

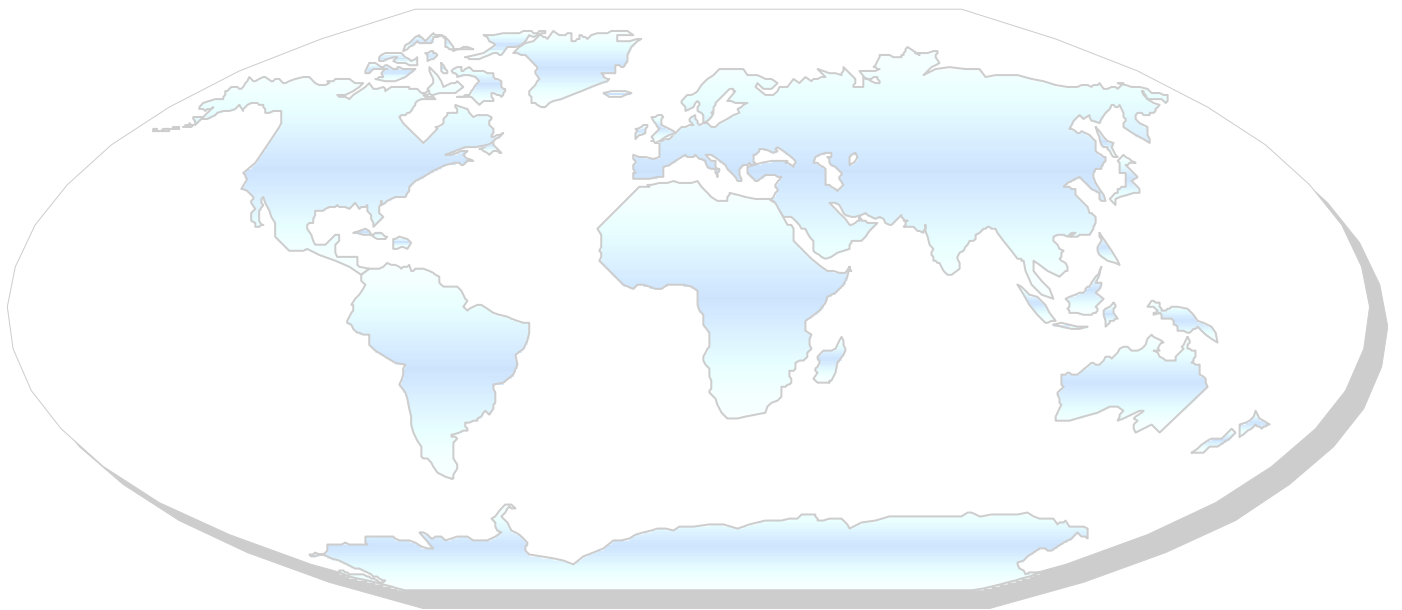
**DELPHI**

---

# **Design-In Health and Safety Guarding**

**Thermal**

**April 2010**



# Table of Contents

8.	Safeguarding	2
8.1.	Fundamentals for Safeguarding	2
8.2.	Guard Design	2
8.2.1.	Point-of-Operation/Machine Guarding	2
8.2.2.	Thermal Hazard Guarding	2
8.2.3.	Perimeter Guarding	3
8.3.	Safeguarding Devices	3
8.3.1.	Safety Interlocks	4
8.3.2.	Presence Sensing Devices (PSD)	4
8.3.3.	Two-Hand Control Devices	5
8.3.4.	Single-Hand Control Devices	5
8.4.	Operator Interface Devices	5
8.5.	Emergency Stop Function and Devices	6
8.6.	Awareness Barriers	7
8.7.	Awareness Devices/Signals	7
Annex A: Safe Distance Formulas		8
Annex B: Test Sequence Design Requirements		
Annex D: Hierarchy of Controls – Solution Illustrations		
Annex E: Safety Circuit Performance Requirements		
Annex F: References		
Annex G: Definitions		

## 1. Safeguarding

This section provides design-in fundamentals and general principles for safeguarding of manufacturing equipment.

### 1.1. Fundamentals for Safeguarding

**Safeguarding** refers to the protection of personnel from hazards by using guards, safeguarding or awareness devices, safeguarding methods, or Safe Operating Procedures (SOP's).

**Guard** refers to a barrier that prevents exposure to an identified hazard.

**Safeguarding Device** refers to a device that detects or prevents inadvertent access to a hazard.

**Awareness Device** refers to a barrier, signal (i.e. audio or visual), or sign that warns individuals of an impending, approaching, or present hazard.

**Safeguarding Methods** refers to the protection of individuals from hazards by the physical arrangement of the machine to ensure that a person cannot reach the hazard.

**Safe Operating Procedure (SOP)** refers to formal written instructions developed for the user to describe how a task is to be performed safely.

The safeguarding methods listed in this section should only be utilized after efforts to eliminate the hazards have been considered. The guarding solution options will be determined by the results of the risk assessment. See *Hierarchy of Health and Safety Controls* and *Risk Assessment* for further information.

For equipment guarding and cycle initiation, refer to the *Delphi Guarding/Cycle Initiate Methodology*.

### 1.2. Guard Design

#### 1.2.1. Point-of-Operation/Machine Guarding

This section covers point-of-operation/machine guarding of hazards on all machinery and equipment (including transport/handling).

Barrier/pinch point guards shall be designed to:

1. Prevent reaching over, under, around, or through a barrier into the point of hazardous motion
2. When frequent access is required, the guard shall be interlocked when determined by risk assessment and/or other applicable standards
3. When infrequent access is required, a tool shall be required to install/remove the guard

**Note:** As a good design practice, guards should not result in a hindrance to production. If a guard were to be considered a hindrance, the result may be that the guard is wrongly removed or defeated, placing employees at serious risk of injury. One solution is to “design-in” a window where a guard would otherwise obstruct visual access.

4. Contain hazardous process byproducts (e.g., coolant spray, sparks, and chips). See *Industrial Hygiene SharePoint site for further information*.

**Note:** Presence Sensing Devices (e.g. light curtains) are acceptable as Point of Operation Guarding, provided they are implemented per the circuit performance requirements determined by the risk assessment. If the PSD is to also be used as a cycle initiation device, see *Application Guideline for the Presence Sensing Device Initiation (PSDI) using Light Curtains* white paper for further guidance.

