Selecting Safeguards

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DISCLAIMER

❄ This presentation does not advocate any particular solution, product, or manufacturer.
❄ The images in this presentation only represent a sample of available products.
❄ All requirements from ANSI/RIA R15.06-1999 (R2009), Clause 5 [Performance requirements of safeguarding devices] & Clause 11 [Safeguarding devices – application requirements] will be included in RIA TR R15.406 (currently in progress)
# Hierarchy of Control

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## Purpose of Safeguarding Devices

* Safeguarding devices shall be used consistent with the manufacturer's instructions; and shall be applied to the robot system to:
  a) prevent access to the hazard, **Around, Under, Through,** or **Over (AUTO)**
  b) cause the hazard to cease before access,
  c) prevent unintended operation,
  d) contain parts and tooling (e.g. loose objects, flying projectiles),
  e) control other process hazards (e.g. noise, laser, radiation)

**NOTE:** Each safeguarding device may not address each criteria a-e, depending on the hazard being protected.
Types of Safeguards

- SAFEGUARD: A barrier guard, device or safety procedure designed for the protection of personnel.
- ANSI/RIA R15.06-1999 (R2009) and CSA Z434-03 give specific performance requirements (Clause 5) and application requirements (Clause 11) for:
  - Barrier guards, fixed and interlocked
  - Fixed guards (hard guards or fences)
  - Mechanical or electrical interlocking guards
- Other devices that signal a stop
  - Safety light curtains / screens
  - Single and multiple beam safety systems
  - Area scanning safeguarding devices
  - Radio frequency (RF) / capacitance safeguarding devices
  - Safety mat systems
  - Two hand control systems

Safe Location Safeguarding

- OSHA 1910.219
  - All applications
    - 84" (7')
- ANSI B15.1-2000 (R2006)
  - All applications
    - 2440 mm
    - “96” (8')
- ANSI B11.19-2010
  - Low risk applications
    - 2500 mm
    - “98.4” (8’ 2 7/8’’)
  - High risk applications
    - 2700 mm
    - “106.3” (8’ 10 3/8’’)
  - Conforms with:
    - CSA Z432-04
    - ISO 13857:2010
Resources

There are additional resources (standards) for requirements of safeguarding measures, including:

- ANSI/RIA R15.06-1999 (R2009) – Safety Requirements for Industrial Robots and Robot Systems
- ANSI B11.0-2010 – Safety of Machinery – General Requirements and Risk Assessment
- CSA Z432-04 (R09) – Safeguarding of Machinery – Occupational Health and Safety
- CSA Z434-03 – Industrial Robots and Robot Systems – General Safety Requirements
- ANSI B11.20-2004 (R2009) – Safety Requirements for Integrated Manufacturing Systems
- CSA Z460-05 – Control of Hazardous Energy – Lockout and Other Means

NEW RIA TR R15.406 is in development

Guidelines for the Selection and Application of Protective Devices According to ISO Standards
Types of Safeguards

- Mechanical solutions that physically prevent or restrict access:
  - Fixed Guards
  - Movable Guards
  - Adjustable Guards
  - Safe Openings
  - Pullbacks
  - Mechanical Restraints

- Mechanical solutions that prevent access and cycle initiation by interconnected or interlocked means:
  - Interlocked Guards
  - Automatic Screens & Doors
  - Type A Gates
  - Type B Gates
  - Probe Detection Devices
  - Rotating Tooling / Fixtures
Types of Safeguards

- Electrical solutions that create a stop signal (presence-sensing devices):
  - Photoelectric (Optical)
    - Light Curtains / Screens
    - Multiple & Single Beam Systems
    - Area Scanners
  - Camera (Vision) Systems
  - Hydraulic Press Brake Safeguarding Systems
  - Pressure Sensitive
    - Safety Floor Mats
  - RF / Capacitance Devices
  - Control Devices
    - Two Hand Control
    - Two Hand Trip
    - Single Control Devices

