What Is Risk Assessment?

- Asset Preservation
  - Risk Management
- Product Liability
  - FMEA
- Machinery Safety
  - Application specific
What Is Risk Assessment?

- A systematic approach to identify all tasks and associated hazards
- A methodology to select the appropriate safeguard for each task/hazard pair
- Verification that the safeguard has reduced the risk of injury

Where did it start?
EN 1050 Process
(ISO 14121)

Start

Determination of the limits of machinery
Hazard identification
Risk estimation
Risk evaluation

Risk analysis
Risk assessment

Yes

Risk reduction option analysis

No

Is the machinery safe?

End

Figure 1. The iterative process to achieve safety

Where is it going?
General Considerations. This chapter describes the general requirements and conditions for the operation of the electrical equipment of the machine. The risks associated with the hazards relevant to the electrical equipment shall be assessed as part of the overall requirements for risk assessment of the machine. (2002)

The risks associated with the hazards identified by the risk assessment shall be reduced such that the safety performance determined by the risk assessment is met. (2007)
ISO 12100-1:2003  
ANSI/ISO 12100-1:2007  

Determination of the limits of the machine (see 5.2)  

Hazard identification (see 4 and 5.3)  

Risk estimation (see 5.3)  

Risk evaluation (see 5.3)  

Can the hazard be removed?  

Has the risk been adequately reduced?  

YES  

NO  

Can the risk be reduced by inherent design measures?  

Can the risk be reduced by guards, protective devices?  

Can the limits be specified again?  

(see 5.5)  

Risk reduction by inherent design measures  

Clause 3 of ISO 12100-2  

Risk reduction by safeguarding, complementary protective measures  

Implementation of complementary protective measures  

Clause 4 of ISO 12100-2  

Risk reduction by information for use  

Clause 5 of ISO 12100-2  

Is the intended risk reduction achieved?  

Is the intended risk reduction achieved?  

Is the intended risk reduction achieved?  

Step 1  

At each step of the iterative process: risk estimation, risk evaluation and, if applicable, risk comparison  

Step 2  

Step 3  

This iterative risk reduction process shall be carried out separately for each hazard, hazardous situation, under each condition of use  

Risk assessment according to ISO 14121  

END  

B11 TR3  

Risk assessment  

Risk reduction  

Documentation  

Risk reduction as per design  

Risk reduction as per design  

Documentation  

Documentation  

Risk reduction as per safeguarding, complementary protective measures  

Risk reduction as per safeguarding, complementary protective measures  

Documentation  

Documentation  

Risk reduction as per administrative controls and other protective measures  

Risk reduction as per administrative controls and other protective measures

Documentation  

Documentation
B11 TR 3 Process
Risk Assessment

1. **Determination of the limits of the machinery (see clause 5)**
2. **Task & hazard identification (see clause 6)**
3. **Risk estimation (see clause 7)**
4. **Has tolerable risk been achieved?**
   - Yes
   - No
5. **Do other task/hazard combinations exist?**
   - Yes
   - No

**Risk reduction**

1. **Can the risk be reduced by administrative controls/other protective measures?**
   - Yes
   - No
2. **Can the risk be reduced by guards, protective devices?**
   - Yes
   - No
3. **Can the hazard be eliminated or the risk be reduced by design?**
   - Yes
   - No

**Documentation (see clause 9)**

END
R15.06 Process

Intended Use (9.1)

Task/Hazard Identification (9.2)

Risk Estimation (9.3)

Risk Reduction Determination (9.4)

Safeguard Selection (9.5)

Validation (9.6)

Tolerable Risk?

NO

YES

Finish (9.7)

R15.06 Matrix

<table>
<thead>
<tr>
<th>SEVERITY OF INJURY</th>
<th>EXPOSURE</th>
<th>AVOIDANCE</th>
<th>RISK REDUCTION CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2 Serious Injury</td>
<td>E2 Frequent exposure</td>
<td>A2 Not Likely</td>
<td>R1</td>
</tr>
<tr>
<td></td>
<td>E1 Infrequent exposure</td>
<td>A1 Likely</td>
<td>R2A</td>
</tr>
<tr>
<td>More than</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-aid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1 Slight Injury</td>
<td>E2 Frequent exposure</td>
<td>A2 Not Likely</td>
<td>R2C</td>
</tr>
<tr>
<td></td>
<td>E1 Infrequent exposure</td>
<td>A1 Likely</td>
<td>R3A</td>
</tr>
<tr>
<td>First-aid</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 – Risk reduction decision matrix prior to safeguard selection
### B11 TR3 Matrix