#### 1.2.2. Thermal Hazard Guarding

Thermal hazard guards should be designed to:

1. Keep personnel from contacting components in their normal work areas, which could cause burns
2. Prevent personnel from contacting surfaces that could cause a reaction, which could result in injury

### 1.2.3. Perimeter Guarding

The purpose of perimeter guarding is to prevent unauthorized personnel from entering into the work area and to contain any material or equipment that has the potential to be ejected from or dropped outside the work area. There are two types of perimeter guarding allowed – hard guarding and Presence Sensing Device (PSD).

#### 1.2.3.1. Perimeter Hard Guarding

All work areas where a hazard exists—due to the ejection of material or equipment—shall have hard mechanical barrier guarding.

Hard guarding shall be designed to:

1. Prevent inadvertent access
2. Contain parts and/or equipment that may be ejected
3. Allow cleaning of the floor at the perimeter
4. Be of a height suitable to contain the hazard
5. Allow visibility into the equipment or work areas
6. Require a tool to install/remove the guard

When frequent access is required, movable gates shall be provided. These gates may be required to be interlocked when determined by the risk assessment.

All access gates should be located as to prevent direct entry into the path of hazardous motions. Gates should not swing inward.

#### 1.2.3.2. Perimeter PSD Guarding

For work areas posing no hazard from material or equipment ejection, perimeter-guarding methods that use presence-sensing devices are acceptable (refer to section *Presence Sensing Devices* for more information on device requirements).

#### 1.2.3.3. When a PSD is used for Perimeter Guarding applications, the following requirements shall be met:

1. A keyless reset switch for the safety circuit shall be located near each PSD that is used as a perimeter guard. This requirement does not apply to a reset switch (provided by the device manufacturer) that requires a tool in order to open a cover to gain access.  
**Note:** Additional reset switches are allowed as long as they meet requirements 3, 4, and 5 below.
2. The reset switch shall be positioned so that it cannot be reached from within the guarded area without interrupting the PSD.
3. The entire area that is protected by the PSD should be visible from the reset switch location. If the entire protected area is not visible from the reset location, multiple hardwired-reset devices shall be installed. These reset locations shall be positioned collectively to allow the entire protected area to be viewed. The number of reset locations should be minimized, and they shall be reset within a maximum specified time. The reset devices shall be properly connected to the safety circuit. When a specific reset sequence is required, the control circuitry should force this reset sequence and the control system shall have the ability to prompt for it.
4. When the device is powered-up, the cell's perimeter guard safety circuit shall be in a faulted (e.g., tripped) condition and shall require a local reset before the resumption of automatic operation.
5. Resetting the photoelectric device shall not—by itself—restart the machinery or equipment.

### 1.3. Safeguarding Devices

The following fundamentals shall be utilized when designing safeguarding devices into systems. These devices shall be used at a position that meets the safe distance formulas (located in [Annex A](#)).

### 1.3.1. Safety Interlocks

Safety interlocks shall be designed, constructed, and installed using the following guidelines:

1. Safety interlocks are to be designed into guard and gate approaches as determined by risk assessment.

**Note:** Gate interlocks for specific applications are covered in more detail in Section *Robotic Cell* and Section *Servo Controlled Equipment and Machining Cells*.

2. Safety interlock systems for guards and gates shall:

- a. Be a safety rated device and implemented as specified by the risk assessment circuit performance.

- b. Be tested or cycled per plant procedures and manufacturer recommendations.

**Note:** This requirement shall be included in plant preventive maintenance.

- c. Prevent the use of unauthorized and/or unintentional bypass devices.

**Note:** A manual bypass may be required based on the defined task (e.g., solenoid override for cell access in a power-off condition).

- d. Be hardware-based.

**Note:** The hardware shall take priority over any software signals used to control the manufacturing process. In addition to this requirement, software monitoring of the safety interlock is allowed.

- e. Be used where hinged or sliding doors provide access to hazards as determined by risk assessment, and any applicable standards.

**Note:** Where interlocks are utilized for other than safety reasons, the requirements of this section do not apply.

### 1.3.2. Presence Sensing Devices (PSD)

1. A PSD (e.g., light curtain or safety mat) shall meet the requirements as specified by the risk assessment circuit performance. The PSD shall be capable of being incorporated into the machinery and equipment control system and shall initiate a stop or prevent hazardous operation of the machine when any object is detected in the sensing field. The PSD may be muted or bypassed at times when no hazards exist for the operator.

**Note:** Where a PSD reset switch is required to reset a fault or during power up, the reset switch shall be keyless.

2. The PSD shall be installed to prevent personnel from going over, under, or around to get into the hazardous area or be trapped. The supports shall be substantial enough to resist deflection and shall be mounted to avoid a pinch point where material or a material carrier enters or exits a cell.

3. Various PSDs employ different sensing and adjustment techniques. The point at which a device responds to an intrusion may vary. The devices shall be located and/or adjusted per the safe distance formula, ensuring that any hazard is controlled upon intrusion ([See Annex A, Safe Distance Formulas](#)). Multiple devices may be required to accomplish a “protected area”.

- a. The effective sensing field shall be of adequate height, width, and depth to guard the area.

- b. The response time of the PSD used in the safe distance formula shall be the maximum response time—taking into account the impact of object sensitivity adjustments and environmental changes.

- c. The PSD resolution shall be appropriate to the design application. (The point-of-operation guarding should be hand-safe. Perimeter guarding should be body-safe).

- d. Indicator lamps shall be provided on all PSDs in order to indicate that the device is functioning.

- e. For devices used for operator protection, when the PSD is muted and the operator may be exposed to a hazard, an indicator shall be provided to alert the operator when the device is

muted. PSD outputs may be bypassed if no hazard is present or another safeguarding device is protecting the operator from the hazard. In this case, no indicator is required.

- f. The PSD shall not be affected by ambient conditions (e.g., smoke, dust, haze, or vibration) or light sources decay such that an increase in response time or object sensitivity occurs.
  - g. The PSD shall at no time fail to respond to the presence of any person's body parts.
  - h. If there is a loss of power to the PSD, the device shall initiate an immediate stop command to the machinery and equipment control system.
  - i. The PSD shall be capable of being incorporated into the machinery and equipment control system in order to stop or inhibit hazardous motion when the device detects an object in its field.
  - j. A plastic safety chain and signs may be hung outside the light curtain to identify the light curtain perimeter.
4. The PSD shall be appropriately rated to an applicable safety standard, per the *Delphi Specification for the Application of Safety Circuits, DA-2001*.