Types of Complimentary Equipment

- Other complimentary equipment that augment safeguarding devices:
  - Safety Blocks, Slide Locks, Chain Locks, and Locking Pins
  - Workholding Equipment
    - Enabling Devices
    - Stopping Performance Monitors
    - Safety Interface Modules
      - Monitoring Safety Relays
      - Safety PLCs
      - Safety BUS Systems
  - Emergency Stop (E-Stop) Devices
    - Pushbuttons
    - Pull Cords (Cable Pulls, Trip Wires)
    - Body Bars
    - Trip Rods
    - Footswitches (without a mechanical guard)
  - Hand Tools
Safe Mounting Distance

For safeguarding devices that signal a stop to the machine, the safety distance must be calculated using one of the following equations:

**ANSI & CSA**

\[ D_s = K (T) + D_{pf} \]

**EN & ISO**

\[ S = (K \times T) + C \]

where:

- \( D_s \) = the safety distance
- \( K \) = the maximum speed that an individual can approach the hazard
- \( T \) = the total time to stop the hazardous motion
- \( D_{pf} \) = the depth penetration factor of the safeguarding device
- \( S \) = the safety distance
- \( K \) = the approach speed of the body or parts of the body
- \( T \) = the overall system stopping performance
- \( C \) = an additional distance based on intrusion towards the danger zone prior to actuation of the protective equipment

Fixed Guards

- Fixed guards are objects that provide a physical boundary and prevents exposure to an identified hazard or area
- Fixed guards are secured to or around the equipment or tooling in such a manner as to enclose all or part of the point of operation or other hazard area
- Not easily removed (requires tools to remove)
- It must not present a hazard (allow someone to get trapped, cut, etc.)
- Can’t reach around, under, through or over to the hazardous area
- Must observe safe mounting distance
Fixed Guards

- Most appropriately used for areas that require seldom (very little) access:
  - Power transmission
  - Process lines
  - Points of operation (some)

Barrier Guards – Safety Distance
(reach Through)

Various Sources:
- OSHA 1910.217, Table O-10
- Liberty Mutual (most ANSI & CSA standards)
- ISO 13857:2010
Barrier Guards – Height
(reach Over)

- Guidelines are available to help determine adequate height of constructed guards in relation to hazard height and distance of guard from hazard
  - ANSI B11.19-2010
  - CSA Z432-04
  - ISO 13857-2008

Barrier Guards – Size Requirements
(reach Over or Under)

- Perimeter barrier guards shall be designed such that:
  - The maximum distance between the bottom of the barrier and the adjacent walking surface ('sweep') is:
    - 0.3m (12") according to ANSI/RIA R15.06-1999 (R2009)
    - 0.15m (6") according to CSA Z432-04 and CSA Z434-03
    - 200mm (7.87") according to ISO 10218-2
  - The maximum height (top) of the barrier above the adjacent walking surface is:
    - 1.5m (60") according to ANSI/RIA R15.06-1999 (R2009)
    - 1.8m (72") according to CSA Z432-04 and CSA Z434-03
    - 1400mm (55.12") according to ISO 10218-2
  - Unless additional safeguarding devices are installed to prevent or detect access to the hazard
Barrier Guards – Clearance

- Provide a minimum clearance from the operating space for manual reduced speed mode (slow speed APV)
  - 0.5 m (20") according to ANSI/RIA R15.06-2012, ISO 10218-2:2011 & CSA Z434-03
  - 0.45 m (18") according to ANSI/RIA R15.06-1999 (R2009)
- Provide a minimum clearance from the restricted space for manual high speed mode (high speed APV)
  - 0.5 m (20") according to ANSI/RIA R15.06-2012, ISO 10218-2:2011 & CSA Z434-03
  - 0.45 m (18") according to ANSI/RIA R15.06-1999 (R2009)
- Where this minimum clearance is not provided, additional safeguarding devices shall be provided.

