III. GUIDELINES FOR CONTROLLING HAZARDOUS ENERGY DURING MAINTENANCE AND SERVICING

(The following guidelines for controlling hazardous energy during maintenance and servicing of machinery, processes, or systems are shown graphically in Figure I. References which support the use of each specific guideline may be found, cross-referenced to the text of this section, in Appendix E.)

In order to protect the worker from energy-related hazards during maintenance or servicing of a machine, process or system, method A or B of hazard control must be chosen.

Several factors must be considered in deciding if energy should be eliminated and determining what method of hazard control should be implemented for a particular application. Factors that should be considered include (1) the energy level, (2) the access or proximity to the energy source necessary to accomplish the work, and (3) whether proven methods exist for performing the task safely with hazardous energy present.

A. *CONTROLLING HAZARDOUS ENERGY SOURCES*

1. ***If deenergizing is chosen, a thorough inspection should be performed to identify all potentially hazardous energy sources, including adjacent equipment or energy sources that represent hazards to personnel.***

2. ***When all potentially hazardous sources of energy have been identified, each source must be controlled and the device controlling the energy source must be secured and verified. The following are steps to accomplish the control of hazardous energy sources:***

   a. ***All energy sources identified as hazardous shall be isolated, blocked, or dissipated at points of control that cannot, with reasonable effort, be overridden or by-passed.*** These isolated points of control must be secured in accordance with paragraph A.2.c. of these guidelines to ensure complete blockage for the duration of the maintenance operation to preclude any possibility of reactivating the flow of energy.

   Energy is considered adequately isolated, blocked, or dissipated when an unplanned event would not reactivate the flow of energy. Adequate isolation can be achieved by many methods or combinations of methods so long as the controls are not likely to be accidentally turned on. Appendix A identifies several examples of methods of effectively isolating or blocking energy.

   b. ***Stored or residual energy that constitutes a personnel hazard shall be isolated, blocked, or dissipated.***

   Another necessary step is to block or dissipate any hazardous residual energy once the decision is made to deenergize. Residual energy is not always as obvious a hazard as the incoming energy supplies. For this reason, special effort must be made to identify any stored energy that could result in personnel hazards. For example, if it is necessary for a worker to climb or move about mechanical linkages, the potential energy due to the worker's weight may be sufficient to cause dangerous movements of the linkages. If this hazard is present, a mechanical block or pin can usually be used to block out the energy and potentially dangerous movement.

Forms of potential energy which may be stored in sufficient quantities to represent hazards include:

- o Hydraulic or pneumatic pressure
- o Pressure below atmospheric (as in vacuum systems)
- o Compressed or extended springs
- o Potential energy due to gravity
- o Stored mechanical energy (as in flywheels)
- o Static electricity
- o Stored electrical energy (as in batteries)
- o Stored electrical energy (as in capacitors)
- o Thermal energy due to residual heat or low temperature
- o Residual chemicals in pipe which may cause thermal or pressure buildups.

If stored hazardous energy is present in any form, care must be taken to ensure that the residual energy is reduced to a nonhazardous level. Extra care must be exercised to avoid reaccumulation of energy to hazardous levels. Special measures to continuously bleed off energy should be used if energy buildup is possible. In addition, monitoring to be sure energy has not accumulated to dangerous levels may be necessary.

c. The point(s) of control shall be secured so that unauthorized persons are prevented from reenergizing the machine, process, or system.

A means of security must be implemented to ensure that the equipment being maintained or serviced is not somehow reenergized. The guidelines allow a choice of three methods. The selection should be based on the particular circumstances and characteristics of each respective facility or application. A farm employee working with potentially hazardous powered equipment in a remote field would not be expected to use a padlock for security. A padlock (or equivalent), however, would be a logical selection for a switch or valve accessible to a large number of people. The use of tags, when only trained personnel have access to the point(s) of control is an accepted industry practice. Any one of the following methods will prevent unwanted reenergization of equipment.