### 1.3.3. Two-Hand Control Devices

When using two-hand control devices in safeguarding design, the device shall:

1. Be protected against unintentional operation
2. Be arranged by design and either construction or separation to require the concurrent use of both hands to initiate the machine cycle
3. Possess an anti-repeat feature, when used in single-cycle mode
4. Require the release of both hands and the reactivation of both control devices before a machine cycle can be reinitiated (anti-tie down)
5. Be located and anchored at least the minimum safe distance from the nearest point-of-operation hazard in order to prevent the operator from reaching the hazard zone either with a hand or another body part (See [Annex A, Safe Distance Formulas](#)).
6. Stop normal cycle action or retract hazardous motion if one or both of the operator's hands are removed at any point in the cycle where a reach-in hazard exists

### 1.3.4. Single-Hand Control Devices

When using single-hand operator controls as the sole safeguarding device, the device shall:

1. Be protected against unintentional operation
2. Possess an anti-repeat feature, when used in single-cycle mode
3. Be fixed in place at a distance such that no part of the person's body can reach the hazard when the button is released, based upon the safe distance formula (See [Annex A, Safe Distance Formulas](#)).

**Note:** These requirements do not apply when the single-hand operator control, is used as a cycle initiation, in conjunction with another safeguarding device (e.g. a whisker switch on a machine which is protected by a light curtain)

### 1.4. Operator Interface Devices

The following parameters shall be adhered to in the design, construction, and installation of the operator interface control panels.

These devices shall:

1. Be readily identifiable and appropriately marked or labeled as to their function
2. Be located in proximity to the operator and properly placed in order to keep the operator from reaching past moving parts that are likely to cause injury
3. Be protected from unintentional operation by normal movement of the operator or flow of work pieces, material, or tooling through the manufacturing process

4. Not initiate any motion unrelated to its designation

Stopping devices shall be clearly marked and require only momentary actuation to stop machine motion.

### 1.5. **Emergency Stop Function and Devices**

Each machine shall be provided with one or more emergency stop devices.

Emergency stops shall:

- Override all other functions and modes of operation
- Remove power to the machine actuators as quickly as possible without creating other hazards
- Be reset at the point of interrupt
- Not initiate restart when reset

The emergency stop function, if required for personnel safety as determined by risk assessment, shall be implemented consistent with the safeguard circuit performance and be operational at all times and in all operating modes.

Resetting an emergency stop function shall be a deliberate action.

The activation of the emergency stop function shall not require a decision by the operator regarding the effects of the emergency stop signal.

A manually operated emergency stop device shall:

- Be provided at each operator station
- Be hardwired into the emergency stop circuit
- Function independently from the system controller

Emergency stop device design shall consider the following:

1. Clear identification
2. Easy and non-hazardous access
3. Ease of operation
4. Red buttons that have a yellow background

**Note:** The buttons shall be mushroom-shaped, not shrouded, and larger than other stop controls.

5. Maintained contact-type buttons that require deliberate action in order to reset
6. Push bars or similar devices
7. Not be used for lockout
8. Cables or ropes

**Note:** Cables should be as tight as possible.

The following requirements apply:

- a. The cables or ropes shall be clearly marked to ensure visibility.
- b. In the event of rope or cable breakage, loss of tension or disengagement, the E-stop command shall be initiated.
- c. The points of reset should be located, where possible, such that the entire length of the cable or rope is visible from that location.
- d. The E-stop shall be activated from any part of the cable. (The application may require switches at both ends of the cable.)

Consideration should be given to the following:

- a. The amount of deflection required to generate the E-stop command and the maximum deflection possible

- b. The minimum clearance between the cable(s) or rope(s) and the nearest component
- c. The force required to activate the E-stop device

#### **1.6. Awareness Barriers**

This barrier method of protection is a lower order of controls (warning). See *Hierarchy of Health and Safety Controls*.

Awareness barriers (e.g., guardrails and chains on posts) shall:

1. Make personnel aware that they are entering or reaching into a hazardous area
2. Provide a point of physical contact before entering the hazardous area
3. Create no pinch points between themselves and other stationary or moving parts of machinery or tooling

#### **1.7. Awareness Devices/Signals**

Awareness devices or signals shall be designed, constructed, and located to provide a recognized signal—audible, visual, or a combination—of an approaching or present hazard.

Consideration shall be given to the following:

1. Lamp failure
2. Color blindness
3. Hearing ability
4. Separation from paging systems
5. Sufficient number of lights for large areas
6. Distinctive and intense enough sound to rise above ambient noise level
7. Annoyance level—as it relates to the likelihood of disconnection



## Annex A: Safe Distance Formulas

- A1. General formula:** The following general safety distance formula should be used to calculate the minimum safe distance to mount the safety device from the hazardous motions. Note that adaptations of this formula for single-device initiation, safety mats and light curtains are listed separately. This is the formula suggested in ANSI B11.19.

$$D_S = K \times (T_S + T_C + T_r + T_{bm})$$

$D_S$  = Minimum safety distance between the device and the nearest point of operation hazard in inches.

$K$  = Hand speed constant of 63 inches per second

$T_S$  = Stopping time of the equipment at the final control element (seconds).

$T_C$  = Response time of the control system (seconds).

$T_r$  = Response time of the safeguarding device (seconds). This response time is available from the manufacturer of the device.

$T_{bm}$  = Additional time required in press applications for the brake monitor to compensate for variations in normal stopping time. Refer to ANSI B11.1 for information on press brake monitors.

**Note:**  $T_S$  and  $T_C$  are usually measured by a stop-time measurement device such as the Gemco model 1999 Semelex SE-3-E Safetimeter test set or equivalent.

- A2. Single-device initiation and safety mats:** The following safety distance formula shall be used to calculate the minimum safe distance to mount the safety device from the hazardous motions. This formula applies to safety mat applications and initiation device in single-device initiation applications where the initiation device is used as the safeguard. Consideration of an individual's stride, reach, and point-of-entry to the hazard should be used in determining the safe distance. This formula is suggested in ANSI B11.19 and EN 999.

$$D_S = K \times (T_S + T_C + T_r + T_{bm}) + C$$

$C = 66$  for single-device initiation applications, and safety mat applications where the individual being protected might be approaching the safety mat in-stride. The typical operator reach is approximately 66 inches.