Fixed Guards

- Advantages
  - Protect all individuals
  - Not dependent on user interaction
  - Simple to install and maintain
  - Saves floor space
  - Can contain hazards (acts as a shield)
    - Ejected material
    - Mist / fluids
    - Hazardous substances / fumes
    - Noise
    - Radiation (laser, light, etc.)
    - Explosion
- Disadvantages
  - Limits access
  - May limit visibility if not properly designed
  - Can be ‘forgotten’ to be replaced when removed for maintenance
Moveable (Interlocked) Guards

- Moveable guards are interfaced with the machine control system in such a manner as to prevent inadvertent access to the point of operation or other hazard during normal operation.
- Interlocked guards shut off or disengage power and prevent starting a machine when the guard is open.
- Interlocked guards require a safety interlock switch to interface to the safety control system.
- Must open laterally or away from the safeguarded space and cannot close by itself and activate the interlocking circuitry.
- Used when access is occasional.

Moveable (Interlocked) Guards

- Prevent access during hazardous portion of the cycle or removes the hazard when the guard is opened.
- Must observe safe mounting distance.
- Used when access is occasional.
- Unless guard is automated.
- Interfaced with the machine controls system with:
  - Mechanical devices
    - Trapped Key Interlocking (Captive Key or Transfer Key)
  - Electrical devices
    - Key Operated Switches
    - Guard Locking (Solenoid Locking) Key-Operated Switches
    - Hinge Switches
    - Limit Switches
    - Magnetic Switches
    - Inductive Switches
    - Optical Switches
Moveable (Interlocked) Guards

- Examples of moveable (interlocked) guards
  - Covers
  - Doors
    - Swing gates
    - Slide gates
  - Gates
  - Automated barriers and doors

Automated Screens & Doors
Interlocking Portion of Moveable Guards

1) Switches designed with positive opening operation shall be mounted in a positive mode

2) Switches that are not positive opening shall be automatically monitored to detect faults
3) The switch shall not be used as an end of travel stop.

4) The switch must be tamper resistant and cannot be defeated without tools.
Interlocking Portion of Moveable Guards

5) Spare keys and actuators shall be supervisory controlled and not readily available

6) The hazard being guarded
   * Cannot be placed in automatic operation until the interlocked guard is closed, and
   * Will stop if the guard is opened while the hazard is present

7) Closing the interlocked guard shall not, by itself, restart automatic operation

8) Resuming automatic operation shall require a deliberate action outside the safeguarded space

Interlocking Portion of Moveable Guards

9) The safeguarded space shall be designed, constructed or fitted with a means of preventing a person from being trapped inside. For example, this may be accomplished by:
   * Providing for manual opening of the movable guards from inside the safeguarded space, regardless of the state of the energy supply, or
   * Providing a means of locking access gates in their open position
Application Consideration

- How to protect equipment with long run-down / stopping times
  1) Use guard locking interlock devices
  2) Install braking devices to achieve a faster stopping time
  3) Position the safeguard at a distance far enough away to prevent access before the hazardous motion has stopped

Trapped-Key Devices

- Trapped key interlock switches work on the principle that no one key can be in two places at the same time
- Systems can be configured to ensure a predetermined sequence of events takes place
- Used in many hazardous environment locations because it is a strictly mechanical system
Trapped-Key Devices

Operation Sequence

1. Turn and release key from the key switch unit at the door. This requests entry.
2. When the robot reaches a programmed stop the yellow LED is illuminated.
3. Open the door using the slide bar. The red LED illuminates indicating gate open.
4. Retain the key as a safety key or use to activate the teach mode inside the guarded area.
Trapped-Key Devices

- Advantages
  - Strictly mechanical operation – can be used in hazardous location areas
  - Unique coding available for higher degree of security
  - Stainless steel or brass housing available for harsh environments
  - No springs or cams that can fail
  - Some have replaceable coded key barrels that can be updated
  - Less space is needed with access control than for other safety devices
  - Provides absolute protection if regularly maintained
  - Little to no wiring necessary (lower installation costs)

- Disadvantages
  - Complex systems can get expensive
  - Lost / missing keys can cause unnecessary stoppages
  - Access to area can be difficult for maintenance or loading / unloading operations

