PB83120162

GUIDELINES FOR APPLICATION AND USE OF INTERLOCK SAFETY DEVICES

NIOSH Contract No. 210-79-0024

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Safety Research
Morgantown, West Virginia 26505

September 1981

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. 210-79-0024	2. NA	3. Recipient's Accession No. PB83 120162

NIOSH 00T22449

4. Title and Subtitle Guidelines for Application and Use of Interlock Safety Devices	5. Report Date September 1981
	6. NA
7. Author(s) Anonymous	8. Performing Organization Rept. No. NA
9. Performing Organization Name and Address The Boeing Aerospace Company Houston, Texas	10. Project/Task/Work Unit No. NA
	11. Contract(C) or Grant(G) No. (C) 210-79-0024 (G)
12. Sponsoring Organization Name and Address NIOSH Cincinnati, Ohio	13. Type of Report & Period Covered Contract
	14. NA

15. Supplementary Notes

NA

16. Abstract (Limit: 200 words)

The results of a study of automatic interlock devices which are used throughout industry to enhance safety in various working environments are discussed. The four major hazards wherein interlock devices could be used to automatically control the hazard are described. Examples of the hazards are discussed. The location, selection and type of interlocks are summarized. Guidelines for effective interlock application are reviewed. The authors recommend that an engineering evaluation of manual versus automatic methods of performing safety functions necessary to control the four generic hazards described in this report be performed and that an independent study of court decisions where the use, failure, or lack of use of interlocks was the determining factor in deciding a case be conducted.

17. Document Analysis a. Descriptors

Safety-equipment, Safety-engineering, Safety-devices, Safety-factors, Safety-measures

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Available to Public	NA	38
	20. Security Class (This Page)	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272

GUIDELINES FOR APPLICATION AND USE

OF INTERLOCK SAFETY DEVICES

NIOSH Contract No. 210-79-0024

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Safety Research
Morgantown, West Virginia 26505

September 1981

The Division of Safety Research, National Institute for Occupational Safety and Health, had primary responsibility for development of the recommended guidelines for application and use of interlock safety devices.

The Boeing Aerospace Company, Houston, Texas, prepared the document under contract No. 210-79-0024 for review and consideration by NIOSH staff. Mr. Sergio R. Concha and Mr. Walter P. Daniel of The Boeing Company had program responsibility for document development. Mr. Ted A. Pettit, Division of Safety Research, NIOSH, served as document manager and project officer.

The views expressed and conclusions in this document are the result of careful review of available evidence, and consideration of comments from external reviews. These views and conclusions however, are not necessarily those of the external reviewers or of the contractor.

ABSTRACT

This report summarizes the results of a study of automatic interlock devices which are used throughout industry to enhance safety in various working environments. During the study it was found that interlock devices are used extensively in configurations ranging from simple mechanical linkages to complex electronic circuits. Safety guidelines for the use of interlocks developed during the study are contained in this report and are applicable to all industries. While these guidelines do not specify when an interlock should be used, they categorize potential interlock control applications for each identified generic hazard type; examine interlock functions for each generic application and review alternative means of accomplishing the interlock functions.

This report is concluded with recommendations for the guidelines to be used as a checklist by personnel responsible for designing, purchasing, or implementing safety interlocks in industrial applications. The conclusions also describe the additional research that should be performed to determine when interlocks should be used. Existing national, state, and international interlock standards have been reviewed and are discussed in the appendix.

CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

For the purpose of this study, an "interlock device" is defined as: "A device which maintains an installed system in a safe condition without operator intervention." The definition of interlock devices implies that interlocks are used to control a system. To control means, in this instance, to regulate or guide the operation of a machine, apparatus or system. It was therefore necessary to determine generic "hazardous" conditions where interlock applications would be beneficial in order to categorize the potential safety interlock applications. To make this determination, the following hazard criterion was used: A hazard exists when the environment, conditions, natural phenomena or equipment characteristic may release energy that will exceed a human tolerance level.

Visits to industrial facilities were made to investigate scenarios suitable for the application of automatic safeguards or interlocks, to observe existing and potential interlock installations, and to solicit industrial expertise and experience related to the application of interlocks. In addition, a worldwide search was performed to identify literature relevant to automatic safety devices and accidents resulting from the lack of automatic safety devices.

Four basic generic hazards were identified wherein interlock devices could be used to automatically control the hazard. These hazards exist when:

1. The energy supplied to a machine, process, or system must be interrupted repeatedly for work to be accomplished safely.

2. Energy must be maintained within safe limits to prevent creating a hazardous condition.

3. Energy which have covers, hatches, or other type of closures to protect personnel require removal of enclosure to perform maintenance.

4. Energy release in uncontrolled manners occurs during machine, process, or system if operations are performed out of sequence.

The following paragraphs illustrate the generic hazards and categorizes them into four types.

TYPE 1 HAZARD - Energy supplied to a machine, process, or system which must be interrupted repeatedly for work, is released unexpectedly.

Type 1 hazards exist whenever hazardous levels of energy are used for production operations and the energy must be shut off repeatedly in order to safely change the workpiece or material. Industrial activities for which energy must be repeatedly shut off (or reduced to a safe level) include:

1. Manufacturing processes such as: cutting, bending, forming, rolling, and stamping used in the production of individual parts. These functions

are performed by presses, press brakes, shears, etc. In general, this subdivision includes machines that work with metals, plastics, or wood to create a product.

2. Batch processes that require repeated stoppage, such as food processing, paint mixing, foundry work, and beer and wine making. These functions are performed in mixers, ovens, etc. This subdivision includes equipment which cooks, blends, mashes, or heat treats to produce a product.

3. Systems which must be stopped and started repeatedly to transport materials to the workplace. These include assembly line conveyances and other machinery used in semiautomated processes.

TYPE 2 HAZARD - Uncontrolled energy released if safe operating limits of equipment are not maintained.

Type 2 hazards exist when high levels of energy must be controlled to safely create a product. Industrial facilities in which this condition occurs include power generation plants, chemical processing plants, petroleum refineries, and foundries. The processes in these types of facilities usually involve the use of high temperatures or pressures. High levels of mechanical energy (such as that generated by high speed machinery) are usually required in the manufacture of paper products, in printing processes, and in textile manufacturing. In general, interlocks or potential interlock applications are possible whenever energy is used at high rates.

TYPE 3 HAZARD - Energy is approached through enclosures.

Type 3 hazards exist when a person removes a cover, hatch, or other type closure and approaches dangerous levels of energy or hazardous materials. The energy may be in the form of motion in operating machinery, heat, or electricity, while the hazardous materials may be toxic or corrosive substances or hazardous atmospheres.

TYPE 4 HAZARD - Uncontrolled energy released if operations are performed out of sequence.

Type 4 hazards exist when actions controlling high levels of energy are not performed in a proper sequence. For example, the startup and shutdown of a furnace can result in an explosion if the startup and shutdown procedures are not performed in the correct sequence; or when deenergizing a high voltage power line, an accident can result if the deenergization and grounding steps are performed in reverse order. Many chemical processes can also become hazardous if process controls are not performed in the proper sequence.

Every safety interlock application may not fit precisely into any one of these four generic hazard types, industrial interlock applications or potential applications may provide protection from combinations of two or more hazard types.