<table>
<thead>
<tr>
<th>Probability of Occurrence of Harm</th>
<th>Severity of Harm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catastrophic</td>
<td>Serious</td>
</tr>
<tr>
<td>Serious</td>
<td>Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td>Minor</td>
</tr>
<tr>
<td>Very Likely</td>
<td>High</td>
</tr>
<tr>
<td>Likely</td>
<td>High</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Medium</td>
</tr>
<tr>
<td>Remote</td>
<td>Low</td>
</tr>
<tr>
<td>Likely</td>
<td>High</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Medium</td>
</tr>
<tr>
<td>Remote</td>
<td>Low</td>
</tr>
<tr>
<td>Likely</td>
<td>High</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Low</td>
</tr>
<tr>
<td>Remote</td>
<td>Negligible</td>
</tr>
<tr>
<td>Likely</td>
<td>High</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Low</td>
</tr>
<tr>
<td>Remote</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

### MIL-STD-882D Matrix

<table>
<thead>
<tr>
<th>Category Frequency</th>
<th>(1) Catastrophic</th>
<th>(2) Critical</th>
<th>(3) Marginal</th>
<th>(4) Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Frequent (X &gt; 10^3)</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td></td>
</tr>
<tr>
<td>(B) Probable (10^3 &gt; X &gt; 10^3)</td>
<td>Red</td>
<td>Yellow</td>
<td>Yellow</td>
<td></td>
</tr>
<tr>
<td>(C) Occasional (10^2 &gt; X &gt; 10)</td>
<td>Red</td>
<td>Yellow</td>
<td>Yellow</td>
<td></td>
</tr>
<tr>
<td>(D) Remote (10 &gt; X &gt; 10^1)</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Yellow</td>
<td></td>
</tr>
<tr>
<td>(E) Improbable (10 &gt; X)</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Yellow</td>
<td></td>
</tr>
</tbody>
</table>

- **Red**: UNACCEPTABLE
- **Yellow**: UNDESIRABLE
- **Orange**: ACCEPTABLE WITH REVIEW
- **Gray**: ACCEPTABLE WITHOUT REVIEW
Benefits of Risk Assessment

- Participation
  - Makes everyone familiar with the safety requirements of the equipment and process
  - Heightened awareness of hazards presented by a robotics cell
  - Identifies potential tasks and hazards
  - Identifies safeguarding requirements
- Documentation
  - Facilitates improved safeguarding
  - Provides for procedures
    - Lockout
    - Safe operating practices
    - Design-In process for future equipment design

Return on Investment

- Improved productivity
  - faster to production
  - better up time
- less cost
  - fewer retrofits

“Getting it right the first time”
A word about product liability...

- Who should be concerned
  - integrators / suppliers
  - employers are shielded
- Documentation challenges
  - be sharp
  - legal counsel

Bottom line: risk assessment is required

Conducting the Risk Assessment

- Assemble team: operators, skilled trades, managers and safety persons
- Evaluate all tasks, identify all hazards
- Notify appropriate safety personnel of any previously unknown hazards
- Determine severity, frequency, and avoidance
- Review data; select safeguards
- Complete any additional cells by comparing cells and gathering difference info from team members on the floor
- Complete and document Risk Assessment
- Identify design-in possibilities for Design-In personnel
Risk Assessment Input to Design-In Safety

Risk Assessments from all plants go into a master data base.

Designer selects components for new cell and pulls tasks and hazards associated with the equipment from master data base.

All parties review designer recommendations to eliminate hazards, reduce risk, and verify risk assessment compliance.