Key-Operated Switches
Key-Operated Switches

- **Advantages**
  - Less space is needed with access control than for other safety devices
  - Low cost
  - Tamper resistant
  - Provides absolute protection if regularly checked and maintained
  - Wide range of sizes

- **Disadvantages**
  - Additional maintenance required for alignment issues
  - May require greater safety distance due to stopping time of the machine
  - Access to area can be difficult for maintenance or loading / unloading operations

Guard Locking Switches

- The guard cannot be opened while a hazard exists or until the machine has stopped operating
- Useful when the stop time may be too large due to the operation or the inertia of the machine
- Most commonly used with key-operated interface
  - The key is attached to the guard and is not released by the solenoid until the control system signals that a safe condition has been achieved
- Two types
  - Power to lock
  - Power to unlock
Guard Locking Switches

Guard locking switches require a safety-rated signal to unlock (release) the switch actuator:
- Timer relays (zero speed)
- Motion detection
  - Back EMF detectors (zero speed)
  - Inductive sensors (zero / safe speed)
- Drive monitoring / control systems (zero / safe speed)
Motion Detection

- **Back EMF (BEMF):** Voltage generated by the rotating motor after power to the motor is cut. When BEMF < threshold stop motion, output is ON.

- The sensors must be arranged so that one is ON when the motion is stopped.
- The cogwheel must be installed BETWEEN the motor and the associated hazard(s).

![Diagram showing BEMF and voltage difference](image-url)
Improving Productivity

Off-delay timer

Off-delay time has to be set for longest run-down time

Unlock the door as soon as the hazard is eliminated.

Extra Waiting Time

Improved Productivity

Guard Locking Switches

Advantages
- Unlocks only when hazardous motion has ceased
- Protect operators after power is disconnected from continuing motion hazards
- Protect machines and processes when a stop in mid-cycle could lead to machine or product damage
- Low cost
- Tamper resistant
- Provides absolute protection if regularly checked and maintained
- Wide range of sizes

Disadvantages
- Additional maintenance required for alignment issues
- Access to area can be difficult for maintenance or loading / unloading operations
Hinge Switches

**Advantages**
- Minimal alignment problems
- Difficult to defeat without removal of switch
- Less space is needed with access control than for other safety devices
- Low cost
- Tamper resistant
- Provides absolute protection if regularly checked and maintained
- Variety of models for both new guarding and retrofitting older guards

**Disadvantages**
- May be difficult to retrofit
- Access to area can be difficult for maintenance or loading / unloading operations
- Large doors may provide access to hazardous area before activating switch

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Limit Switches

Advantages
- Minimal alignment problems
- Wide variety of actuators
- Difficult to defeat when mounted in the positive mode
- Less space is needed with access control than for other safety devices
- Low cost
- Tamper resistant (when installed correctly)
- Provides absolute protection if regularly checked and maintained

Disadvantages
- Can easily be replaced with non safety-rated limit switch
- Access to area can be difficult for maintenance or loading / unloading operations
NON-CONTACT SWITCHES

- Other types of safety interlock devices are available that require no contact between the switch and the actuator, including:
  - Magnetic Switches
  - Coded Transponder Switches
  - Inductive Switches
  - Optical Switches
  - RFID Switches

Magnetic Switches
Coded Transponder Switches

- Coded transponder devices consist of three components:
  - Coded actuator
  - Read head
  - Evaluation unit
- Name comes from transmitter and responder

Inductive Switches

- Inductive switches work like other industrial proximity switches
- Triggered by any steel product – no special actuator necessary
Optical Switches

- Optical interlock switches are used in place of traditional electro-mechanical switches to provide safeguarding on movable guards
- Utilize same concept as light curtains, but light is transferred by fiber optic cables

RFID Switches

- RFID interlock switches are used in place of traditional electro-mechanical switches to provide safeguarding on movable guards
- RFID = Radio Frequency Identification
NON-CONTACT SWITCHES