INVESTIGATING THE HAZARDS

Manual and automated literature searches for accident data were initiated in order to further investigate the need for safety interlocks when industrial hazards such as the four generic hazards mentioned in the previous section are present. It was desirable to obtain accident data that would indicate statistically the advantages and disadvantages of using, not using, or misusing interlocks. As the search continued, however, it became apparent that significant accident data identifying the cause or contributing causes of accidents are not available. Overall accident data are available that can be useful for determining which industries have high and low accident rates, in developing a limited comparison of industries within a given Standard Industrial Classification (SIC) Code group, and in judging injury severity. The overall data establish that approximately two million disabling injuries occur annually as a result of non-motor vehicular accidents. These data, however, are of little use in determining the accident causes, which is a necessary step in a systematic effort to diminish the total number of accidents.

Attempts to obtain more detailed accident data from such sources as trade associations, insurance companies, labor unions, and industry proved unsuccessful because of one or more of the following reasons:

1. Trade associations did not collect the data or the data were not collected in a useful format or for specific enough instances.

2. Data from insurance companies, private companies, and unions are considered proprietary and/or involve liability considerations. Changing format and editing the data would be too time consuming or costly (the data are considered proprietary without changing format and editing and insurance companies are not interested in reworking the data).

The absence of data that provide the reason accidents are occurring is now a recognized national problem and may be the greatest single obstacle to improving industrial safety.

ACCIDENT SCENARIOS

Details of a small number of accidents were available from sources such as court proceedings. Several accidents and their surrounding circumstances are described below in order to provide a few real examples of the conditions where interlocks can be beneficial.

Examples of Type 1 Hazard - Control of energy sources requiring repeated shutoff.

Accident 1

On October 4, 1967, John Doe was injured when a press at Company A cycled while his left hand was beneath the ram. Although the double-operator press was designed to function only when both operators' palm buttons were depressed, Doe was pressing only his right-hand button when the accident occurred. Investigation revealed that a broken case on the snap-action precision switch of the left-hand control had caused the press to cycle unexpectedly*.

The injured worker brought a breach-of-warranty and negligence suit against Company B, the manufacturer of the palm-button assembly, and Company C, producer of the switch. Doe claimed that the defendants had failed to equip the press with an adequate safety device. After being instructed that any negligence or lack of due care on Doe's part would bar his negligence claim, the jury returned a verdict against him. The Court of Appeals affirmed the trial court's judgment, and Doe appealed that decision to the State Supreme Court. The court ruled that contributory negligence on the part of an injured worker is not a defense in a product-liability suit based on the manufacturer's failure to provide adequate safety devices. Hence, Doe was entitled to a new trial.

Accident 2. No interlock used. Worker trapped in hazardous area.

On October 19, 1971, John Doe was struck in the head by a moving part of an insulation-batt-packing machine he operated for Company A. Doe, who was working as a bagger on the machine, suffered severe injuries to his skull and brain. There was evidence that Doe caught his hand under the bag clamp and was unable to extricate himself in time to avoid the descending "shroud." No provisons were made to control the release of energy until the path of the moving part of the machine was cleared.

Doe and his wife filed a product-liability suit against Company B, the designer of the machine. When the jury returned a $750,000 verdict for Doe and a $25,000 verdict for his wife, Company B appealed, claiming numerous errors on the part of the trial court. The State Court of Appeals rejected the manufacturer's contention that Doe's injuries were caused by the open and obvious dangers presented by the batt-packing machine's descending shroud, and therefore were not compensable as a matter of law. According to the court, it was up to the jury to assess any evidence of the machine's open and obvious dangerous characteristics in considering the ultimate question of whether the machine was unreasonably dangerous. While the court upheld the jury's $750,000 award to Doe, it reversed the damage award to the worker's wife, ordering a separate trial on that issue.

Both of these accidents occurred because of the condition 1 type hazard "Energy must be interrupted repeatedly in order for the work to be accomplished safely." The first describes an accident which (apparently) occurred because the interlock (two-hand controls) had failed, but the failure was either undetected or ignored by the operator. The second occurred when there was no attempt to automatically control the hazard; instead it was up to the operator to clear the danger. This procedure failed when the operator's hand was caught, preventing him from clearing the hazard.

*The snap-action precision switch is part of the energy control system whose failure allowed the energy to be released unexpectedly.

Example of Type 2 Hazard - Control of high rate of energy.

Accident. No interlock used.

The operator of an overhead monorail crane was transporting molten metal to the area where the iron was being poured into molds. These cranes were directed to the various pouring areas by floor switchmen who could transfer the ladles of metal from one track to another by both mechanical and pneumatic systems. Two cranes were being operated on the same track and were switched from an outside rail to an inside rail by means of an "S" switch. The first crane passed through the switch, while the second crane followed 15 feet behind. As the second crane approached the switch, the switch opened, allowing the crane to run off the track and fall to the floor. About 2 tons of molten metal splashed onto the floor and on the operator, setting his clothes afire. The operator died 6 weeks later.

This accident describes another situation wherein apparently no attempt was made to automatically protect the employees with an interlock. The manual or procedural method of maintaining energy within safe parameters (on the tracks) failed.

Examples of Type 3 Hazard - Control of exposure to normally protected energy or hazardous materials to perform maintenance.

Accident 1. Interlock removed.

While at work at Company A, Jane Doe injured her hand in a plastic-bottle trimmer which activated as she reached into it to free a jammed bottle. The trimmer had been manufactured by Company B with a set of clear plastic safety doors, which automatically shut off the machine each time an operator opened the doors. Sometime before the accident, Company A's manager had the safety doors removed to give operators easier access to bottles jammed in the machine.

Doe brought suit against Company B to recover for her injuries, claiming that the trimmer's safety doors were easily removable and that the manufacturer reasonably should have foreseen that Company A would take them off. Hence, she said, the trimmer was dangerously designed. The state trial court ruled that Company B had no reason to know that Company A might remove the safety doors. The state appeals court sustained the judgment. According to the court, the safety doors, which had been attached to the trimmer with a 1/2-inch rod and eight 1/4-inch bolts, were not readily removable by the machine operator. Consequently, Company B was not lax in failing to foresee that the doors would be removed.

Accident 2. Interlock removed.

John Doe was injured when the plastic pelletizer he operated for Company A accidentally activated while he was reaching through an unguarded porthole to clean it. The machine was manufactured by Company B in 1964 and purchased by Company C, which placed a guard and an interlock device over one of the machine's two portholes. In 1969, Company C sold the machine through a broker company to Company D, a used machinery dealer. Company D ultimately sold the pelletizer to Company A (Doe's employer) in 1975. Company A made the machine operable but did not install any safety devices.

The injured worker brought suit in state court against the manufacturer and the various other parties in the chain of sale. The broker sought summary judgment in its favor, claiming that, as a broker, it had no control over the manufacture or repair of the pelletizer and could not be held strictly liable for Doe's accident. According to the broker, subsequent purchasers were responsible for installing safety devices. Ruling that factual issues concerning the broker's liability to Doe had to be decided at trial, the Superior Court refused to enter judgment for the broker. Under the state's law of strict liability, said the court, it is necessary to show not that a defendant created a defect but only that the defect existed when the product was distributed under the defendant's control. Moreover, vendors of used machinery are not automatically immunized from liability.

Finally, the court noted, the mere fact that subsequent purchasers might be in a superior position to recognize the need for safety devices on a machine was not automatically a defense and the broker would have to prove that it had reason to believe that the machine would undergo safety modifications at the hands of later purchasers.