ANSI/RIA R15.06-1999
American National Standard – for Industrial Robots and Robot Systems – Safety Requirements
Selecting Your Safeguarding Strategy

The ANSI/RIA R15.06-1999 robot safety standard requires (in § 7.5) users to select a safeguarding strategy that identifies and controls hazards, including process-specific hazards, by either:

- installing the prescribed safeguarding (Clause 8),

or

- conducting a risk assessment (Clause 9)

and then installing the appropriate safeguards to control the identified hazards (Clause 10)

Logic Flow of R15.06

Clause 1 - Scope, purpose, application and exclusions
Clause 2 - Normative references
Clause 3 - Definitions
Clause 4 - Manufacture, remanufacture, and rebuild of robots
Clause 6 - Installation of robots and robot systems
Clause 7 - Safeguarding of personnel - Introduction
Clause 8 - Safeguarding of personnel - Prescribed method
Clause 9 - Safeguarding of personnel - Risk assessment method
Clause 10 - Safeguarding of personnel - Procedures
Clause 11 - Safeguarding devices - Application Requirements
Clause 12 - Maintenance of robots and robot systems
Clause 13 - Testing and start-up of robots and robot systems
Clause 14 - Safety training of personnel
The Standard Writing Challenge

- Open Issues in 1992 edition of R15.06
  - How to do a risk assessment?
  - What are the goals of risk assessment?
  - Documentation?
- Response
  - Give risk assessment goals with a “how to” guide in the Annex
  - Add matrix setting criteria for safeguards based on risk and hazard; and specific limitations for programming, teaching, and operating capability

The Result

- Risk Assessment ties back into installer/user requirements of safeguards —
The Result

- Risk Assessment ties back into installer/user requirements of safeguards — but Risk Assessment selects the risk reduction category and the control circuit reliability

R15.06 Process

- Intended Use (9.1)
- Task/Hazard Identification (9.2)
- Risk Estimation (9.3)
- Risk Reduction Determination (9.4)
- Safeguard Selection (9.5)
- Tolerable Risk?
- Validation (9.6)
- Finish (9.7)
Preparation

- Assemble the team
  - Operator(s)
  - Maintainers/skilled trades
  - Engineers/management
- Set up the room
- Facilitator
- Documentation
Preparation

- Assemble the team
  - Operator(s)
  - Maintainers/skilled trades
  - Engineers/management
- Set up the room
- Facilitator
- Documentation
<table>
<thead>
<tr>
<th>Sequence No.</th>
<th>Task Description</th>
<th>Hazards</th>
<th>Severity</th>
<th>Exposure</th>
<th>Avoidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 or S2</td>
<td></td>
<td>E1 or E2</td>
<td></td>
<td>A1 or A2</td>
<td></td>
</tr>
<tr>
<td>§9.5</td>
<td></td>
<td>E1 or E2</td>
<td></td>
<td>A1 or A2</td>
<td></td>
</tr>
<tr>
<td>§9.5</td>
<td></td>
<td>E1 or E2</td>
<td></td>
<td>A1 or A2</td>
<td></td>
</tr>
</tbody>
</table>
Robot Risk Assessment Software

R15.06 Process

- Intended Use (9.1)
- Task/Hazard Identification (9.2)
- Risk Estimation (9.3)
- Risk Reduction Determination (9.4)
- Safeguard Selection (9.5)
- Validation (9.6)
- Tolerable Risk?
  - NO
  - YES
- Finish (9.7)
Define Intended Use

- Describe the application
- Describe the process
- Define the stage of development
- Define who need access to the robot
- Define who needs protection
- Define the limits associated with the robot, system and its intended use

Implementation Stages

- Design/development
- Integration/installation
- Verification/testing
- **Production operation**
- Maintenance
- Training
- Research and development
- Re-application
- De-commissioning
Define Intended Use

- Describe the application
- Describe the process
- Define the stage of development
- Define who needs access to the robot
- Define who needs protection
- Define the limits associated with the robot, system and its intended use

R15.06 Process

Intended Use (9.1)
Task/Hazard Identification (9.2)
Risk Estimation (9.3)
Risk Reduction Determination (9.4)
Safeguard Selection (9.5)
Tolerable Risk ?
NO
YES
Finish (9.7)
Validation (9.6)
Task/Hazard Identification

- Identify all reasonably foreseeable tasks associated with the robot and robot system and the stage of development
- Identify hazards associated with each task
- Repeat until all task/hazard combinations are determined
- Teach tasks require specific protection

Hazards

- Moving components
- Trapping or crushing
- Power sources
- Stored Energy
- Hazardous materials or atmospheres
- Loose objects, projectiles
- Interference – EMC Electromagnetic compatibility
- Vibration, shock
- Ergonomics
- Slips, trips and falls
- Moving, handling
- Protective failures
- Noise
- Inadvertent operation
- Actions by personnel
- Human errors – design, development, construction
Task/Hazard Identification