**Advantages**
- Minimal alignment problems
- Recommended for wash down areas (common in food industry)
- Less space is needed with access control than for other safety devices
- Low cost
- Provides absolute protection if regularly checked and maintained

**Disadvantages**
- Must be automatically monitored to detect faults
- Magnetic: some can be bypassed with strong permanent magnets
- Inductive: can be bypassed with any metal object – installation is very important
- Optical: must be properly installed (movement must be on axis perpendicular to optical path)
- Access to area can be difficult for maintenance or loading / unloading operations

PHOTOELECTRIC DEVICES

**Photoelectric (optical) presence-sensing devices** use a system of light sources and controls which can interrupt a machine’s operating cycle when the light field is broken

**Types of photoelectric devices**
- **Light Curtains / Single Beam Systems**
- **Area (Laser) Scanners**
**Light Curtains**

- Safety light curtains are photoelectric barriers composed of parallel infrared (IR) beams
- Each beam is constantly monitored to detect for an object in the protected field
- A stop signal is initiated when an object is detected

**Light Curtains**

- Safety light curtains can provide two types of protection
  - Point of operation (Finger / Hand detection)
  - Area / perimeter (Body detection)
    - Body detection can be accomplished with:
      - Conventional light curtains
      - Single beam devices
Light Curtains
(reach Through)

- The type of protection is determined by the number of light beams and the spacing of the lenses
  - Commonly referred to as 'Resolution' or 'Minimum Object Sensitivity' (MOS)
  - MOS is the smallest size that is guaranteed to be detected in the sensing field
  - MOS is the sum of the center-to-center lens spacing and the diameter of the lens

Point of Operation Light Curtains
Perimeter Access Light Curtains

NOTE: Because personnel can pass through the device and be undetected inside the safeguarded area, a reset must be provided OUTSIDE the safeguarded area and within CLEAR VIEW of the safeguarded area.

Guidelines are available to help determine adequate height of optical safeguards in relation to hazard height and distance of safeguard from hazard:

* ISO 13855-2010
Light Curtains

- Light curtains can be used with mirrors to protect more than one side of a machine
- Many types and styles of light curtains exist
  - Various housings (two or three box designs)
  - Various MOS (spacing between beams) – including single beam
  - Selection of protected heights
  - Different ranges (distance between transmitter and receiver)
Segmented Light Curtains

Other Options for Light Curtains

- Wash Down Enclosures
- Explosion Proof Enclosures
- Programming Diagnostic Module (PDM)
- Programmable Functions
Light Curtain Features

* Light curtains can incorporate blanking options such as:
  * Fixed blanking
  * Floating blanking

Fixed Blanking

* Fixed blanking (channel blanking, channel select) is used to disable a fixed, selected area in the protective field of a light curtain
* This is used when a permanent object (such as a die, tool, work piece, or conveyor) will always be in the sensing field
* This requires that the permanent object always remains in the sensing field
* If the object moves or is removed, the device will prevent machine operation

* NOTE: It is important to prevent access through the deselected beams on either side of the permanent object - otherwise the effective MOE of the safety device has increased
Floating Blanking

* Floating blanking (floating select) is used to disable a selected area in the protective field of a light curtain that is permitted to move throughout the sensing field.
* This is used when a moving object (such as stock from a coil) will always be in the sensing field, but not always in a predetermined location.

Floating Blanking

* The MOS of the safety device will increase.
* Must account for the increased minimum object sensitivity by increasing the safe mounting distance.
Light Curtain Safety Distance

with object sensitivities less than 6.4 cm (2.5 in)

Note: Where individuals can place themselves between the safeguarding device and the hazard zone and remain undetected, additional measures must be taken.

Depth Penetration Factor ($D_{pf}$)

Penetration factor, $D_{pf}$, for presence sensing devices used in a vertical application with object sensitivity less than 6.4 cm (2.5 inches)

($D_{pf}$), the distance added to the safety distance due to the penetration factor compensates for varying object sensitivities of electro-optical presence sensing devices.