Both of these condition 3 type hazards resulted in accidents at least partly because interlock devices had been removed and no longer automatically protected the employees.

Example of Type 4 Hazard - Control of proper sequence of operations.

Accident. No interlock.

Three workers at Company A were burned when molten metal released from a cupola erupted after contacting wet sand below. At the time of the explosion, the three employees were at work in an area of between 20 and 25 feet above the floor and 50 feet from the cupola. Although the cupola was equipped with an alarm, the foreman had failed to sound it.

The three workers brought a suit against Company B, the manufacturer, claiming that the cupola had been dangerously designed. They contended that the cupola should have been equipped with an automatic interlock to prevent its doors from opening unless the alarm had been sounded. When the state jury returned substantial verdicts for the injured workers, Company B appealed, arguing that it could not reasonably have foreseen Company A's use of wet rather than dry sand beneath the cupola. The combination of molten metal and wet sand was the cause of the explosion. The manufacturer also claimed that it had no duty to equip the cupola with devices to protect the three workers, since it could not have foreseen that they would be near the cupola when it was emptied. The State Court of Appeals sustained the verdicts against the manufacturer, concluding that the issues of design sufficiency were properly for the jury to decide.

The condition 4 type of accident was at least partly attributable to the lack of a warning prior to discharging molten metal. The jury (evidently) decided that an automatic interlock should have been installed to ensure the correct sequence of alarm first, then the discharge of molten metal.

These examples of court decisions of accidents caused by failure of devices used as interlocks or the lack of such provisions, illustrate that interlocks can be used to automatically control the four generic hazardous conditions and that if hazards are to be controlled, the control function must be performed by interlocks or manually. Figure 1 shows the actions interlocks must perform to control the hazards, and the manual hazard control functions are shown in the last column.

Examples of interlock devices used for hazard controls are shown in Table 1. The generic hazard types and the specific hazards are shown along with typical devices used for hazard control, including the "sensors" or monitors and the "operators" or energy controls.

HAZARD TYPES	INTERLOCK CONTROL FUNCTION	ALTERNATIVE FUNCTION (MANUAL)
(1) POSSIBILITY THAT ENERGY SUPPLIED TO A MACHINE, PROCESS, OR SYSTEM INTERRUPTED REPEATEDLY FOR WORK IS RELEASED UNEXPECTEDLY AND INJURE PERSONNEL.	AUTOMATICALLY REDUCE MACHINE OR SYSTEM ENGERY TO A SAFE LEVEL WHEN THE HAZARD IS APPROACHED.	MANUALLY OPERATE SWITCH OR OTHER CONTROLS TO REDUCE ENERGY TO A SAFE LEVEL EACH TIME THE HAZARD IS APPROACHED.
(2) UNCONTROLLED ENERGY RELEASE DEVELOPS IF ENERGY IS NOT MAINTAINED WITHIN SAFE PARAMETERS OF EQUIPMENT.	AUTOMATICALLY INITIATE ACTION TO PREVENT EXCEEDING SAFE LIMITS.	OPERATOR MUST MONITOR PARAMETERS AND INITIATE ACTION TO PREVENT EXCEEDING SAFE LIMITS.
(3) PERSONNEL MAY BE INJURED WHEN A PERSON APPROACHES HAZARDOUS LEVELS OF ENERGY OR MATERIALS THROUGH A COVER, HATCH, OR OTHER TYPE OF CLOSURE.	INITIATE ACTION TO DE-ENERGIZE OR OTHERWISE ELIMINATE THE HAZARD OR PREVENT COVER, HATCH, OR CLOSURE FROM BEING OPENED WHEN THE HAZARD IS PRESENT.	MANUALLY SECURE OR POST WARNING SO THAT PROTECTIVE COVER, HATCH, OR CLOSURE WILL NOT BE OPENED AND HAZARD APPROACHED.
(4) UNCONTROLLED ENERGY RELEASED DEVELOPS IF ACTIONS ARE NOT PERFORMED IN A PARTICULAR SEQUENCE.	AUTOMATICALLY PREVENT OUT-OF-SEQUENCE ACTIONS.	MANUALLY PERFORM ACTIONS IN CORRECT SEQUENCE.

Figure 1 INTERLOCK HAZARD CONTROL FUNCTIONS

TABLE 1

EXAMPLES OF INTERLOCK HAZARD CONTROL APPLICATIONS

GENERIC HAZARD TYPE	HAZARD CONTROL	HAZARD EFFECT OR POTENTIAL INJURY	SENSORS	OPERATORS
(1) (4)	Machine tools - Fail-Safe press controls preventing repeat cycles.	Crushing of fingers, hands, or other parts of the body.	Rotary cam switches	Electrical circuitry (relays, contactors, solid state devices)
(1)	Machine tools - Interlock shield at the point of operation on metal cutting saw. The machine will not start if the shield is raised.	Laceration or amputation of fingers or hands.	Limit switch	Electrical circuitry (relays, contactors, solid state devices)
(1)	Machine tools - Interlock on arbor of metal-cutting saw to assure the workpiece is properly positioned and clamped in place.	Impact by ejected workpiece or accelerated particles.	Pressure switch	Electrical circuitry (relays, contactors, solid state devices)
(1)	Machine tools - Guarding the point-of-operation of press brakes by using a two-hand palm button and foot control.	Crushing of fingers, hands or other parts of the body.	Two-hand palm button and foot pedal	Two-hand palm button and foot pedal

Generic Hazard Type		
	1	Energy supply interrupted repeatedly.
	2	Energy is not maintained within safe limits.
	3	Persons approach hazardous energy or materials through closures.
	4	Actions are not performed in proper sequence.

GENERIC HAZARD TYPE	HAZARD CONTROL	HAZARD EFFECT OR POTENTIAL INJURY	SENSORS	OPERATORS
(2)	Material handling - Regulate the flow of material on conveyors to prevent jam-ups.	Mashing of fingers and hands. Impact from falling objects.	Electric eye	Electrical circuitry (relays, contactors, solid state devices)
(2)	Material handling - Rollers of a conveyor are designed so that pressure from fingers or a hand caught in a pinch point between the rollers will force the roller back in its horizontal slot and stop the conveyor.	Pinching of fingers and hands.	Limit switch	Electrical circuitry (relays, contactors, solid state devices)
(3)	Material handling - Interlocked sections of hinged cover over the screw of a screw conveyor. Screw rotation stops when the cover is lifted.	Laceration or amputation of fingers, hands or feet.	Limit switch	Electrical circuitry (relays, contactors, solid state devices)
(2)	Process machinery - Switches within the control circuits of of paper-folding machinery shut down the machine when a jam occurs.	Mashing or laceration of fingers and hands.	Limit switch	Electrical circuitry (relays, contactors, solid state devices)
(3)	Process machinery - A cover installed over the rolls of textile machinery. The cover cannot be raised while the machine is operating.	Laceration or amputation of fingers and hands.	Mechanical linkage	Mechanical linkage

GENERIC HAZARD TYPE	HAZARD CONTROL	HAZARD EFFECT OR POTENTIAL INJURY	SENSORS	OPERATORS
(3)	Process machinery - A cover installed over the toothed rolls of a wool picker machine. The machine will not start if the cover is raised.	Laceration or amputation of fingers and hands.	Mechanical linkage	Mechanical linkage
(4)	Furnaces - Fuel flow to burners is shut down if a flame failure occurs.	Burns from fire and explosion.	Ultraviolet detectors	Fuel shutoff valve actuator
(2)	Cranes - Incorporate switches on the hoist portion to prevent overrunning of the load.	Impact from dropped load.	Limit switch	Electrical circuitry (relays, contactors, solid state devices)
(2) (4)	Chemical processing plant - Flow and temperature sensors provide a rapid and controlled shutdown of a reactor hot oil cooling system if out-of-tolerance conditions occur.	Burns from overheated product.	Thermal switch and flow sensor	Valve actuators

Generic Hazard Type		
	1	Energy supply Interrupted repeatedly.
	2	Energy is not maintained within safe limits.
	3	Persons approach hazardous energy or materials through closures.
	4	Actions are not performed in proper sequence.