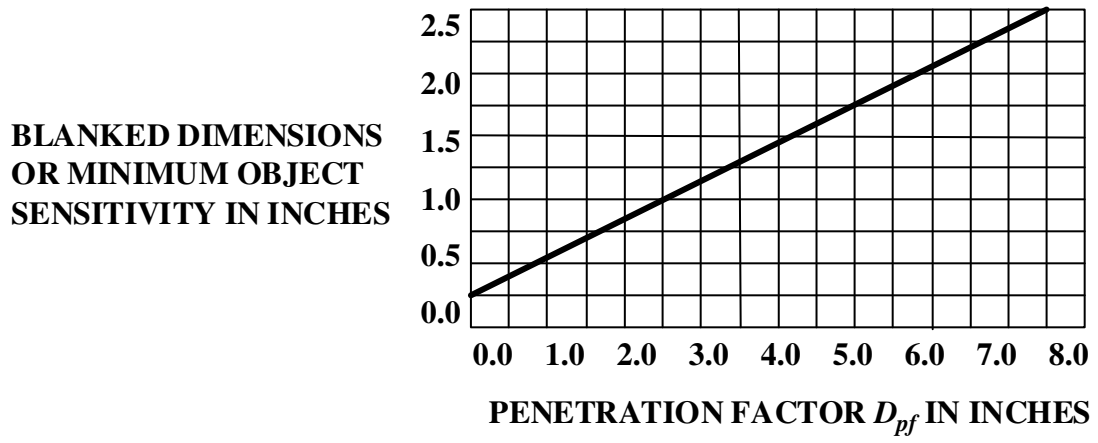
$C = 48$  for safety mat applications where the individual being protected does not approach the safety mat in-stride, i.e., the individual's first step toward the hazard is also directly onto the safety mat.

- A3. Light curtains:** The following safety distance formula shall be used to calculate the minimum safe distance to mount the light curtain from the hazardous motions. This is the formula suggested in ANSI B11.19-1990.

$$D_S = K \times (T_S + T_C + T_r + T_{bm}) + D_{pf}$$

$D_{pf}$  = Added distance due to the penetration factor as shown on [Chart 1](#). The minimum object sensitivity is stated by the light curtain manufacturer. If beam blankouts or floating-window features are used, these figures should be added to the object sensitivity figure before using chart 1.

**CHART 1**



## Annex B: Test Sequence Design Requirements

When a design is not Delphi common, a new test sequence shall be developed at the component level. This new test sequence shall be developed by the responsible controls engineer using the design requirements listed below. After the test sequence is complete, send it to the Divisions Controls Engineering COE representative for review and approval.

### B1. Cell lockout

This test proves that the cell can be locked out.

- Referencing the posted placard, locate the lockout disconnects for each piece of equipment within the cell.
- Follow Union/Delphi lockout procedures in order to lock out the cell and verify that all live energy has been removed.

**Note:** Verify that all energy sources (i.e., electrical, pneumatic, hydraulic) to each piece of equipment are disconnected and no energy is available at the equipment.

### B2. Perimeter guarding

This test determines the following:

- No access into the cell/work area via unauthorized routes can be attained
- Perimeter guarding is located at a safe distance from hazardous motion to prevent pinch points

Visually inspect the cell to:

1. Verify that the perimeter guarding properly prevents access into the cell and that the guarding prevents persons from reaching into a hazardous area
2. Confirm that all access gates are equipped with safety interlocks and do not open into the cell
3. Verify that the perimeter guarding is located at a safe distance from all hazardous motion

**Note:** If there is not sufficient clearance and a pinch point exists, verify that other safeguarding devices (e.g., safety mats, light curtains) prevent access or stop hazardous motion if someone is in the pinch point area. These devices shall be tested as outlined in [Step 9](#) of this annex.

4. Verify that all material entrance points do not create pinch/crush areas or allow undetected access into the cell.

### B3. E-stop, reset and power on

This test ensures that all of the equipment can be stopped with an emergency stop device and the equipment will not re-start until it receives specific instructions to do so. The tests in this step shall be carried out on individual pieces of equipment in the cell before groups of equipment are tested, when applicable. All equipment that passes into, across, or out of the cell/work area shall pass this test before continuing the validation process.

1. Every manual E-stop control device shall be tested to ensure it stops all hazardous motion within its span of control.

**Note:** Conduct this test in the manual, automatic and teach mode for each E-stop device. All of the equipment should be in motion in order to ensure that each E-stop affects every piece of equipment. For robots, the teach pendant E-stop shall function identically to all other E-stops in the cell.

2. Each E-stop device shall be tested to ensure that no motion occurs when it is returned to its normal position (i.e., E-stop push button is pulled out).
3. No motion shall occur when each safety system is reset (e.g., station reset push button is depressed).
4. All safety system resets shall be tested for anti-tie down capability.

**Note:** This test is typically performed by holding the reset button in and trying to start the equipment. No motion should occur when the reset button is held in. Conduct this test in both the manual and automatic mode.

5. All power on and start control devices that initiate hazardous motion shall be tested for anti-tie down capability.

**Note:** With all safety systems reset, operate the power on or start control device and hold in the depressed (on) state. No motion should occur. Conduct this test in both the manual and automatic mode. If the start device cannot be held “in” (e.g., HMI input), skip this step.

#### **B4. Power device duplication and monitoring**

This test proves that the power devices that are used to control the energy (which creates hazardous motion) are also duplicated and monitored. Also, this test shows that a failure of either device will remove hazardous motion and prevent further operation.

Use the risk assessment data summary sheet for CLS as well as the final “as built” control circuit drawings to identify which power devices (e.g., contactors and valves) control hazardous motion. All power devices that are part of the CLS and used to control the energy (which creates hazardous motion) shall be duplicated.

1. To test for duplication, verify that the redundant devices control all hazardous motion in the CLS and that both devices de-energize when a safety device (e.g., E-stop, gate switch) is actuated. If any equipment comes standard with redundant control devices (e.g., a control reliable robot), check one of each model to ensure they meet this requirement.
2. To test the monitoring of power devices, check each power device individually to ensure that when it is in a failed state the safety systems cannot be reset. This verification can be performed by holding each device in the failed state (i.e., hold contactor “in”) while trying to reset the safety systems.
3. To test the monitoring of control devices, check each control device individually within each safety circuit to ensure that when it is in a failed state the safety systems cannot be reset. This verification can be performed by holding each single device in the failed state (e.g., hold relay “in”) while trying to reset the safety systems.
4. To test the functionality of CLS circuit design status indicator, verify that it is not illuminated if any CLS controlled power device is in the failed state.

#### **B5. Perimeter guard interlock**

This test verifies that the safety interlocks on the perimeter guarding stop all hazardous motion in the safeguarded area.

The following actions shall be taken to verify the perimeter guard interlock:

1. Test each perimeter guard interlock device by opening each gate or tripping each perimeter guard light curtain with every piece of equipment in motion.

**Note:** When actuated, each device (e.g., gate switch or light curtain) shall stop and prevent a restart of all hazardous motion in the cell. Conduct this test for each perimeter guard interlock device in the automatic mode.