When blanking features are used and when the blanked area is not completely filled by the workpiece or part, or by mechanical guarding, the minimum object sensitivity can be calculated as:

Object sensitivity = size of the blanked area plus minimum object sensitivity without blanking.

Once this value is found, then determine $D_{pf}$.

If the entire blanked area is filled with mechanical guarding or other fixed material or guards, use the device’s object sensitivity to determine $D_{pf}$. 
Light Curtain Safety Distance
with object sensitivities greater than 6.4 cm (2.5 in)

If the individual cannot reach over the top of the sensing field and the bottom of the sensing field is no more than 30 cm (1 ft) above the floor.

The top of the sensing field ("A") is between 90 and 120 cm (3 and 4 ft) above the floor. The bottom of the sensing field ("A") is no more than 30 cm (1 ft) above the floor.

**Note:** For electro-optical presence sensing devices using large blanked areas, or if an individual can otherwise reach through or over the sensing field and not be detected, the distance between any two adjacent detection points shall not be greater than 60 cm (24 in), i.e., from one active point to the next active point above.

Dpf = 120 cm (4 ft) for reach-through applications
Dpf = 90 cm (3 ft) for reach-over applications

NOTE: Where individuals can place themselves between the safeguarding device and the hazard zone and remain undetected, additional measures must be taken.

Depth Penetration Factor \( (D_{pf}) \)

Example of guarding with various object sensitivities

Safety Distance \( (D_s) \) for devices with a larger value for object sensitivity must be placed farther from the hazard than a device with higher resolution.
Safety Distance for Ground Level Devices that can be Reached Over (30° or less from horizontal)

Minimum depth of field or sensing area must hinder an individual from stepping over the presence sensing device or safety mat. This distance is:
- 120 cm (4 ft) if an individual can step over and pass unrestricted
- 90 cm (3 ft) if supplemental safeguarding or physical barriers are used such that an individual must stand within the sensing area.

Allowable Sensing Field Heights in cm (in)

<table>
<thead>
<tr>
<th>Minimum Object Sensitivity</th>
<th>Mounting Height (cm)</th>
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<tbody>
<tr>
<td>&gt; 5</td>
<td>0–99 (39)</td>
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<tr>
<td>0.4 (2.5)</td>
<td>18 (7.5)</td>
</tr>
<tr>
<td>7.6 (3.0)</td>
<td>38 (15)</td>
</tr>
<tr>
<td>8.9 (3.5)</td>
<td>57 (22.5)</td>
</tr>
<tr>
<td>10 (4.0)</td>
<td>76 (30)</td>
</tr>
<tr>
<td>10.8 (4.25)</td>
<td>86 (33.75)</td>
</tr>
<tr>
<td>11.7 (4.6)</td>
<td>99 (39)</td>
</tr>
</tbody>
</table>

Minimum mounting height (h) can also be determined by the following equations:

\[ h = 15 (S - 5) \text{ cm} \]
\[ h = 15 (S - 2) \text{ in} \]

where \( S \) is the object sensitivity.

Vertical vs. Horizontal Application

\[ \Delta = 243.32 \text{ sq. ft.} \]

\[ X = \$ (\text{sq. ft.)} \]

\[ \Delta = 243.32 \text{ sq. ft.} \times X \]

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Light Curtains

**Advantages**
- Protects anyone at the point of operation
- Large protection areas possible with one device
- Can guard multiple sides with the use of mirrors
- Permits easy and safe access to hazardous areas for repetitive operations (loading/unloading)
- Provides maximum productivity for frequent access operations
- Transparent to the operator (no operator fatigue)

**Disadvantages**
- Must be placed at the safe mounting (minimum safety) distance
- May require adjustment for specific operations when using blanking
- Supplemental guarding may be necessary
- Limited to machines that can be immediately stopped

Area Scanners

![Area Scanners Image]