HAZARD CONTROLS

WHEN INTERLOCKS SHOULD BE USED

There is no uniform answer to the question of when interlocks should be used. There are situations in which the answer is obvious; e.g., when Government regulations require interlocks (See National, State, and International Interlock Standards); however, the decision usually must be based on an evaluation of specific circumstances. An interlock function that is practical and easy to implement in one situation may be unreasonable to use in others. Therefore, when an employee can be exposed to one or a combination of the generic hazardous conditions, an evaluation should be performed to determine if interlocks should be used. To conduct the evaluation, a set of typical questions must be asked. Following are examples of the types of questions that should be considered.

1. Is there an existing OSHA requirement for interlocks?
2. How long is the activity expected to continue? (duration)
3. How often is human intervention required or anticipated? (frequency)
4. What are the consequences if the hazard control function is not performed? (severity)
5. How effective is the manual or procedural method likely to be over the full expected time of the activity.
6. What additional personnel, controls, or training are necessary to implement an effective manual hazard control function?
7. What are the requirements for designing and installing effective interlocks?

Complete answers to these questions can only be derived by systematically evaluating each potential generic hazard. The advantages and disadvantages of manual versus automatic hazard controls should be apparent after compiling the answers. One of the most important answers is the length of time the activity is expected to continue. For very short term activities, manual hazard controls may be the most practical. For long term activities, automatic interlocks would be expected to offer advantages over manual control methods because it may be unreasonable to expect an employee to be continually safety conscious. Each pro or con should be a trade-off between the two techniques allowing the selection of the best hazard control technique for each application.

SELECTION OF INTERLOCKS

If an evaluation of the hazards indicates that an interlock should be used, the questions that remain to be answered are:

1. What type of interlock should be used? Electrical? Mechanical? Electromechanical? Software? Or any combination of these?

2. Are the design and construction of the interlock compatible with the application, the required reliability, and the environment?

3. How can it be verified that the selected interlock is going to perform its safety function adequately?

The following organizes the data needed to make a selection. It categorizes interlocks by type, establishes general interlock selection and implementation criteria, and defines interlock verification activities.

TYPES OF INTERLOCKS

Interlocks as safety devices are as diverse in their application as in their use in the various industries. Interlock devices consist of a sensing element and an actuating or operating element. Interlocks are classified according to whether the sensing and operating functions are performed by mechanical, electrical, or electromechanical elements*. Some typical examples of interlock devices are listed in Table 2.

GUIDELINES FOR EFFECTIVE INTERLOCK APPLICATION

The following guidelines should be used in choosing the device that is best suited for each application. The process of selecting and implementing interlocks starts by compiling a list of candidate devices that are capable of performing the required interlock functions. Each device should be capable of performing the hazard control functions automatically.

Design To Tolerate Failure

The interlock device or system should be designed to tolerate failure. Planning the design to accommodate failure can be almost as important as planning to ensure a device performs its intended function. In spite of the best designs, failures can still occur. The consequences of any failure should be evaluated and plans made to tolerate the failure before an interlock is installed. Very good designers often fail to consider the consequences of failure in their desire to make sure an installation functions properly. There is no substitute for a systematic evaluation of what can go wrong with a design before putting it into use. Figure 2 is an example of one logical sequence of failure considerations that should be evaluated before installing or designing interlocks.

*Interlock functions are also performed by computerized programs and programmed into the "software." These guidelines do not apply to software; however, software interlocks should have the same attributes as the ones outlined in this report.

TABLE 2

Typical Interlock Devices

Mechanical	Electrical	Electromechanical
Pressure Relief Valves (Automatic and manual)	Circuit Interrupters	Switches (Micro, reed, mercury, and magnetic)
Ratchet Lock-up and Holding Mechanisms	Fuses	Proximity Switches
Mechanical (Centrifugal) Brakes	Various solid state current sensing and limiting devices and ground switching devices	Electromagnetic Brakes and Clutches
Safety Latching and Holding Mechanisms (Automatic and manual reset)	Thermal sensing devices and circuits	Solenoids and Solenoid Valves
Inertial Reel Mechanisms	Proximity sensing units and circuits	Thermocouples and Thermostats
Control Valves (Pneumatic and Hydraulic)	Various automatic discharging or dissipating devices and circuits	Solid-state Sensors and Piezoelectric Devices