2. Test that the automatic mode cannot be obtained under any condition while any gate is open or perimeter guard is tripped.
3. Test that no motion occurs when the gate safety interlock system is reset.
4. Review the functionality of the gate to determine under which conditions hazardous motion can continue when the gate is opened. For example, with the selector switches on the gate box in the correct position and either a teach or enabling pendant in use, hazardous motion may be allowed to continue when the gate is open.
  - a. For conditions in which no hazardous motion is allowed in the cell, ensure that all hazardous motion stops when the gate is opened.
  - b. Test each position of every selector switch to ensure it only enables the motion intended.

**Note:** Conduct this test in both the manual and teach mode because when the gate is open, hazardous motion is only permitted in these modes.

- c. Test every safety device (e.g., E-stop buttons, gate switches, and light curtains) that stops hazardous motion in the cell to ensure it causes the hazardous motion power devices to open (i.e., de-energize) and remain open.

#### **B6. Teach pendant verification**

This test verifies that the robot teach pendant(s) or machine pendant cannot be overridden by any other control device. It also ensures that the teach pendant provides exclusive control of the equipment, and it does not unintentionally enable the equipment.

The following actions shall be taken to verify the robot teach pendant:

1. With a gate open, verify that each teach pendant initiates servo motion only when the switches located on the gate box are in a position that permits robot servo motion.
2. Test each teach pendant to ensure that no robot motion is allowed until the hold-to-run switch is engaged.
3. Test each teach pendant to ensure that all robot motion controlled by the teach pendant stops when the hold-to-run switch is released.
4. Test each teach pendant to ensure that no robot motion occurs when the hold-to-run switch is engaged until motion is initiated by a separate action (i.e., joystick).
5. In the teach mode, ensure that robot motion cannot be initiated by any other control device.

#### **B7. Enabling pendant**

This test verifies that the enabling pendant(s) cannot be overridden by any other control device. It also ensures that the enabling pendant provides exclusive control of the equipment, does not unintentionally enable any piece of the equipment, and only enables the equipment in its intended span of control.

With the switches on the gate control console in the correct position, an enabling pendant permits motion in the safeguarded area while a gate is open.

1. With a gate open, test that each enabling pendant only enables the motion indicated by the switches on the gate control console.
2. Test each enabling pendant to ensure that no motion is allowed until the hold-to-run switch is engaged.
3. Test each enabling pendant to ensure that all motion enabled by the pendant stops when the hold-to-run switch is either squeezed or released.
4. Test each enabling pendant to ensure that no motion occurs when the hold-to-run switch is engaged until motion is initiated by a separate action (e.g., HMI input).

#### **B8. Point-of-operation safeguarding device**

This test verifies that the point-of-operation safeguarding device(s) are mounted in the correct position, and that the equipment will safely stop before any person reaches the hazardous area.

1. Verify that the safeguarded zone is sufficiently sized to prohibit any person from contacting the hazardous motion.
2. Verify that barriers or other safeguarding devices prevent a person from passing through the safeguarded area into the hazardous area.
3. Verify that no access (e.g., reaching over, under, or around the safety device) to a danger point exists.
4. Verify that the safety device is securely mounted and that it cannot be adjusted or removed without the use of tools.
5. For all devices guarding hazardous motion, verify that the device is dual channel (i.e., control reliable).

6. Test that the hazardous motion (which the operator may be exposed to) stops when the safeguarded area is entered and before the operator is exposed to it (reference [Annex A: Safe Distance Formulas](#)).

**Note:** Conduct this test only in the automatic mode.

7. Test that no motion occurs when the safeguarding device is reset.

#### **B9. Pinch point safeguarding device**

This test verifies that pinch point safeguarding devices inside the safeguarded area are mounted in the correct position and that no hazardous motion can be initiated when the devices are actuated.

1. Verify that the safeguarded area is sufficiently sized so that the operator cannot be present in the pinch point area without actuating the safeguarding device.
2. Verify that the safety device is securely mounted and that it cannot be adjusted or removed without the use of tools.
3. For all devices guarding hazardous motion, verify that the device is dual channel (i.e., control reliable).
4. Test that the hazardous motion creating the pinch point cannot be initiated when a person is in that pinch point area.

**Note:** Conduct this test only in the manual mode.

5. Test that no motion occurs when the safeguarding device is reset.

## Annex D: Hierarchy of Controls – Solution Illustrations

The basic thought process must recognize the work to be done, evaluate the hazards and exposures associated with the tasks and provide the most effective H&S control solutions.

Safety for all processes, cells and machines shall be addressed through the Hierarchy of Health and Safety Controls. The following examples are intended to provide a better understanding of the hierarchical approach.

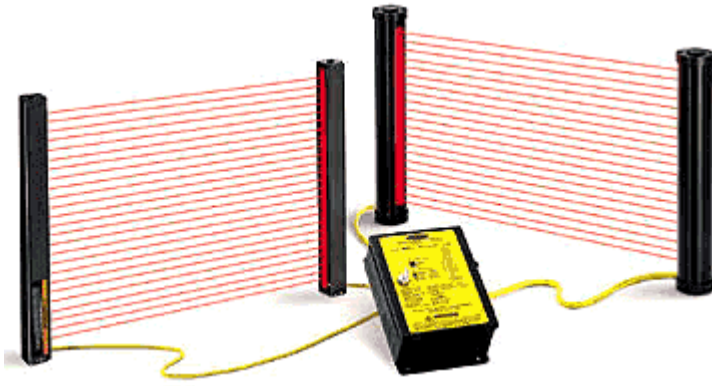
### D1. Elimination or Substitution:

- a. Eliminate equipment
- b. Simplify equipment
- c. Improve initial equipment design
- d. Remove/minimize human interaction with equipment
- e. Eliminate pinch points
- f. Eliminate or simplify material handling
- g. Place adjusting devices and other requirements for human interaction outside the hazard area
- h. Substitute less hazardous processes and/or chemicals



### D2. Engineering Controls:

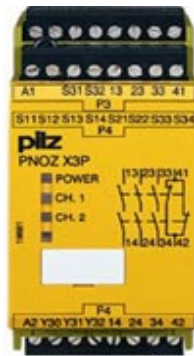
- a. Perimeter guards
- b. Light curtains
- c. Safety mats
- d. Interlocks
- e. Safety relays, switches and other control devices
- f. Ventilation, local or point of operation exhaust
- g. Automatic/Manual material handling (e.g. lift for ergonomics issue)
- h. Movable interlocked guard