- Identify all reasonably foreseeable tasks associated with the robot and robot system and the stage of development
- Identify hazards associated with each task
- Repeat until all task/hazard combinations are determined
- Teach tasks require specific protection

R15.06 Process

Intended Use (9.1) → Task/Hazard Identification (9.2) → Risk Estimation (9.3) → Risk Reduction Determination (9.4) → Safeguard Selection (9.5) → Tolerable Risk? → NO → Finish (9.7) → YES → Validation (9.6)
## Risk Estimation

<table>
<thead>
<tr>
<th>Factor</th>
<th>Category</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Severity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>Serious Injury</td>
<td>Normally irreversible; or fatality; or requires more than first-aid as defined in OSHA §1904.12</td>
</tr>
<tr>
<td>S1</td>
<td>Slight Injury</td>
<td>Normally reversible; or requires only first-aid as defined in OSHA §1904.12</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E2</td>
<td>Frequent exposure</td>
<td>Typically exposure to the hazard more than once per hour</td>
</tr>
<tr>
<td>E1</td>
<td>Infrequent exposure</td>
<td>Typically exposure to the hazard less than once per day or shift</td>
</tr>
<tr>
<td><strong>Avoidance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Not Likely</td>
<td>Cannot move out of way; or inadequate reaction time; or robot speed greater than 250 mm/sec</td>
</tr>
<tr>
<td>A1</td>
<td>Likely</td>
<td>Can move out of way; or sufficient warning/reaction time; or robot speed less than 250 mm/sec</td>
</tr>
</tbody>
</table>

Table 1 – Hazard Severity/Exposure/Avoidance Categories
§1904.12 Definitions

(e) *First Aid* is any one-time treatment, and any follow-up visit for the purpose of observation, or minor scratches, cuts, burns, splinters, and so forth, which do not ordinarily require medical care. Such one-time treatment, and follow-up visit for the purpose of observation, is considered first aid even though provided by a physician or registered professional personnel.

OSHA reportable

### Risk Estimation

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<th>Criteria</th>
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</thead>
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<td>S2</td>
<td>Serious Injury Normally irreversible; or fatality; or requires more than first-aid as defined in OSHA §1904.12</td>
</tr>
<tr>
<td></td>
<td>S1</td>
<td>Slight Injury Normally reversible; or requires only first-aid as defined in OSHA §1904.12</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
<td>E2</td>
<td>Frequent exposure Typically exposure to the hazard more than once per hour</td>
</tr>
<tr>
<td></td>
<td>E1</td>
<td>Infrequent exposure Typically exposure to the hazard less than once per day or shift</td>
</tr>
<tr>
<td><strong>Avoidance</strong></td>
<td>A2</td>
<td>Not Likely Cannot move out of way; or inadequate reaction time; or robot speed greater than 250 mm/sec</td>
</tr>
<tr>
<td></td>
<td>A1</td>
<td>Likely Can move out of way; or sufficient warning/reaction time; or robot speed less than 250 mm/sec</td>
</tr>
</tbody>
</table>

Table 1 – Hazard Severity/Exposure/Avoidance Categories
## Risk Estimation

<table>
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<tr>
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<th>Category</th>
<th>Criteria</th>
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<tr>
<td>S1</td>
<td>Slight Injury</td>
<td>Normally reversible; or requires only first-aid as defined in OSHA §1904.12</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
<td></td>
<td></td>
</tr>
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<td><strong>Avoidance</strong></td>
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<td></td>
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<tr>
<td>A1</td>
<td>Likely</td>
<td>Can move out of way; or sufficient warning/reaction time; or robot speed less than 250 mm/sec</td>
</tr>
</tbody>
</table>

Table 1 – Hazard Severity/Exposure/Avoidance Categories

### R15.06 Process

1. **Intended Use (9.1)**
2. **Task/Hazard Identification (9.2)**
3. **Risk Estimation (9.3)**
4. **Risk Reduction Determination (9.4)**
5. **Safeguard Selection (9.5)**
6. **Validation (9.6)**
7. **Tolerable Risk?**
   - **NO**
   - **YES**
8. **Finish (9.7)**
# Risk Reduction Determination