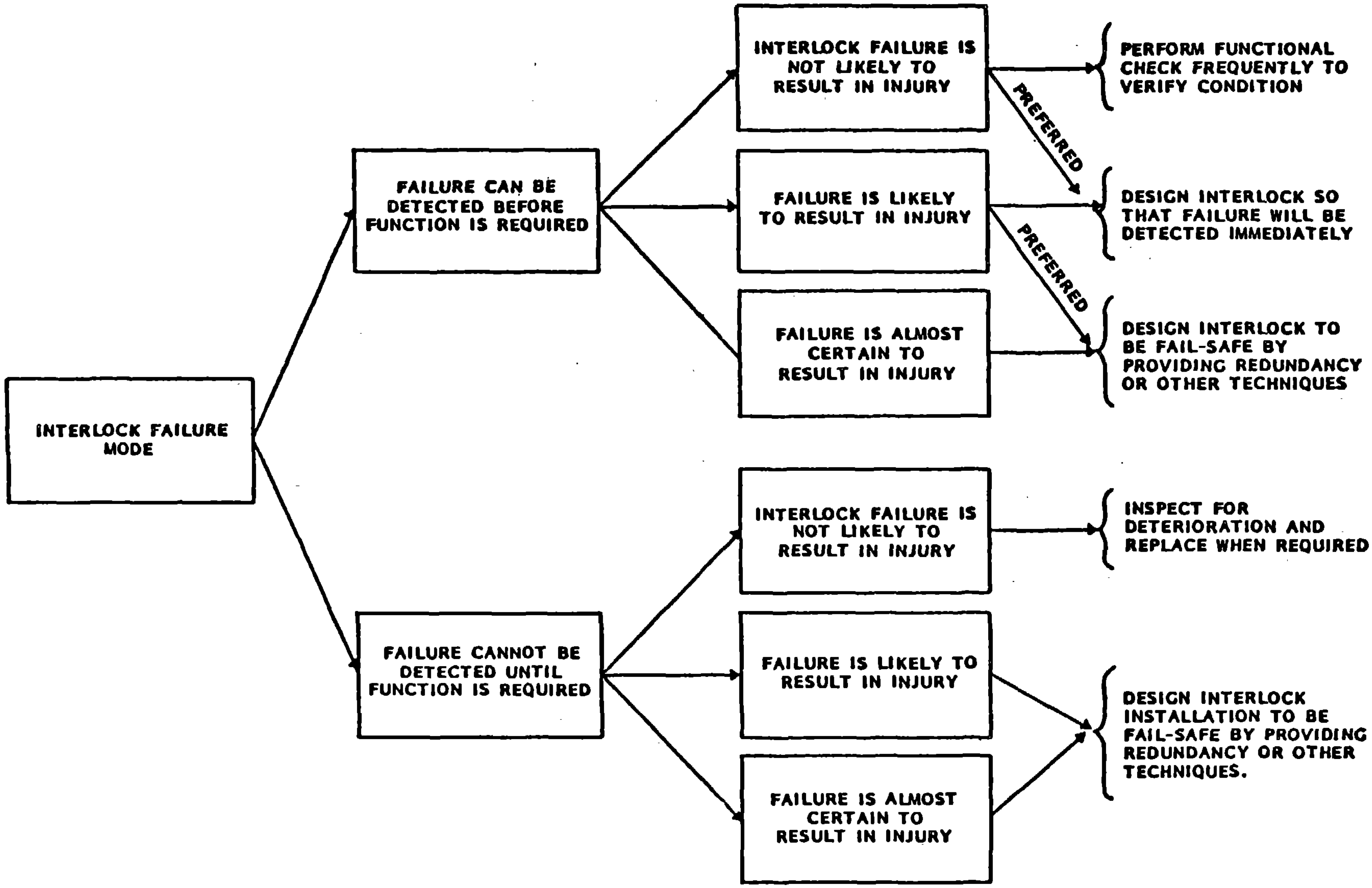

Figure 2 PLAN TO TOLERATE FAILURE

The first step is to consider ways or modes in which a device can fail. Depending on the type of device, generic failure modes that may be possible include failure to initiate the function, initiating the function prematurely, and failure to shut off the function. Electrical devices in particular can often fail in these modes.

The next step is to consider each failure mode individually and determine whether the failure mode could be "hidden" until the function is needed or if the failure can be readily detectable.

At the same time, the consequences of a failure and its effect should be evaluated. Determining the effect of a failure may be straightforward and simple or may involve detailed analyses in order to consider all the possible cascading results of a failure.

Figure 2 includes recommended design practices for interlock installation depending on the likelihood of the failure resulting in injury and whether the failure can be detected before the interlock function is needed. The differences between a failure that "can be detected" and one that "will be detected immediately" may not be immediately obvious. A failure that "can be detected" may require a separate device and activity to periodically check the integrity of the interlock. An interlock installation in which failure "will be detected immediately" requires no special checks, but by one means or another the failure is made known when it occurs. The failure of an interlocking mechanical linkage may make itself known, but the failure of an electrical device may require signals to announce the failure.

If there is no realistic way to detect an interlock failure until the function is required and injury is likely to be the result, the interlock should be designed to be fail-safe. "Fail-safe" in this report means that no matter when, where, and how any single failure occurs in the interlock, the system remains in a safe condition. In other words, the installation can tolerate a single failure without an injury resulting. The means of designing a fail-safe installation depend entirely on the particular application, but may require redundant or backup devices to function after the potential failure mode occurs.

Caution should be exercised if redundancy is used to provide the fail-safe feature. Consider the possibility that one of the redundant functions may fail and the failure is undetected. Unless each redundant functional path is or can be checked periodically, a hidden failure can change a fail-safe design to one that fails catastrophically. Detailed analyses may be required to determine the best way to provide fail-safe designs. A detailed analysis may be warranted if the consequences of interlock failure are severe.

Use Reliable Interlocks

Designing or selecting highly reliable interlocks can be complicated and initially expensive. Unreliable interlocks that cause consistent interference with production can be even more expensive. A compromise must be reached that considers the consequences of unnecessary system or machine shutdown due to failure of an interlock component, and the effort necessary to assure the desired degree of interlock reliability. Where the consequences warrant, special features must be incorporated into the interlock design to attain high reliability. Very high reliability can be achieved for structural or load-bearing members by using substantial safety factors that assure that the load-carrying ability of each structural element exceeds the maximum possible load that would be applied under the most severe conditions. Deterioration of strength over a period of time must be considered for many materials. Designing high reliability for other than structural elements cannot be easily accomplished with the same certainty. It is often necessary to use redundant designs to achieve high reliability with electrical or electromechanical components. Redundant designs may incorporate series or parallel redundancy, or combinations of both. Care must be taken to avoid design errors that can effectively destroy redundancy. For example, if redundant components are used that are not suitable for a vibratory environment, all redundant components may fail under the same vibration spectrum; or if the redundant signals are routed in the same conduit or trays which may be susceptible to rupture by the same cause.

If all environmental conditions are properly considered and the components are not overstressed in their applications, very high reliability can be achieved. In order to maintain that degree of reliability, however, failure of components in redundant functional paths must be detected. The interlock design should incorporate means for the operator to detect failures in redundant paths.

Interlock Verification

In order to provide effective hazard controls, an interlock must perform its function in a safe and reliable manner. Verification and testing should be performed to assure that a specific interlock application performs as required. The verification and testing should establish that hazardous energy is either blocked, controlled, or dissipated in a timely and safe manner. The interlock system should be analyzed and tested to demonstrate that:

1. It operates as designed.

2. Failures are planned for and do not introduce unexpected risks.

3. The interlock does not impede or interfere with production operations in such a manner to cause repeated attempts to defeat or bypass the interlock action.

4. It is compatible with its application and environment.

Use of Interlocks That Cannot be Easily Circumvented (Except by Authorized Personnel)

The most important requirement for an interlock is that it should perform its intended function. Another important requirement is that the interlock should not be prevented from performing its intended function except by authorized personnel. Circumventing an interlock voids the hazard control function and may expose the worker to the specific hazard which the device is intended to control. Deactivating or circumventing the interlock should only be accomplished by personnel who are trained to use other hazard controls while the interlocks are not functional. Once the necessary work is completed, authorized personnel should reactivate the interlocks and reverify that the hazard control functions are performed properly.

Installing interlocks that cannot be easily circumvented may require ingenuity, depending on the device used and the particular application. An excellent reference in which this requirement is given extensive consideration is "Electrical Limit Switches and Their Applications," published by Her Majesty's Stationery Office, London, England, Health and Safety at Work Series.

Manual vs. Automatic Reset

Some interlock devices have design characteristics which reenergize the system automatically as opposed to requiring manual reset. The applications engineer or designer of the interlock system must consider the risk to personnel when selecting automatic modes of reenergizing the system. No firm rule can be formulated to cover all applications; however, when there is doubt as to the adequacy of automatic reenergization, manual reset should be selected. Manual reset of the interlock system requires the worker to perform a deliberate action to restore energy to the machine, equipment, system, or process, thereby assuring an awareness of the presence of energy. Automatic reset interlock systems may restore energy unexpectedly.

Interlock Maintenance

Interlock devices that require minimum maintenance should be selected. Maintenance can be a vital element in assuring successful interlock applications because interlock devices usually require only slight movements or forces to operate. A routine maintenance program and schedule should be instituted to assure correct functioning of interlock systems during production and work cycles. Maintenance includes servicing, repair, or refurbishment activities. The frequency of maintenance should conform to the recommendations of the device manufacturer. In cases where the interlock system is uniquely designed, the designer should define the servicing and maintenance periods and procedures.