Figure 5.2: Setup for Area Scanning
Area Scanners

* Area scanners are photoelectric barriers which utilize rotating lasers that can be programmed to guard irregularly shaped areas
* A stop signal is initiated when an object is detected in the danger zone
* Warning zones are also available to alert personnel when they are approaching the danger zone

Area Scanners – Programming

Configuration Tool

- Setting up zones
- Programmable configuration
- Safety zones
- Warning zones
- Live perimeter of the work space
- Customizable zones
Area Scanners in Action

Area Scanners in Action
Area Scanners in Action

Area Scanners – Stationary Examples
Area Scanners – Stationary Examples
Area Scanners – Mobile Examples

![Diagram of Area Scanners](image)

**Advantages**
- Protects anyone in the hazardous area
- Protect large areas and complex shapes with one device
- Provides warning zones to avoid unwanted machine stoppage
- Permits easy and safe access to hazardous areas for repetitive operations (loading/unloading)

**Disadvantages**
- Sensitive to polluted environments (dust and smoke)
- Take up valuable floor space
- Optimized for protection of large areas
- More expensive than other presence sensing devices
- Limited to machines that can be immediately stopped
- Cannot ‘see’ through objects

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PRESSURE SENSITIVE DEVICES

- Pressure sensitive devices provide a quick means of signal a stop to a machine
- Will initiate an immediate stop signal when a force is applied to the device
- Because pressure sensitive devices cannot restrain an individual from reaching the hazardous area, these devices must only be used on machines that can be stopped mid-cycle
- Types of pressure sensitive devices
  - Safety floor mats
  - Safety edges / bumpers

Safety Floor Mats

- Safety floor mats are pressure sensitive electric switches that are sensitive to both foot and vehicular traffic
- A stop signal is initiated when an object is sensed in the danger area
Safety Floor Mats

* IMPORTANT:
  - Pressure on the mat **must** initiate an immediate protective/safety stop
  - **NOT** allow / initiate motion
  - i.e., place safety mat(s) where individuals should not be, rather than where they are permitted to be
Safety Floor Mats – Installation

Advantages
- Protects anyone in the hazardous area
- Protect large areas
- Low maintenance
- Provides visual reminder and warning to personnel
- Permits easy and safe access to hazardous areas for repetitive operations (loading / unloading)

Disadvantages
- Cannot be easily relocated when machine is moved
- Expensive for large areas
- Mats cannot be cut by user for new applications
- Take up valuable floor space
- Surface beneath must be flat
- Limited to machines that can be immediately stopped

Safety Floor Mats
Safety Vision Systems

- Uses multiple cameras and software to create a virtual view of the area guarded
- Can be used to replace traditional safeguarding measures (barrier guards, light curtains, area scanners, safety mats, etc.)
- NEW on market
  - No N.A. standards exist that address their use (as of yet)
  - DRAFT EU standards in process (IEC 61496-4)
Safety Vision Systems

**Advantages**
- Protects anyone at the point of operation
- Reduces need for mechanical barriers and/or multiple traditional safeguarding devices
- Direct visible feedback for start-up & troubleshooting (i.e. video)
- Possible to protect complex areas
- Can guard multiple sides of the machine
- Permits easy and safe access to hazardous areas for repetitive operations (loading / unloading)

**Disadvantages**
- Sensitive to polluted environments (dust and smoke) and reflective surfaces
- External light source required
- Optimized for protection of large areas
- Susceptible to false tripping
- More expensive than other presence sensing devices
- Limited to machines that can be immediately stopped (or ramped down using multiple zones)
- Cannot ‘see’ through objects
- Fixed guarding may still be necessary
- Potentially larger safety distance when using a single zone

Muting

- Muting is the temporary automatically controlled suspension of the safeguarding function during a non-hazardous portion of the equipment cycle and can be used in conjunction with any safeguarding device that electrically signals a protective stop

- Muting is permitted when:
  1. Personnel are not exposed to the hazard,
  2. The hazard cannot be accessed without a stop being initiated,
  3. The muting system is designed and installed consistent with the safety circuit performance required for the device being muted, AND
  4. Presence in the muted safeguarded space is continually sensed for operator interface applications.
Muting