<table>
<thead>
<tr>
<th>SEVERITY OF INJURY</th>
<th>EXPOSURE</th>
<th>AVOIDANCE</th>
<th>RISK REDUCTION CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S2 Serious Injury</strong></td>
<td>E2 Frequent exposure</td>
<td>A2 Not Likely</td>
<td>R1</td>
</tr>
<tr>
<td>More than First-aid</td>
<td>E1 Infrequent exposure</td>
<td>A1 Likely</td>
<td>R2A</td>
</tr>
<tr>
<td><strong>S1 Slight Injury</strong></td>
<td>E2 Frequent exposure</td>
<td>A2 Not Likely</td>
<td>R2C</td>
</tr>
<tr>
<td>First-aid</td>
<td>E1 Infrequent exposure</td>
<td>A1 Likely</td>
<td>R3A</td>
</tr>
</tbody>
</table>

Table 2 – Risk reduction decision matrix prior to safeguard selection
R15.06 Process

Intended Use (9.1)

Task/Hazard Identification (9.2)

Risk Estimation (9.3)

Risk Reduction Determination (9.4)

Safeguard Selection (9.5)

Safeguard Selection

CATEGRO | SAFEGUARD PERFORMANCE | CIRCUIT PERFORMANCE
--- | --- | ---
R1 | Hazard elimination or hazard substitution (9.5.1) | Control reliable (4.5.4)
R2A | Engineering controls preventing access to the hazard, or stopping the hazard (9.5.2), e.g. interlocked barrier guards, light curtains, safety mats, or other presence sensing devices (10.4) | Control reliable (4.5.4)
R2B | Single channel (4.5.2) |
R2C | Single channel (4.5.2) |
R3A | Non-interlocked barriers, clearance, procedures and equipment (9.5.3) | Single channel (4.5.2)
R3B | Simple (4.5.1) |
R4 | Awareness Means (9.5.4) | Simple (4.5.1)

Table 3 – Safeguard Selection Matrix
Table 3 – Safeguard Selection Matrix

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>SAFEGUARD PERFORMANCE</th>
<th>CIRCUIT PERFORMANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Hazard elimination or hazard substitution (9.5.1)</td>
<td>Control reliable (4.5.4)</td>
</tr>
<tr>
<td>R2A</td>
<td>Engineering controls preventing access to the hazard, or stopping the hazard (9.5.2), e.g. interlocked barrier guards, light curtains, safety mats, or other presence sensing devices (10.4)</td>
<td>Control reliable (4.5.4)</td>
</tr>
<tr>
<td>R2B</td>
<td></td>
<td>Single channel with monitoring (4.5.3)</td>
</tr>
<tr>
<td>R2C</td>
<td></td>
<td>Single channel (4.5.2)</td>
</tr>
<tr>
<td>R3A</td>
<td>Non-interlocked barriers, clearance, procedures and equipment (9.5.3)</td>
<td>Single channel (4.5.2)</td>
</tr>
<tr>
<td>R3B</td>
<td></td>
<td>Simple (4.5.1)</td>
</tr>
<tr>
<td>R4</td>
<td>Awareness Means (9.5.4)</td>
<td>Simple (4.5.1)</td>
</tr>
</tbody>
</table>

Hierarchy of Safeguarding Controls

1) Elimination or Substitution
   - change the process to eliminate human interaction
   - elimination of pinch points (increase clearances)
   - automated material handling

2) Engineering Controls (Safeguarding Technology)
   - mechanical hard stops
   - barriers
   - interlocks
   - presence sensing devices
   - two hand controls

3) Awareness Means
   - lights, beacons and strobes
   - computer warnings
   - signs
   - painted marking of the restricted space on floor
   - barriers
   - horns
   - labels

4) Training and Procedures (Administrative Controls)
   - safe job procedures
   - safety equipment inspections
   - training
   - lockout

5) Personal Protective Equipment
   - safety glasses
   - ear plugs
   - face shields
   - gloves
   - hard hats
Safeguard Selection