A good maintenance program includes scheduling and the keeping of maintenance records. It is suggested that these records be reviewed periodically to determine if maintenance periods need changing or if the interlock system needs to be modified to reduce maintenance requirements. Maintenance should also include inspections to determine that the interlock is in "good working condition" and that interlock operation has not been degraded; i.e., dried grease, gummed or contaminated oil, paint, water (resulting in rust), or that other solid or fluid contamination has not occurred.

Care should be exercised in performing maintenance tasks and activities to prevent compromising the design or degrading the safety integrity of the interlock system, for example:

1. Oil or grease applied to electrical or mechanical components where it can be detrimental to the interlock function, such as in a pressure port, on an oxygen immersed part, or on electrical contacts.

2. Substitute lubricants used instead of the specified lubricants. Examples include the use of either too heavy or too light a grade of lubricant, causing restricted movement which may alter response time, or excessive wear; or oil or grease used instead of dry lubricant which may

cause a fire or excessive dust or dirt accumulation resulting in poor response time, lockup due to friction, or freezing due to cold temperature effects.

3. Substitution of components, electrical wire, or pipe such as using the wrong size tubing which could change system response time; the wrong size wire changing response time or causing malfunction; wrong fuses resulting in too little or no circuit protection; wrong springs resulting in possible valve malfunction; or wrong burst discs or orifices.

4. Incorrect settings of electrical or mechanical components or incorrect calibration resulting in incorrect settings of functions. Examples include incorrect relief valve settings, spring tension, or switch lever or action settings; incorrect clearance settings of solenoids, levers, ratchets, or cam settings; incorrect setting due to removal or nonremoval of system components or loads such as electrical voltage or current settings; out-of-sequence system operations; and incorrect hydraulic or pneumatic flow or pressure setting.

Interlock Procedures

Operational procedures for interlock applications should be documented as required to provide a clear understanding of the interlock system and operation to ensure correct use.

For complete installations, the procedure should contain the purpose of the interlock and a table identifying all systems and operations which are directly or indirectly affected by the operation of the interlock. A section of the procedure should be clearly labeled "Emergency Procedures." This section should address worst-case conditions and define actions that must be taken in cases of emergency.

Procedures should be modified to address any changes in failure condition(s) that are the results of effects of modifications, and normal or emergency actions to be taken if failures occur. The importance of this recommendation is stressed because many accidents can be attributed to the fact that the system did not operate as intended because changes had been made that were not coordinated or fully analyzed to determine the effect of the modification on the system. No interlock system modification should be implemented until the system's operators have been trained in the operation of the modified interlock system.

Interlock Training Considerations

Training should be conducted to assure that the purpose of the interlock(s) is understood and its functionality maintained. This training should involve elements of management and labor concerned with interlock use and maintenance. Provision should be made to require that only personnel with the prerequisite knowledge and skill be allowed to perform interlock maintenance.

Periodic Assessment of Interlock Applications

The objective of periodic assessment of interlock applications is to ensure that the level of safety provided by the interlock application is being maintained or improved. Industrial workplaces change constantly and interlock applications may change with them. In order for interlocks to continue to perform their safety functions, changes in the workplace should be assessed to assure that hazard controls have not diminished in effectiveness.

The assessment of changes should consider interlock operation (startup, normal shutdown, and emergency conditions arising from failures); testing; validation; maintenance; new technology; changes in the machine, equipment, system, and process procedures; and training. Information for this continuing assessment should be derived from changes in the intended use of the system and from design modifications, maintenance reports, accident/injury reports, interlock failure and reliability assessments, applicable technical articles and reports, and operational procedures. Particular emphasis should be placed upon accident/injury reports, state-of-the-art interlock developments, and the experience gained from the interlock use.

The results of the continuing assessment program should be reported to management and personnel concerned with interlock use.

CONCLUSIONS

Guidelines for application and use of interlocks have been developed which, if followed, will help assure installation of effective and reliable automatic safety devices. The developed interlock application guidelines should be used because they will enhance the performance of the system.

The criteria for determining when to use interlocks are inherent within the decisions to automatically or manually perform safing functions.

Interlocks are used in thousands of applications to control the four generic hazards identified in the study. No devices classified as "interlock" are sold in the market, since an interlock is "a device which maintains an installed system in a safe condition without operator intervention," and can be any part, component, or system which automatically combines the operation of two or more components or systems into a larger system. Any part, component, or equipment may function as an interlock in an application or may function independently in another application. Therefore, types of equipment covered by these guidelines have not been identified.

Court decisions in the liability cases reviewed in this study are inconclusive when used to set a criteria for selecting automatic versus manual control methods. Accident and incident reports do not provide primary causal factors; thus no statistical analysis of the need for a standard could be performed.

There is no absolute recommendation on when interlocks should be used in lieu of an alternate hazard control technique, except as required by safety regulations shown in the Appendix. The lack of specific recommendations on when to use interlocks results from questions which cannot be answered regarding the advantages and disadvantages of hazard control functions performed automatically as compared to manually. Until these questions can be answered (see Research Needs), the use of interlocks cannot be recommended in place of other hazard control techniques. Interlocks installed and used in accordance with the guidelines, however, are recommended to anyone desiring to purchase, design, or install effective automatic safety devices.

RESEARCH NEEDS

An engineering evaluation of manual versus automatic methods of performing safety functions necessary to control the four generic hazards described in this report should be performed. The study should identify and evaluate the significant factors that must be considered when determining whether manual or automatic methods are the most practical, effective, reliable, and safest means of hazard control. The results of the evaluation should be organized in a way that would aid in selecting the best control method for each unique industrial hazard applicable to one or a combination of the generic hazards.

An independent study of court decisions where the use, failure, or lack of use of interlocks was the determining factor in deciding a case should be conducted. The study may reflect a consensus of what are acceptable criteria for deciding when to use interlocks, and provide guidance to employers. The study results may be one of the many considerations that should be used to select automatic versus manual operations.

REFERENCES

1. Occupational Health and Safety Regulations, 1976; Alberta; Workers' Health, Safety and Compensation, Occupational Health and Safety Division, Research and Education Branch, Alberta, Canada, 1976, 256 pp.

2. Accident Prevention Specification, Draft "Power-Driven Equipment" (German Translation); Status; December 1978 Incomplete Citation

3. Safeguarding of Machinery; British Standards Institution, London, England, BS 5304, 1975, 4 pp.

APPENDIX

NATIONAL, STATE AND INTERNATIONAL INTERLOCK STANDARDS

APPENDIX

There are no known industry-wide regulations or standards for the application of interlocks on machines, plants, or processes. Requirements do exist for the application of interlocks on specific machines or within specific industries; however, generally only the function of the interlock is stated without providing criteria for selecting acceptable interlocking devices. A review of national, state, and international standards for interlock requirements and criteria is presented in the following paragraphs.

NATIONAL STANDARDS

The existing national standards (OSHA 29 CFR 1910 and 1926) on interlocks are written for particular industries or specific equipment and only for very specific functions. The types of equipment for which OSHA requires at least one interlock function are powered lift platforms or manlifts; woodworking and sawmill machinery; power presses; welding, cutting, or brazing equipment; paper manufacturing equipment; textile manufacturing machinery; bakery equipment; and certain types of material handling equipment. While many of the OSHA standards require interlocks which help provide protection from major hazards, they do not provide uniform or consistent requirements across industries. These sporadic requirements do not encourage comprehensive hazard assessment within a facility and implementation of consistent hazard controls.