Light Curtain



Safety Gate Switch



Safety Relay



Emergency Stop Pushbutton

- D3. Warnings:
- a. Lights, beacons and strobes
  - b. Computer warnings
  - c. Signs
  - d. Markings indicating a restricted space on the floor
  - e. Equipment start-up alarms, beepers and horns
  - f. Labels



Laser Equipment

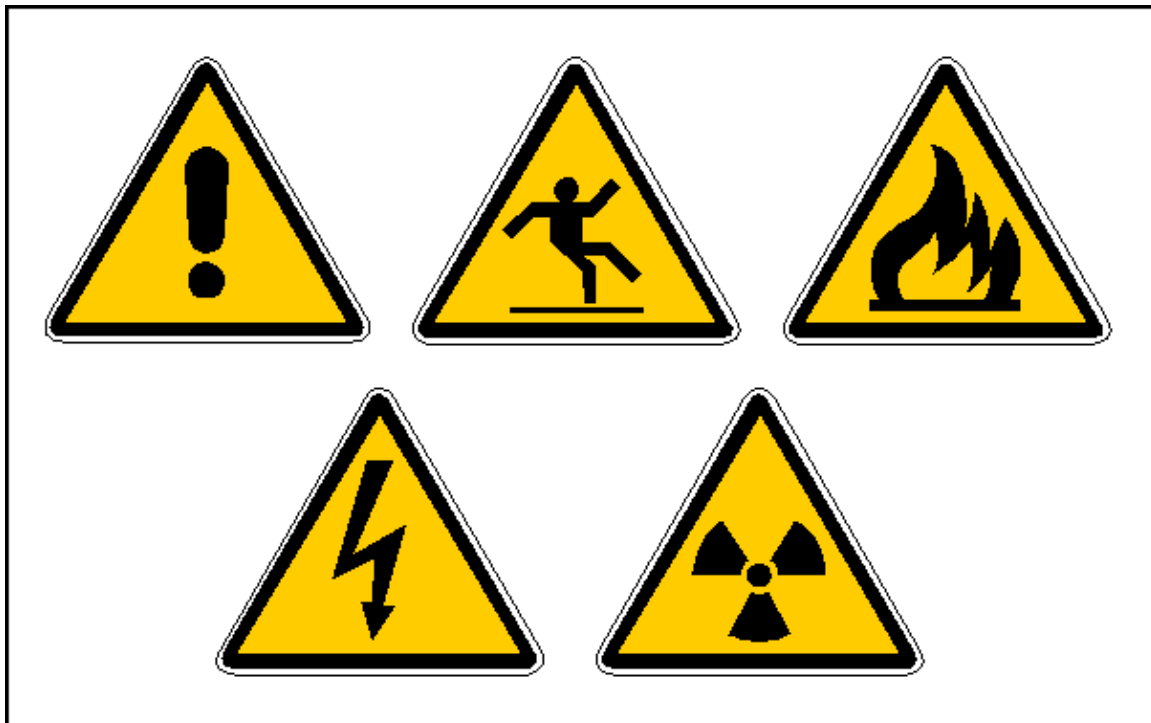


Ionizing Radiation Equipment





Stack Light

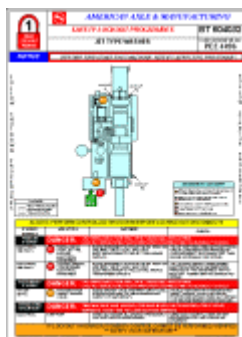


European Safety  
per  
European Directive 92/58/EEC and ISO 3864

D4. Training and Procedures (Administrative Controls)

- a. Safe operating practices and procedures
- b. Standardize Work
- c. Job rotation
- d. Written Training Programs

**Note:** Written training, procedures and administrative controls are used when higher-level alternatives are not feasible, and when the risk is adequately controlled. Personnel must be properly trained before operating and maintaining equipment. This includes being provided with up-to-date and accurate written instructions (Safety, Standardized Work, Set-up, Start-up, Run, Stop, etc.). The training and instructions must be implemented, enforced and followed.



Lockout / Tag-out Placard



D5. Personal Protective Equipment (PPE):

- a. Face shields
- b. Safety glasses
- c. Hearing protection
- d. Gloves
- e. Protective sleeves
- f. Respirators
- g. Welding screens
- h. Expendable tools



Welding Screen



Safety Glasses



Ear Plugs



Face Shield

## Annex E: Safety Circuit Performance Requirements

Delphi	ISO13849-1 (EN954-1)	Interpretation of Circuit Requirements
Simple ( <a href="#">3.5.5.1</a> )	Category B	Control as per basic specifications.
Single Channel ( <a href="#">3.5.5.2</a> )	Category 1	Use of well-tried and tested components and principles.
Single Channel w/ Monitoring ( <a href="#">3.5.5.3</a> )	Category 2	Safety function shall be tested/checked at suitable intervals (frequency determined according to application).  Single fault may cause the loss of the safety function.
Control Reliable ( <a href="#">3.5.5.4</a> )	Category 3	A single fault must not cause the loss of the safety function. The fault should be detected whenever reasonably practicable.  An accumulation of faults may cause the loss of the safety function.
	Category 4	A single fault must not cause the loss of the safety function. The fault shall be detected at or before the next demand of the safety function.  An accumulation of faults must not cause the loss of the safety function.

**Notes:**

1. The above information is derived from Table 3, page 8, ANSI B11.TR4, 2004.
2. The ANSI B11 series of machine tool safety standards include a note within an explanatory annex stating that control reliability for machine tools is not directly comparable to the requirements of ISO 13849-1 and exceed a Category 2.
3. The Delphi task based risk assessment process is based on the robot risk assessment per ANSI/RIA R15.06. Further, ANSI/RIA R15.06 (clause 4.5) includes a note that states that the ISO 13849-1 Categories are different from the performance criteria within R15.06, and exceed Categories B, 1, 2, and 3. Control reliability for robots typically exceeds a Category 3, but is not necessarily intended to be a Category 4. Circuits that are “dual channel with monitoring” and safeguarding devices with dual safety outputs that are certified for Category 3 usage, such as safety mats and area scanners, are generally accepted for use in robot applications that require Control Reliable safety performance, as defined in that standard.