<table>
<thead>
<tr>
<th>CATEGROY</th>
<th>SAFEGUARD PERFORMANCE</th>
<th>CIRCUIT PERFORMANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Hazard elimination or hazard substitution (9.5.1)</td>
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</tr>
<tr>
<td>R2A</td>
<td>Engineering controls preventing access to the hazard, or stopping the hazard (9.5.2), e.g. interlocked barrier guards, light curtains, safety mats, or other presence sensing devices (10.4)</td>
<td>Control reliable (4.5.4)</td>
</tr>
<tr>
<td>R2B</td>
<td>Non-interlocked barriers, procedures and equipment (9.5.3)</td>
<td>Single channel with monitoring (4.5.2)</td>
</tr>
<tr>
<td>R2C</td>
<td>Simple (4.5.1)</td>
<td>Single channel (4.5.2)</td>
</tr>
<tr>
<td>R3A</td>
<td>Simple (4.5.1)</td>
<td>Simple (4.5.1)</td>
</tr>
<tr>
<td>R4</td>
<td>Awareness Means (9.5.4)</td>
<td>Simple (4.5.1)</td>
</tr>
</tbody>
</table>

Table 3 – Safeguard Selection Matrix

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<table>
<thead>
<tr>
<th>Safeguard Performance</th>
<th>Risk Reduction Lines</th>
<th>Circuit Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard elimination</td>
<td>R1</td>
<td>Control reliable (4) 3(6) 3(6) 2(7)</td>
</tr>
<tr>
<td>R2A</td>
<td>Control reliable</td>
<td>(6) 3(6) 3(6) 2(7)</td>
</tr>
<tr>
<td>R2B</td>
<td>Single channel</td>
<td>2 c 2(4) 1</td>
</tr>
<tr>
<td>R2C</td>
<td>Single channel</td>
<td>1 c 1</td>
</tr>
<tr>
<td>Non-interlocked barriers, procedures and equipment</td>
<td>R3A</td>
<td>Single channel 1 b 1</td>
</tr>
<tr>
<td>R3B</td>
<td>Simple B b 1</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>Simple B a n/a</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 – Safeguard Selection Matrix
Selecting the Proper Safeguarding Devices

- Prevent access to the hazard
- Cause the hazard to cease before access
- Prevent unintended operation
- Contain parts and tooling
  - Loose objects, flying projectiles
- Control other process hazards
  - Noise, laser, radiation

R15.06 Process

- Intended Use (9.1)
- Task/Hazard Identification (9.2)
- Risk Estimation (9.3)
- Risk Reduction Determination (9.4)
- Safeguard Selection (9.5)
- Validation (9.6)
- Finish (9.7)
### Table 4 – Safeguard selection validation matrix with safeguards installed

<table>
<thead>
<tr>
<th>EXPOSURE</th>
<th>AVOIDANCE</th>
<th>SEVERITY OF INJURY</th>
<th>RISK REDUCTION CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E2 Frequent Exposure</strong></td>
<td>A2 Not Likely</td>
<td>S2 Serious Injury</td>
<td>R1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S1 Slight Injury</td>
<td>R2C</td>
</tr>
<tr>
<td></td>
<td>A1 Likely</td>
<td>S2 Serious Injury</td>
<td>R2A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S1 Slight Injury</td>
<td>R3A</td>
</tr>
<tr>
<td><strong>E1 Infrequent Exposure</strong></td>
<td>A2 Not Likely</td>
<td>S2 Serious Injury</td>
<td>R2B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S1 Slight Injury</td>
<td>R3B</td>
</tr>
<tr>
<td></td>
<td>A1 Likely</td>
<td>S2 Serious Injury</td>
<td>R3A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S1 Slight Injury</td>
<td>R4</td>
</tr>
</tbody>
</table>
Tolerable Risk - Definitions

adj  1 : capable of being borne or endured
      2 : moderately good or agreeable
      : PASSABLE

Risk Reduction Category R3 or R4 after applying appropriate additional safeguards to control residual risk
The concept of risk reduction using protective measures including safety functions.

- **INSIGNIFICANT**
- **LOW**
- **MODERATE**
- **HIGH**
- **EXTREME**

**RISK**

*Concept of risk reduction using protective measures including safety functions.*
Safeguarding Device Application

- Cell enabling device
- Safety mat
- Safety Light Curtain
- Operators panel
- Safety Distance
- Light curtain status
- Restricted Space
- Hard stop
- Safety mats
- Safety mats
- Building column
- Fencing
- Tip dresser
- Interlocked gate
- Operating Space
- Lockable gate box
- Clearance
- Teach pendant with enabling device
- Key box
- Lockable Disconnect
- Lockable air and water shutoffs
- Robot controller
- Emergency stop buttons

Questions?