Existing OSHA interlock standards are listed in Table 3 by number. Standards are presented and the industry or machinery to which each standard applies, together with the interlock function required. Additionally Table 3 shows the generic hazard or hazards which the interlock function would help to control.

STATE STANDARDS

The existing state standards (states with approved OSHA plans) on interlocks are essentially identical to the National General Industry and Construction Standards. The states have either adopted the national standards by reference, reprinted the national standards verbatim, or reprinted the national standards with some rearrangement and changes in section numbers to cover only the specific industries applicable to that state.

INTERNATIONAL STANDARDS

The Alberta, Canada, regulations [1] cover interlock provisions for several different industries. For example, in the materials handling industry, positive steps or limiting devices are required to prevent machinery and equipment from exceeding safe limits. Hoisting equipment and laundry equipment must be provided with automatic devices which either prevent the equipment from exceeding safe limits or prevent normal startup or shutdown operations except under the proper conditions. Automatic devices are provided to prevent derrick drilling rigs and rig mud pumps from exceeding safe limits. These devices perform such functions as limiting the travel of the lifting blocks and preventing overpressurization of the pump and piping systems. The regulations governing these devices cover only specific industries and therefore have limited effectiveness.

The German specification [2] states that any power-driven equipment with hazardous movements must have its own control system that is capable of actuating startup and shutdown to control the beginning and ending of hazardous movements. The use of limit switches as control elements is one method of automatically controlling hazardous movements. Other interlocks may be used as protective devices on an optional basis.

The British Code of Practice for Safeguarding of Machinery [3] parallels the recommended guidelines. The British code identifies and describes methods of safeguarding dangerous parts of machinery and indicates the criteria to be observed in the design, construction, and application of such safeguards. Interlocking guards are recommended for energy shutoff to allow the worker to safely accomplish his task and to prevent startup operations except under the proper conditions. A control guard is recommended to shut off energy whenever a person attempts to pass through a cover, hatch, closure, or movable guard. Fail-safe safety catches are recommended for stopping any moving machinery part that may endanger personnel by exceeding safe parameters. The code of practice views machinery safeguards as prime features to be incorporated at the design stage and not as afterthoughts.

TABLE 3

EXISTING OSHA INTERLOCK REGULATIONS

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.66(c)(22)(xii)	Powered Platforms for Exterior Building Maintenance	Provide a device to cut off the electric power to the hoist motors if the load exceeds 125 percent of the normal tension.	2
1910.66(c)(22)(xiii)	Powered Platforms for Exterior Building Maintenance	Provide an automatic device that will cut off the electric power to the motor and apply the brakes if any hoisting rope becomes slack.	2
1910.66(c)(22)(xiv)	Powered Platforms for Exterior Building Maintenance	Provide upper and lower directional limit devices that prevent travel of the platform beyond the normal upper and lower limits.	2
1910.66(c)(22)(xv)	Powered Platforms for Exterior Building Maintenance	Provide a directional limit device that prevents further motion in the appropriate direction if the normal limit of travel has been reached.	2

GENERIC HAZARD TYPE		
	1	ENERGY SUPPLY INTERRUPTED REPEATEDLY
	2	ENERGY IS NOT MAINTAINED WITHIN SAFE PARAMETERS
	3	PERSONS APPROACH HAZARDOUS ENERGY OR MATERIAL THROUGH CLOSURES
	4	ACTIONS ARE NOT PERFORMED IN PROPER SEQUENCE

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.66(c)(22)(xvi)	Powered Platforms for Exterior Building Maintenance	Provide a device to disconnect the electric power from the hoist and apply the brakes in the event of failure of the driving mechanism.	2
1910.66(c)(22)(xvii)(a)	Powered Platforms for Exterior Building Maintenance	Provide final terminal stopping devices as a secondary means of preventing overtraveling at the terminals.	2
1910.66(c)(22)(xvii)(c)	Powered Platforms for Exterior Building Maintenance	The final terminal stopping device shall disconnect the electric power from the hoist and apply both brakes.	2
1910.68(b)(7)(ii)	Manlifts	Use a floating type safety cone guard on underside of floor openings to actuate a limit switch to stop the lift.	3
1910.68(c)(5)(i)	Manlifts	Provide two separate automatic stop devices to cut off the power and apply the brake when a loaded step passes the upper terminal landing.	2 & 4
1910.212(a)(4)	General Requirements for all Machines	Revolving drums, barrels and containers shall have a guard enclosure interlocked with the drive mechanism so it cannot revolve unless the enclosure is in place.	3 & 4
1910.213(b)(3)	Woodworking Machinery	Provide a means to prevent machines from automatically restarting upon restoration of power after a power failure.	4

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.213(q)(7)	Woodworking Machinery	Provide power-driven guillotine veneer cutters with an emergency device which will prevent the machine from operating if the brake fails.	2
1910.217(c)(2)(iv)	Mechanical Power Presses	An interlocked barrier guard shall be attached to the frame or bolster so that the clutch cannot be activated unless the guard is in position.	2 & 4
1910.217(c)(2)(v)	Mechanical Power Presses	An interlocked barrier guard shall prevent opening of the interlocked section prior to die closure or prior to the cessation of slide motion.	1 & 4
1910.217(c)(3)(i)(a)	Mechanical Power Presses	A point of operation device shall prevent and/or stop normal stroking if the operator's hands are placed in the point of operation.	1 & 4
1910.217(c)(3)(i)(e)	Mechanical Power Presses	A point of operation device shall be provided which requires application of both of the operator's hands to the buttons to activate the machine.	1 & 4
1910.217(c)(3)(iii)	Mechanical Power Presses	A presence sensing point of operation device shall be interlocked into the control circuit to prevent or stop the motion if a part of the operator's body is in the sensing field during the down stroke.	1

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.217(c)(3)(iii)(c)	Mechanical Power Presses	The interlocked device shall be constructed to be fail-safe and the failure shall be indicated by the system. Initiation of a successive stroke is prevented until the failure is corrected.	1 & 4
1910.252(c)(2)(ii)	Welding, Cutting and Brazing	All doors on capacitor welders shall be provided with interlocks in the control circuit to interrupt power and short circuit all capacitors if the door is opened.	3
1910.252(c)(2)(iii)	Welding, Cutting and Brazing	All doors and access panels of all resistance welders and control panels shall be kept locked and interlocked to prevent access to live portions of the equipment.	3
1910.252(c)(2)(iv)	Welding, Cutting and Brazing	All press welding machine operations shall be guarded by an electric eye safety circuit or by two-hand controls.	1
1910.261(k)(1)	Pulp, Paper and Paperboard Mills	Paper machines shall be equipped with devices that are interlocked with adequate braking action to stop the machine.	2 & 4
1910.261(k)(26)(i)	Pulp, Paper and Paperboard Mills	The nipping points of all drum winders and rewinders shall be guarded by barrier guards interlocked with the drive mechanism.	2

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.261(k)(26)(ii)	Pulp, Paper and Paperboard Mills	On drum winders and rewinders, a zero speed switch should be installed to prevent the guard from being raised while the roll is turning.	3
1910.261(l)(9)(i)	Pulp, Paper and Paperboard Mills	Finishing roon rewinders shall have barrier guards that are interlocked with the drive mechanism to prevent operating above jog speed without the guard in place.	3
1910.262(b)(15)	Textiles	An interlock is a device that operates to prevent the operation of machine while the cover or door of the machine is open or unlocked, and which will also hold the cover or door closed and locked while the machine is in motion. (Definition)	3
1910.262(c)(1)	Textiles	Provisions shall be made to prevent machines from automatically restarting upon restoration of power after power failures.	4
1910.262(d)(1)	Textiles	Covers on openers and pickers shall be provided with an interlock which will prevent the cover from being raised while the machine is in motion and prevent the operation of the machine while the cover is open.	3