(1) ***Secure by physical means ("Lockout") such that reenergizing the system requires the use of special equipment routinely available only to the person who applied the control. A warning containing appropriate information shall be displayed at the point(s) of control.*** The method of securing the points of control by physical means that prevent unauthorized persons from reenergizing the machine, process, or system is widely used. The most common device used for security is the padlock. Often each worker is provided with his own padlock and the only key.

(2) ***Post a warning ("Tagout") at the point(s) of control providing information as to why the energy sources have been isolated, blocked, or dissipated, the date, the person(s) responsible for the control measure, and the person(s) responsible for the work to be accomplished. In addition, access to the control point(s) must be limited to persons who are trained to understand and observe the posted warning.*** Access may be limited by physical location (such as elevation) or by procedural means such as color-coded badges. When this method of security is used, each new employee should receive training to observe the guidelines before having access to the point(s) used for controlling energy. The training should include the purpose of the warning, the format and color of the warning, and should stress the responsibility of each person for his co-workers' safety. Retraining should be given as necessary so that the importance of observing the posted warning is not forgotten.

(3) ***Post qualified personnel, with the specific responsibility of protecting against unauthorized actuation, at the point(s) of control throughout the maintenance activity. This applies mainly to short duration work in the immediate vicinity of the control point(s).***

d. ***Before starting maintenance, verify that steps a. through c. have been effective in isolating, blocking or dissipating hazardous energy, and securing the point(s) of control.***

In applying any method or technique to isolate, block, or dissipate energy from specified areas, devices, machines, systems, or processes, it should be verified that deenergization has been effected prior to the start of maintenance. Verification should be accomplished each time energy is eliminated and reapplied, regardless of the time interval between removal and reapplication. Proven methods should be used to effectively demonstrate that all hazardous energy has been isolated, blocked, or dissipated in the areas where personnel will perform the required tasks. If there is the possibility of reaccumulation of energy to hazardous levels, verification should be continued until the maintenance activity is completed.

If sensing devices are used for verification, these devices shall be used according to established procedures that have been determined to safely and consistently indicate the presence of energy. These sensing devices should be primary; i.e., they should not depend upon secondary or derived indications which could induce greater probability

used according to established procedures that have been determined to

of error. The devices should be regularly and frequently inspected and/or calibrated to ensure that they are functional and accurate and to detect any potential device failures.

Good intentions to eliminate energy have failed and injuries have resulted when the wrong sources of energy were controlled. To avoid this possibility, the energy should be verified to be below hazardous levels before proceeding.

e. ***Verify that all personnel are clear of the point(s) of danger before reenergizing the machine, process, or system.***

This action is so obvious that many references fail to identify it; yet it is vitally important that it be included in each procedure.

3. ***For the five steps listed above to comprise a valid technique for controlling hazardous energy sources, the following two preconditions must be met:***

a. ***The procedures to be used to accomplish the above steps shall be documented.***

Procedures for energy control applications should be documented to the detail required to provide a clear understanding of the devices and methods of application and removal, so that the controls are uniformly and safely applied and removed each time. The procedures should clearly assign responsibility for each step of the criteria as well as indicate where isolation, blocking, or dissipation of energy is to be accomplished, how deenergization is to be verified, what method is to be used for security, and how responsibility is to be transferred during shift changes. The procedures need not be unique for a single machine or task; procedures may be used which apply to a group of similar machines or tasks. Depending upon the complexity of the equipment and its application, good procedures may vary from one to many pages. No matter how simple and straightforward the procedures may seem, they should be documented so that all levels of personnel understand company policy, as well as the required safety procedures.

b. ***The personnel who implement the above steps shall be qualified. Each worker must thoroughly understand all documented procedures. Training shall be accomplished as necessary to establish and maintain proficiency, and to encompass procedural or equipment changes which affect energy control during maintenance.***

After the energy control need has been identified, the methods of implementation selected, and the procedures finalized, a training program should be instituted to ensure that the procedures are followed and the purpose and functions are understood. The training should involve elements of management and the workforce concerned with maintenance activities so that the criteria are expeditiously and uniformly applied. The training should ensure that the understanding and skills required for the safe application and removal of energy controls are available as required. Retraining should be scheduled as

that the criteria are expeditiously and uni-

often as necessary to maintain proficiency and to introduce revised devices, practices, and methods.

