed safeguard should become ineffective (improper use, failure, inability to operate under unexpected conditions, or other cause), then erroneous or inadvertent use of manual hand or foot controls could lead to an injury.

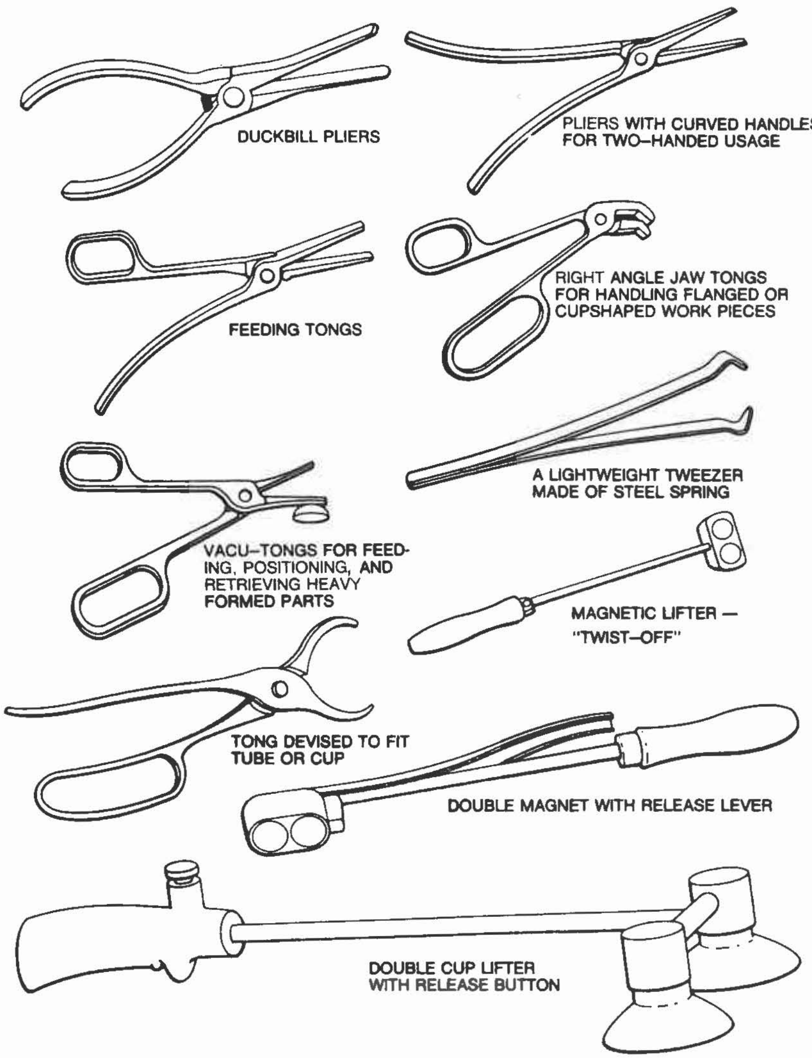

Fig. 7.5.15. Hand tools for keeping hands out of danger areas. Caution should be taken to avoid tools that cause excessive fatigue or that create conditions of use associated with repetitive trauma disorders.

Visibility. A safeguard that diminishes visibility into a machine work area, whether by color (reflective vs. nonreflective) or position (vertical vs. horizontal bars), will be used less often and less effectively than a safeguard that does not thus interfere. If work is not visible, a need to reach into a hazardous position may be created.

Posture. If a worker is in an unbalanced seated or standing position, an inadvertent step onto a foot switch or a reach into a danger zone to catch oneself while falling are potential factors in injury causation. Seating height and postural stability are factors to consider when access to a work area is possible. Figure 7.5.17 illustrates an unstable working posture. Knee room and foot rests contribute to postural stability when seated. Standing while using a foot control is not recommended in some cases.

Sabotage. The possibility that a worker will ruin or destroy a safety device that is not accepted can render worthless a well-intended safety expenditure. There persists a human tendency to disregard or underestimate the risk of injury on a machine task. Such attitudes become the rationale for eliminating safety devices that are not adapted to easy, convenient use.

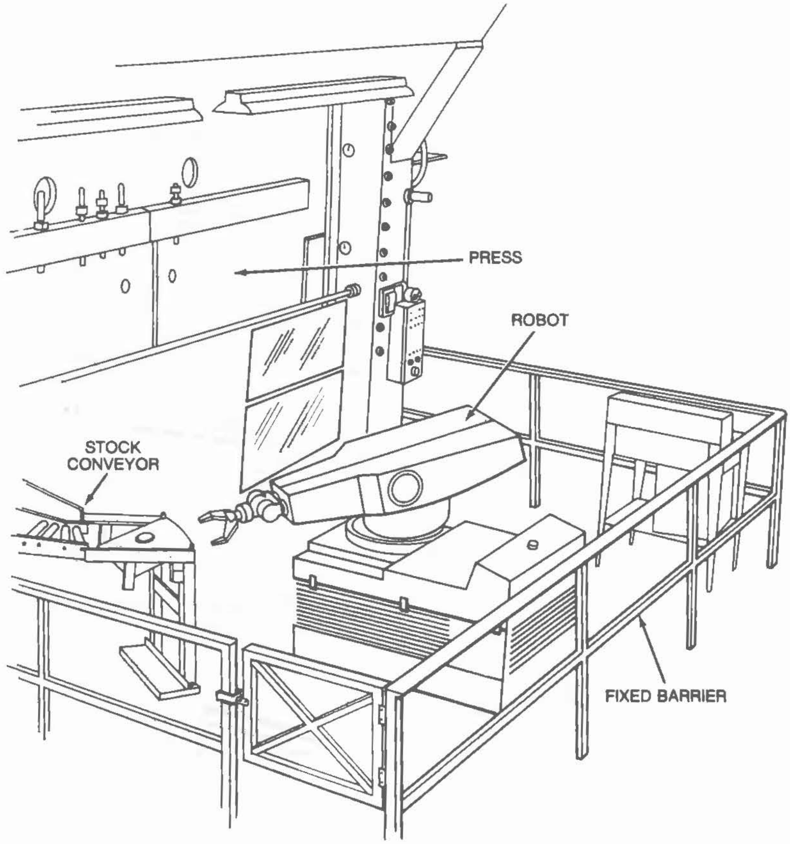

Fig. 7.5.16. A robot for relieving a person from the hazards of placing workpieces into a dangerous machine work area.

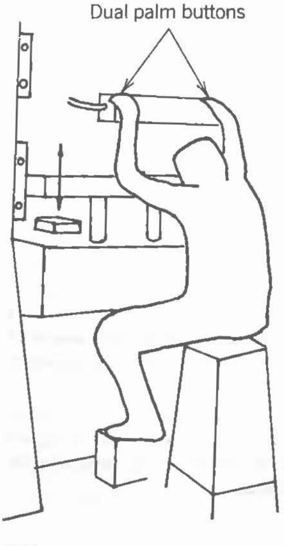

Fig. 7.5.17. Unstable working posture.

7.5.9 CONCLUSION

Giving consideration to human factors in the selection, design, and installation of safety devices will have as its final proof the result that the device is used as intended, that injury is indeed avoided, and that the user of the safeguard has confidence enough in the effectiveness of the safeguard that its use is accepted. The unfortunate side effects of some devices may be that while protecting against a sudden, traumatic injury they may be, over time, causing musculoskeletal injuries. The human-factors specialist must be cognizant of the consequences of both machine safety device use and misuse.

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