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.262(i)(1)	Textiles	Gates on warpers shall be so interlocked that the machine cannot be operated until the gate is in the closed position except for the purpose of inching or jogging.	3
1910.262(j)	Textiles	Gear housing covers on all installations of drawing frames, slubbers, roving frames, cotton combers, ring spinning frames, and twisters shall be equipped with interlocks.	3
1910.262(m)	Textiles	On sliver and ribbon lappers, an interlocking cover guard shall be installed over the large calender drums and the lap spool.	3
1910.262(y)(1)(ii)	Textiles	Each extractor shall be equipped with an interlocking device that will prevent the cover from being opened while the basket is in motion, and also prevent the power operation of the basket while the cover is open.	3

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.262(cc)(1)	Textiles	Each drying tumbler, double cylinder shaker or clothes tumbler, and washing machine shall be equipped with an interlock device which will prevent the power operation of the inside cylinder when the outer door on the case or shell is open, and which will also prevent the outer door on the case or shell from being opened without shutting off the power.	3
1910.263(d)(1)(i)(d)	Bakery Equipment	Control circuits for magnetic controllers shall be so arranged that the opening of any one of several limit switches, which may be on an individual unit, will serve to deenergize all of the motors of that unit.	4
1910.263(d)(6)(vi)	Bakery Equipment	The main entrance cover of large storage bins shall be provided with an electric interlock for motors operating both feed and unloading screws, so that these motors cannot operate while the cover is open.	3
1910.263(e)(1)(v)	Bakery Equipment	All mixers with power and manual dumping arrangements shall be equipped with safety devices which shall (a) engage both hands of the operator, (b) prevent the agitator from being started while the bowl is more than one-fifth open.	1

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.263(e)(1)(viii)	Bakery Equipment	On mixers, only minor openings in the cover representing less than 1 1/2 square feet in area, shall be capable of being opened while the mixer is in operation.	3
1910.263(f)(3)	Bakery Equipment	The rear cover of dividers shall be provided with a limit switch in order that the machine cannot operate when this cover is open.	3
1910.263(h)(2)	Bakery Equipment	Provide an emergency stop bar on dough brakes to positively open a circuit that will deenergize the drive motor and apply a brake if the operator gets his hand caught in the rolls.	2
1910.263(i)(11)(i)	Bakery Equipment	On emulsifiers, the top covers should be interlocked so that power will be shut off whenever the cover is opened.	3
1910.263(j)(1)(iii)	Bakery Equipment	On reciprocating-blade slicers, provide an interlocking arrangement on the cover over the knife head so that the machine cannot operate unless the cover is in place.	3
1910.263(j)(1)(iv)	Bakery Equipment	On slicers with endless band knives, doors, panels and other points of access to the blades shall be mechanically or electrically interlocked so that the motor will be de-energized if all accesses are not closed.	3

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.263(j)(1)(vii)(c)	Bakery Equipment	Controls for slicing machine conveyors and wrapping machines shall be arranged so an operator can control both machines from one location.	4
1910.263(k)(1)(i)	Bakery Equipment	On meal, peanut and fig grinders, provide an electric interlock so that the machine cannot be put in operation when the hopper is removed.	4
1910.263(k)(1)(ii)	Bakery Equipment	On meal, peanut and fig grinders, hoppers shall be provided with hinged covers that are electrically interlocked to prevent operation with the cover open.	3
1910.263(k)(5)	Bakery Equipment	Reversible dough brakes shall be provided with a guard interlocked to stop the machine or reverse the direction of the rolls if the guard is moved by contact with the operator.	1
1910.263(l)(9)(iv)(a)	Bakery Equipment	On ovens, in case of current failure, both the electric source to the ignition device and the fuel supply shall be turned off simultaneously.	4
1910.263(l)(9)(v)(g)	Bakery Equipment	On ovens where blowers are used for supplying the air for combustion, the safety shutoff valve shall be interlocked so that it will close in case of air failure.	4

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.263(l)(g)(v)(h)	Bakery Equipment	On ovens with burners equipped with combustion safeguards, the safety shutoff valve shall close in case of burner flame failure.	4
1910.263(l)(ii)(i)	Bakery Equipment	Each circulating fan in direct recirculating ovens shall be interconnected with the burner so the fuel is shut off by a safety valve when the fan is not running.	4
1910.263(l)(ii)(ii)	Bakery Equipment	In direct recirculating ovens, the fuel supply to the burners shall be automatically shut off in case of burner flame failure.	4
1910.265(c)(26)(viii)	Sawmills	Entrances to landing areas of stackers and unstackers should be protected by electrically interlocked gates which, when opened, will disconnect the power and set the hoist brakes.	1
1910.265(d)(1)(ii)(b)	Sawmills	On hydraulically operated log handling machines, provide a positive device for preventing the uncontrolled lowering of the load or forks in case of a failure in the hydraulic system.	2

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1910.265(d)(1)(ii)(c)	Sawmills	On powered log handling machines, provide a limit switch to prevent the lift arms from traveling too far in the event the control switch is not released in time.	4
1926.154(e)(1)	Temporary Heating Devices	Flammable liquid-fired heaters shall be equipped with a primary safety control to stop the flow of fuel in the event of flame failure.	4
1926.302(b)(3)	Power-operated Hand Tools	All pneumatically driven nailers, staplers, and other similar equipment provided with automatic fastener feed, which operate at more than 100 psi pressure at the tool shall have a safety device on the muzzle to prevent the tool from ejecting fasteners, unless the muzzle is in contact with the work surface.	4
1926.400(h)(2)	Electrical General Requirements	All 120-volt, single-phase, 15- and 20-ampere receptacle outlets on construction sites, which are not part of the permanent wiring of the building or structure and which are in use by employees, shall have approved ground-fault circuit interrupters for personnel protection.	2
1926.550(c)(4)	Cranes and Derricks	Cranes mounted on rail tracks shall be equipped with limit switches limiting the travel of the crane on the track.	2

EXISTING NATIONAL STANDARD	MACHINERY OR INDUSTRY	EXISTING INTERLOCK PROVISIONS FUNCTION	GENERIC HAZARD TYPE
1926.552(c)(8)	Material Hoists, Personnel Hoists, and Elevators	Doors or gates shall be provided with electric contacts which do not allow movement of the hoist when door or gate is open.	4
1926.553(a)(3)(i)	Base-mounted Drum Hoists	A device shall be provided to disconnect all motors from the line upon power failure and not permit any motor to be restarted until the controller handle is brought to the "off" position.	4
1926.555(a)(3)	Conveyors	Emergency stop switches shall be arranged so that the conveyor cannot be started again until the actuating stop switch has been reset to running or "on" position.	4

GENERIC HAZARD TYPE		
	1	ENERGY SUPPLY INTERRUPTED REPEATEDLY
	2	ENERGY IS NOT MAINTAINED WITHIN SAFE PARAMETERS
	3	PERSONS APPROACH HAZARDOUS ENERGY OR MATERIAL THROUGH CLOSURES
	4	ACTIONS ARE NOT PERFORMED IN PROPER SEQUENCE