If energy isolation, blocking, or dissipation are secured according to criterion 2.c.(2), then every person having job related access to the point(s) of control should be trained. This training is in addition to that required for personnel involved in applying energy controls. The training should include the purpose of the warning, the format and color of the warning, and should emphasize the extreme importance for all personnel to obey the warnings in order to protect their co-workers. The personnel who implement the procedures should be trained not only to know how to accomplish the steps required to control energy sources, but also to understand the hazards associated with energy sources. All levels of supervision concerned with maintenance and servicing, with special emphasis on first-line supervision, must be trained in order to ensure that procedures are followed.

B. CONTROLLING HAZARDS WITH ENERGY PRESENT

Controlling maintenance hazards with energy present is the only alternative to deenergizing to perform maintenance tasks safely. For some types of machines or processes, the conditions or combination of conditions that must be evaluated and controlled in energized systems can be much more complex than deenergized systems. The following paragraphs describe guidelines for maintaining "energized" systems.

1. ***Hazardous energy sources, including residual energy sources, shall be identified.***

   Identification of the hazards needs no justification, for a hazard cannot be controlled unless it is identified.

2. ***Documented procedures, which have been determined to control each hazardous energy source, shall be used. Procedures shall assign responsibility and accountability for controlling personnel hazards.***

   Before a worker is exposed to a hazard, the hazard controls must be known to be effective. Determination of hazard control effectiveness can be based on physical demonstration prior to implementation on a day-to-day basis. This can be by similarity to a demonstrably effective hazard control, or by analysis.

3. ***Personnel who perform the maintenance shall be qualified to use the procedures. Qualification to use the procedures may be obtained by education, experience and/or training.*** The personnel who perform the maintenance and servicing activities must be trained to understand the particular hazards, the controls for the hazards, and how to implement the controls effectively.

IV. CONCLUSIONS

This study confirms that the need to control hazardous energy during maintenance activities is recognized by industry, labor, and the Government. This need is manifested by the different approaches implemented by industry to reduce injuries, the evidence submitted to the Occupational Safety and Health Administration at public hearings on the subject of lockouts and tagouts, and results of the literature search in which a great number of articles were found which emphasize the need for some type of control.

The literature review did not produce statistical evidence of the effectiveness of any one specific type of energy control method over another, nor did it identify accident causative factors leading to injuries. No values could be developed which differentiate accidents and injuries occurring during maintenance from aggregate U.S. injury statistics; i.e., data to provide indices on the probability of injury occurrence, the magnitude of the injuries, and the exposure to the hazard (population of workers at risk) that correlate with the identified primary hazard causes.

Industrial accident and injury data available in the U.S. describe the injuries sustained by the workers in greater detail than the causes of the accidents that inflicted the injuries. The hazard causes found in the analyzed accident reports are categorized by fire, explosion, impact, fall, caught in or between, and others. The hazard causes identified by this study are different. Consequently, the published statistics (aggregates of accident/injury reports) cannot be broken down into accident causes identified as specific to maintenance and servicing activities.

The study identified the following hazard causes:

1. Maintenance activities were initiated without attempting to deenergize the equipment or system or control the hazard with energy present.