Two Hand Control & Two Hand Trip

- Two-hand control and trip devices require the use of both hands at a fixed location (removing the operator from the hazardous area)
- The actuating devices require concurrent activation within a specified period of time [500ms in accordance with NFPA 79, ANSI B11.19, IEC 60204-1 & ISO 13851]
- The individual hand controls must be arranged by design, construction, or separation to require the use of both hands to activate the equipment
- Recommended minimum distance of 23” between the controls (when mounted on the same plane)
Two Hand Control & Two Hand Trip

* Must utilize Anti-Tie Down and Anti-Repeat
  * **Anti-Tie Down**: If both of the controls are not concurrently activated, the machine cycle will not initiate (all contacts must close within 0.5 seconds of each other)
  * **Anti-Repeat**: All controls must be released and reinitiated before another machine cycle may begin

Differences

* **Two Hand Control**
  * The machine will only operate when the two-hand controls are activated
  * If one or both of the controls are released or not concurrently activated, a stop command is sent to the machine and the cycle must be reset

* **Two Hand Trip**
  * Two-hand trips require concurrent activation of both control buttons to activate the machine cycle – then the hands are free
  * Usually only used with machine equipped with full-revolution clutches

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Two-Hand Control Devices

- Various types of actuation devices can be used
  - Electro-mechanical palm buttons
  - Capacitive type devices
  - Opto-electronic (through beam) devices

**NOTE:** The installation must provide protection to ensure use of two hands for activation

Two Hand Control & Two Hand Trip

**Advantages**
- Operator’s hands are required to be at a predetermined location during the hazardous portion of the machine cycle
- Can be adapted to multiple operations
- No obstruction to hand feeding
- Does not require adjustment for each operation

**Disadvantages**
- Only protects the operator (multiple stations must be supplied for multiple operators)
- Limited to machines that can be immediately stopped
Two Hand Control & Two Hand Trip Safety Distance

Safety Distance ($D_h$) for Two-Hand Control and Two-Hand Trip applications have a $D_h = 0$. When used as a safeguarding device, the position must be placed such that the safety distance is measured from the closest hand control to the hazard.

Enabling Devices

- Used when personnel must enter the hazardous area to perform work while allowing safe motion
- Provides the margin of safety needed during trouble-shooting, set-up, programming, or servicing of robotic or automated machinery when no other safeguarding means are possible or practical
Enabling Devices

- ANSI/RIA R15.06-2012: (Part 1, 5.8.1) Where a pendant control or other teaching control devices has the capability to control the robot from within the safeguarded space ... (Part 1, 5.8.3) the pendant or teaching control device shall have a three-position enabling device in accordance with IEC 60204-1.
- ANSI/RIA R15.06-1999 (10.3):
  - New installations [AFTER 21 June 2001] require a three position ("live man") switch which, when continuously held in a detented (middle) position, permits motion. Release of or compression past the midpoint detent of the device shall stop the hazardous motion using circuitry consistent with the risk level (see Clause 4.7.3).
  - Existing installations [BEFORE 21 June 2001] with an enabling device or function (including two position "dead man") do not require retrofit. Retrofit to the three position switch is not required and should not be done unless ergonomically accomplished (see Clause 10.3.2).

Functionality

- If the enabling device is released or compressed past the midpoint, a stop command is sent to the machine and the cycle must be reset
- Tests have shown that human reaction to an emergency may be to release an object or to hold on tighter
- Design and installation of the enabling device should consider the ergonomic issues of sustained activation
Enabling Devices

Advantages
- Gives the individual control of the motion inside the hazardous area
- Built in to all new robot teach pendants

Disadvantages
- Only protects the teacher (multiple devices must be supplied when more than one person is inside the safeguarded area)
- Ergonomic issues of sustained activation

Complete Solutions

Most (if not all) complete solutions will use a combination of safeguarding measures to protect against identified hazards
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