## **National Documents:**

**ANSI – American National Standards Institute**      **website:** [www.ANSI.org](http://www.ANSI.org)

- ANSI/ASME B15.1, Mechanical Power Transmission Apparatus
- ANSI/ASME B20.1, Safety Standard for Conveyors and Related Equipment
- ANSI B11.1, Machine Tools – Mechanical Power Presses – Safety Requirements for Construction, Care, and Use
- ANSI B11.19, Machine Tools, Safeguarding when referenced by the Other B11 Machine Tool Safety Standards - Performance Criteria for the Design, Construction, Care, and Operation
- ANSI B11.20, Manufacturing Systems/Cells-Safety Requirements for Construction, Care, and Use
- ANSI B11.23, Machining Centers - Safety Requirements for Construction, Care, and Use
- ANSI/RIA R15.06, American National Standard for Industrial Robots and Systems – Safety Requirements
- ANSI Z136.1, American National Standard for the Safe Use of Lasers
- ANSI Z244.1, Lockout/Tagout of Energy Sources
- ANSI Z9.7 (when available), Recirculation of Industrial Process Exhaust System

**NFPA – National Fire Protection Association**      **website:** [www.NFPA.org](http://www.NFPA.org)

- NFPA 79, Electrical Standard for Industrial Equipment, 2002 Edition

**OSHA – Occupational Safety & Health Administration**      **website:** [www.OSHA.gov](http://www.OSHA.gov)

- [OSHA 29 CFR 1910](#) (applicable provisions)
- [OSHA 29 CFR 1910.147](#), The Control of Hazardous Energy (Lockout/Tagout); The Ontario Occupational Health & Safety Act; the Quebec Occupational Health & Safety Act; the Ontario Hydro Act.

## **International Documents**

**HSC – Health & Safety Council**      **website:** [www.HSE.gov.uk](http://www.HSE.gov.uk)

**New Approach Directives**      **website:** [www.Newapproach.org](http://www.Newapproach.org)

- 73/23/EEC – Low Voltage Directive
- 93/68/EEC
- 89/336/EEC – Electromagnetic Compatibility Directive (EMC)
- 98/37/EEC – Machinery Directive
- 98/79/EEC
- 2003/10/EC – Noise Directive regarding the exposure of workers
- 89/655/CEE – Health & Safety Directive

**IEC – International Electro-Technical Commission**      **website:** [www.IEC.ch](http://www.IEC.ch)

- IEC 60204-1, Electrical Equipment of Industrial Machines - General Requirements
- IEC 60034-9, Rotating Electrical Machines – Noise Limits

**BSI – British Standards Institute**      **website:** [www.BSI-Global.com](http://www.BSI-Global.com)

- BS EN 999, Safety of machinery – The positioning of protective equipment in respect of approach speeds of parts of the human body.
- BS EN 574, Two Hand control device
- BS EN 292, Safety of machinery; basic concept, general principles for design

- BS EN 294, Safety distances to prevent danger zones being reached by the upper limbs
- BS EN 953, Guards
- BS EN 954-1, Safety related parts of control systems
- BS EN 982, Safety of Machinery – Safety requirements for fluid power systems and their components. Hydraulics
- BS EN 983, Safety of Machinery – Safety requirements for fluid power systems and their components. Pneumatics
- BS EN 1050, Principles for risk assessment
- BS EN 1088, Interlocking devices associated with guards
- BS EN 1760, Pressure sensitive protective device
- BS EN 12101-2, Specification for natural smoke and heat exhaust ventilators
- BS EN 14122-2, Safety of Machinery -- Permanent means of access to machinery, working platforms, and walkways
- BS EN 14122-3, Safety of Machinery -- Permanent means of access to machinery, stairways, step ladders, and guard rails
- BS EN 61496-1, Electro-sensitive protective devices
- COSHH – Control of substances hazardous to health     **website:** [www.hse.gov.uk](http://www.hse.gov.uk)

**ISO – International Standards Organization     website:** [www.ISO.org](http://www.ISO.org)

- ISO 1819 -- Safety code for continuous mechanical handling equipment
- ISO 4413, Hydraulic fluid power - General rules relating to system.
- ISO 4414, Pneumatic fluid power - General rules relating to systems.
- ISO/TR 5045 -- Safety code for belt conveyors
- ISO 11014-1, Safety data sheets for chemical products
- ISO 11553, Safety of Machinery – Laser processing safety requirements
- ISO 9612, Acoustics – Guidelines for the measurement and assessment of noise in a working environment
- ISO 10218, Manipulating industrial robots – Safety
- ISO 13849-1, Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design
- ISO 14159, Safety of Machinery - - Hygiene requirements for the design of machinery
- ISO 14121, Safety of machinery – Principles of risk assessment
- ISO 14159, Safety of Machinery – Hygiene requirements for the design of machinery

## Annex G: Definitions

**actuators:** A power mechanism used to affect the motion of the robot by converting electrical, hydraulic or pneumatic energy.

**anti-repeat:** The function of the control system that limits the machine to a single cycle with the actuating control(s) held in the operating mode.

**anti-tie down:** 1) With a two-hand control device, the function of the control system that requires the release of all actuators before the machine operation can be reinitiated. 2) With a safety circuit reset, the function of the safety circuit that requires the reset signal to cycle on and off with each circuit reset.

**attended program verification (APV):** The act of verifying the robot's programmed tasks at the programmed speed while within the safeguarded area.

**automatic mode:** Any operating mode that produces continuous cycling.

**awareness barrier:** An attachment that, by physical contact, warns personnel of a present or approaching hazard.

**awareness device:** A device or signal that, by means of audible sound or visible light, warns personnel of a present or approaching hazard.

**barrier:** A device or object that provides a physical boundary to a hazard.

**cell:** An area surrounded by a defined perimeter that contains part processing machines, robots, and transfer equipment.

**chemical:** Any element, chemical compound, or mixture of elements and/or compounds.

**concurrent:** Acting in conjunction, this term is used to describe a situation where two or more controls exist simultaneously in an operated condition, but are not necessarily executed simultaneously.

**control devices:** Any piece of control hardware providing a means for human intervention in the control of a machine or system (e.g., an emergency stop button, start button, or selector switch).

**control reliability:** A method of ensuring the integrity of performance of the safety devices or control systems. As a result, a single component failure within the device, interface, or system shall not prevent the normal stopping action from taking place, but shall prevent a successive machine cycle.

**control system:** Sensors; manual input and mode selection elements; interlocking and decision-making circuitry; and output elements to the machine or robot operating devices and mechanisms comprise the control system.

**cycle:** A complete movement of the machine or robot from its initial start position back to that same start position. This may include feeding and removal of the material or work piece(s).

**design-in health and safety:** The process by which health and safety processes, tools, methods, and requirements are integrated early in the design phase to improve safety, quality, cost and productivity.