2. Energy blockage or isolation was attempted, but was inadequate.

3. Residual energy was not dissipated.

4. Energy was accidentally activated.

The worker population at risk could not be defined because employers who implement procedural controls may choose to make the procedures applicable to (1) all personnel; (2) personnel engaged in any one or any combination of activities such as construction, operations, manufacturing, testing, etc.; or (3) maintenance personnel only. Thus, the effectiveness of any one method of control with respect to another cannot be determined. However, the implementation of any method which increases worker awareness of potentially hazardous energy sources is better than no method at all.

Existing Federal and State Government safety regulations (California and Michigan excepted) of energy control during maintenance are inconsistent, fragmented, and only applicable to certain equipment, processes, and industries (e.g., telecommunication and construction). Most of these existing regulations use the concept of "power off" to prevent injuries, and do not provide guidance on how to discern when to apply locks, tags, or a combination of locks and tags. They also do not allow for the performance of maintenance with power on, even under normal, everyday conditions, or when such maintenance cannot be performed with power off.

V. RESEARCH NEEDS

While developing the guidelines, areas were identified in which additional research would prove valuable.

A. STUDY CONTINUATION

The result of this study, "Guidelines for Controlling Hazardous Energy During Maintenance and Servicing," is a consolidation of different approaches already in use. These guidelines increase the latitude of implementation methods available. The greater latitude, in turn, may create problems which have not been anticipated. It is therefore recommended that studies be conducted to:

1. Develop universal procedures for the recommended guidelines
2. Identify problems created by the guidelines, if any
3. Identify effectiveness of different hazard control methods in preventing injuries
4. Identify costs of implementing the guidelines.

B. GUIDELINES FOR OTHER MAINTENANCE HAZARDS

This technical report addresses one of several maintenance activities which require decision criteria. These activities are: selection and use of tools; selection and use of ancillary equipment; selection of access routes to and from the maintenance area; evaluation of the maintenance environment; selection of skilled personnel; and identification and verification of energy sources. The guidelines herein suggest actions that should be taken after the energy sources have been identified. Guidelines which address the selection and use of tools, as well as the selection of personnel, should be developed. Further, guidelines addressing selection of access methods to and from the maintenance area, and evaluation of maintenance environments should be developed.

Materials having toxic, caustic, or asphyxiant properties can present serious hazards to maintenance personnel. Suitable control measures for materials having these dangerous properties do not necessarily match the criteria for control of hazardous energy recommended within this document. In fact, personnel can be harmed by toxic, caustic, or asphyxiant materials with no concurrent release of energy. It is therefore recommended that criteria be developed specifically to protect maintenance personnel from such hazardous materials.

C. POTENTIAL HAZARDS IN NEW TECHNOLOGICAL APPLICATIONS

Currently, U.S. industries utilize many old machines and processes. To compete more effectively in the world marketplace, U.S. industry will have to replace aging machines and processes with new, more efficient equipment including robotic and fully automatic machines. In some cases, the influx of new machines and technology into U.S. industry may mean greater safety for the worker; in other cases, it may pose new or unknown hazards. A research effort is needed to assess the safety of these new technologies and materials.

Some examples of recent advances in manufacturing techniques and materials that could pose unique hazards to workers include: numerical control; robotic machines; laser applications; new materials for tools, workpieces, finishes, lubricants, molds, bonding, and welding; ultrasonic applications; and explosive forming. The research effort should focus on identifying potential hazards and determining corrective action which either reduces hazardous energy levels or changes the worker's proximity to hazardous energy.

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VII. APPENDIX A

EXAMPLES OF ALTERNATE METHODS OF ISOLATING OR BLOCKING ENERGY AND SECURING THE POINT(S) OF CONTROL

APPENDIX A

EXAMPLES OF ALTERNATE METHODS OF ISOLATING OR BLOCKING ENERGY AND SECURING THE POINT(S) OF CONTROL

ENERGY TYPE	METHOD OF ISOLATING OR BLOCKING ENERGY	METHOD OF SECURING THE POINT OF CONTROL	REMARKS
Mechanical Motion Rotation Translation Linear Oscillation	1. Remove segments of operating mechanical linkages such as dismantling push rods, removing belts, and removing flywheels.	(1) Tag the linkages and place them in a locked cabinet away from the machine. or (2) Attach warning tags where the linkages were removed and restrict access to trained personnel. or (3) Post a person to protect against unauthorized reinstallation of the linkages.	
	2. Use blocking devices such as wood or metal blocks.	(1) Chain and lock in point of control or use metal pins driven or welded in place. or (2) Attach warning tags on the blocking devices and restrict access into the area to trained personnel. or (3) Post a person to protect against unauthorized removal of the blocking devices.	

ENERGY TYPE	METHOD OF ISOLATING OR BLOCKING ENERGY	METHOD OF SECURING THE POINT OF CONTROL	REMARKS
Mechanical Motion (continued)			
	3. Remove power or energy from the driving mechanism, such as: a. Disconnect main electrical source. b. Close hydraulic or pneumatic valves, bleed.	(1)a. Padlock in the "off" position. b. Disconnect pneumatic and hydraulic lines and tag. or (2) Attach warning tags at control points and restrict access to trained personnel. or (3) Post a person to protect against unauthorized reconnection of the energy sources.	Check for alternate sources of power. Check for residual pneumatic and hydraulic energy.
Electrical	1. Place the main electrical disconnect switch in the "off" position.	(1) Secure by a padlock, a clip and padlock, or a bar and padlock. or (2) Attach a warning tag and restrict access into the area to trained personnel. or (3) Post a person to protect against unauthorized actuation of the switch.	Check for alternate sources of power.

ENERGY TYPE	METHOD OF ISOLATING OR BLOCKING ENERGY	METHOD OF SECURING THE POINT OF CONTROL	REMARKS
Electrical (continued)	2. Remove segments of electrical circuit, such as printed circuit modules.	(1) Tag the module and place in a locked cabinet away from the control center and tag the control center door. or (2) Attach a warning tag at the module location and restrict access to trained personnel. or (3) Have a person remain at the control center to protect from unauthorized installation of a spare or replacement module.	
Thermal (Steam)	1. Close valves and maintain an open bleed.	(1) Chain and padlock valve or use blind flanges or slip blinds. or (2) Attach warning tags to the valves and restrict access to the area to trained personnel. or (3) Station a person at the valve locations to protect against unauthorized or inadvertent opening of valves.	Allow time for residual heat to dissipate.

ENERGY TYPE	METHOD OF ISOLATING OR BLOCKING ENERGY	METHOD OF SECURING THE POINT OF CONTROL	REMARKS
Potential Pressure	1. Close valves and maintain open vent to relieve.	(1) Secure, block, blind flange, slip blind, or valve with locking device. or (2) Attach warning tags and restrict access to trained personnel. or (3) Station a person at the valves to protect against unauthorized actuation.	
Potential Gravity	2. Block in place by using metal or wood blocks under the mechanism or pin the linkages in a position where gravity will not cause the mechanism to inadvertently fall.	(1) Secure, block, or pin with a locking device. or (2) Attach warning tags to blocks, linkages, and pins and restrict access to trained personnel. or (3) Station a person at the mechanism to prevent unauthorized removal of blocks and pins and reinstallation of linkages.	Energy could be dissipated by lowering to a point where gravity could no longer cause inadvertent falling.

ENERGY TYPE	METHOD OF ISOLATING OR BLOCKING ENERGY	METHOD OF SECURING THE POINT OF CONTROL	REMARKS
Potential (continued) Springs	3. Block in a safe position by pinning or clamping the device eliminating the potential of unrestricted and undesired travel.	(1) Secure pin or clamp in place with a locking device. or (2) Attach warning tags to the pins and clamps and restrict release or access to trained personnel. or (3) Station a person at the control point to protect against pin or clamp removal and unauthorized activation of the spring mechanisms.	Spring energy could be dissipated by release or dismantling of the mechanism.