**disconnect (mechanically interrupted):** An electrical-energy interrupting device that uses mechanical linkage to force a break in the power supply to an individual piece of equipment.

**dynamic limiting device (DLD):** A limiting device that may be activated or muted in the course of executing the application program of a robot; thereby, redefining the safeguarded space.

**enabling device:** A manually operated device that permits motion when continuously activated.

**end-effector:** An accessory device or tool specifically designed for attachment to the robot wrist or tool mounting plate to enable the robot perform its intended task (e.g. gripper, spot weld gun, arc weld gun, spray paint gun, or any other application tools).

**emergency stop:** The immediate or controlled stopping of all hazardous machine motion, which is usually accompanied by the removal of the source power to the machine.

**ergonomics:** The evaluation, design or redesign of facilities, environments, jobs, job tasks, training methods and equipment to match the capabilities of people.

**exclusive control:** A station or pendant control on any piece of equipment that allows an individual to operate it in a manual mode. In addition, the operation cannot be overridden from any other location.

**firmware:** The executive control program (e.g. operating system) code provided by the manufacturer of the component in a non-volatile internal storage mode and is not changeable by the user.

**guard:** A barrier that prevents entry into the point-of-operation or any other hazardous area.

**hard stop:** A mechanical device that restricts the robot's or machine tool's ability to move to its full capability.

**hazard:** A condition or set of circumstances that can cause physical harm to exposed personnel.

**hazard area:** An area or space that poses an immediate or impending physical hazard.

**hazardous motion:** Motion of the equipment or a release of energy that can pose as a hazard.

**hazardous zone:** See hazard area.

**hierarchy of health and safety controls:** Health and safety control solutions that are listed in the order of effectiveness from most to least (i.e., elimination or substitution, engineering controls, warnings, training and procedures, and personal protective equipment).

**industrial equipment and systems:** A physical apparatus (e.g., welder, conveyor, machine tool, fork truck, turn table, positioning table, or robot) that is used to perform industrial tasks.

**industrial hygiene:** The anticipation, recognition, evaluation, elimination, and control of chemical, biological and physical hazards.

**interlock:** A means or device that allows a hazardous condition to exist only when a predetermined set of conditions is met.

**interlocked barrier guard:** A barrier, or section of a barrier, interlocked with the [machine] control system to prevent inadvertent access to the point of operation during normal [machine] operation.

**light curtain:** A device that creates a sensing field or plane to detect the presence of an individual or object.

**limiting device:** A device that prevents a machine or machine elements from exceeding a designed space limit.

**lockout:** A lock placed on an energy isolating device (e.g., a disconnect switch or shut-off valve) in accordance with Union/Delphi lockout energy control procedures.

**machine tool:** A power-driven tool used for machining.

**manual mode:** Any operating mode of the machine or system that requires the operator to initiate and maintain the motion of the machine or system during the cycle, or portion of the cycle, by use of the actuating control.

**MSDS:** Material Safety Data Sheet.

**muting:** The automatic temporary bypassing of any safety related function(s) of the control system or safeguarding device.

**operating space:** The part of the work (maximum) space that is used by a robot, including a work piece, during automatic operation.

**operating modes:** The systems of operating machines, robots, and other equipment for various operations generally consisting of automatic, manual, and jog/inch/set-up modes.

**perimeter guard:** A barrier at the perimeter (or segment of the perimeter) of a machine or production system.

**pinch point:** Any point at which it is possible for a portion of the body to be caught between two moving physical devices or between one moving and one stationary physical device.

**placard:** A form of quick reference documentation placed on the equipment or at the entrances into the safeguarded areas. This documentation identifies the machine name, number, location, location of energy control devices, energy sources, methods of energy control, and methods of verification for locking out and controlling energy.

**point-of-operation:** The location in the machine where the material or work piece is positioned and work is performed.

**positive-guided relay:** Relay designed to eliminate any springing of the contacts to ensure a true making and breaking of contacts and, in the case of a failure, to ensure that a minimum clearance of 0.5 mm between the open contacts is maintained. These relays are sometimes called guided-contact, captive-contact, direct-drive, force-guided-contact, or forced-contact relays.

**positive-opening contacts:** The achievement of contact separation as a direct result of a specified movement of the switch actuator through non-resilient members (i.e., not dependent upon springs).

**presence sensing device (PSD):** A device (e.g. light curtain, scanner, safety mat) that creates a sensing field, area, or plane that detects the presence of an individual or object.

**Programmable Electronic System (PES):** An electronic system that performs logical, decision-making or arithmetic functions by executing instructions in a specific manner. The system usually includes input and output elements (ports) and is usually re-programmable.

**redundancy:** Duplication or repetition of elements in electronic or mechanical equipment that provides alternative functional channels in case of a failure(s).

**restricted space:** The maximum distance that a robot, including the work piece, can travel in all directions after a limiting device has been installed.

**risk:** The potential for injury based on exposure to a hazard(s) during a given task.

**safe distance:** A minimum distance from a hazard that safeguarding shall be located to prevent persons from exposure to the hazard.

**safe operating procedure (SOP):** A specific written procedure that must be followed when it is determined that the equipment design prohibits a particular task from being performed in accordance with either the plant lockout procedure or CLS procedure. (Reference Union/Delphi lockout implementation guidelines.)

**safeguarding:** Methods of protecting personnel from hazards by using guards, safeguarding devices/methods or safe work procedures.

**safeguarding device:** A means (device) that detects or prevents inadvertent access to a hazard.

**safety interlock:** A means or device that prevents entry into a zone or cell while hazardous conditions exist. Entry can be attained only when a predetermined set of conditions is met.

**shall:** Denotes a requirement that is to be strictly followed in order to conform to this specification.

**should:** Denotes a recommendation, practice, or condition among several alternatives or a preferred method or course of action.

**single component failure:** Relates to a redundant control system whereby the failure of any one component of the system will have no effect on the stopping action of the system.

**single point of control:** The ability to operate the machine or robot such that initiation of machine or robot motion from one source of control is only possible from that source and cannot be overridden from another source.

**stop device:** A part of the machine operating system (e.g., emergency stop button, presence sensing device, pull cord, monitored power circuitry, or a cycle stop/hold button) that causes the cycle to stop when it is either automatically or manually activated.

**stored energy:** Any source of energy (e.g., hydraulic systems, air cushions, springs under pressure, or gravity) that could still present a hazard after a piece of equipment or process has been stopped from performing its normal function.

**two-hand control device:** A device that requires the concurrent use of both of the operator's hands to initiate and continue the machine cycle during the hazardous portion of that cycle.