Machine Guarding Risk Assessment

One Approach

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NOG-L Industrial Health & Safety
Risk Assessment

• “The process by which the intended use of the machine, the tasks and hazards, the level of risk are determined”.
  
  • ANSI B11.0-2010, Safety of Machinery – General Requirements and Risk Assessment

• A future key attribute and skill safety professionals will need to possess

• This presentation details methods used to accomplish this task at Babcock & Wilcox Nuclear Operations Group – Lynchburg, VA (NOG-L)
Topics of Discussion

- Preparing for risk assessments
- Examples of risk assessment methods
- Tips for conducting risk assessments
- Abatement and management of risk
- Sources of help – the “Prevention through Design” (PtD) tool box
- Conclusions based on our experiences
“The Babcock & Wilcox Nuclear Operations Group – Lynchburg site principally manufactures naval reactors for submarines and aircraft carriers”.

As such we cannot provide examples or exact information regarding some of our successes.

USS Nautilus, world’s first nuclear-powered submarine
Getting Started

• Obtain management support
• Assemble an effective “Tool Box”
  ‣ A Prevention through Design (PtD) principle
  ‣ Valuable resources for effective hazard assessment performance, documentation and confirmation of results
  ‣ Several recommendations will be provided
• Choose an analysis method that suits the desired level of detail to demonstrate analysis rationale, results and recommendations
• Prepare for conducting risk assessment
Risk Assessment Preparation

• What are we trying to accomplish?
  ‣ Assure safe use of industrial machinery
  ‣ Protect/maintain valuable resources
  ‣ Reduce product damage
  ‣ Assure effective operation
  ‣ Reduce downtime and maintenance costs
  ‣ Reduce regulatory liability
  ‣ Arrive at an “acceptable” (“The risk level achieved after risk reduction measures have been applied - ANSI B11.0-2010) or “tolerable” risk (“risk that is acceptable for a given task and hazard combination” – ANSI B11.TR3-2000)
Risk Assessment Preparation Cont’d

• Establish assessment limit or depth of analysis
  ‣ NOG-L: Meet OSHA point-of-operation regulations:
    • Fixed barriers
    • Interlocked guards
    • Guarding devices in conformance with appropriate standards;
      – In the absence of specific standards, designed and constructed to
        prevent the operator from having any part of their body in the
        danger zone during operating cycles.
  ‣ Considerations:
    • Risk/reduction benefit
    • Technological feasibility
    • Economic feasibility
    • Durability and maintainability
    • Usability
    • Productivity and quality
Risk Assessment Preparation Cont’d

• Situations requiring risk assessments:
  ‣ Machines that present more than an acceptable risk
  ‣ Personnel exposure to point-of-operation with credence to:
    • Frequency & duration of exposure
    • Number of personnel exposed
    • Hazard avoidance
    • Level of training, skill and experience, etc.
  ‣ Machinery with prior incident history
  ‣ Onsite designed equipment
  ‣ Purchase of used equipment
  ‣ Machines that incorporate presence-sensing devices
Risk Assessment Preparation Cont’d

• Establish a Machine Guarding Committee
  ‣ Chair with authority, Manager of Manufacturing Improvement Engineering
  ‣ Industrial Engineering (Facilities)
  ‣ Electronics and controls expert
  ‣ Product engineering
  ‣ Tooling & design
  ‣ Industrial Health and Safety
  ‣ Appropriate site management
  ‣ Operators and affected personnel
  ‣ Human Performance Employee Teams (HPETs)
Risk Assessment Preparation Cont’d

- Procedure Elements for Performance of RA
  - Applicability & Purpose
  - Process to Conduct Assessments
  - Assessment Methodology and Guidelines
  - Identification of Machine & Process Specifications and Related Hazards
  - Methods to Reduce Risk
  - Regulations, Standards and Other Sources of Information Related to Assessing Machine Guarding
  - Manufacturer’s Machine Assessments
  - Responsibilities
  - Techniques that can be utilized
Risk Assessment Preparation Cont’d

Administrative Procedure for RA Performance

1. Determine Limits of Machinery
2. Identify Tasks & Hazards
3. Estimate Risk

- Has tolerable risk been achieved?
  - Yes: Risk Assessment
  - No: Reduce risk by:
    - Design
    - Safeguarding
    - Protective devices
    - Administrative Controls

- Can hazard be eliminated or reduced?
  - Yes: Reduce risk by:
  - No: Re-evaluate machine limits

- Do other task/hazard combinations exist?
  - Yes: Validate solutions
  - No: Process assessment

Source: ANSI B11.TR3-2000
Some risk assessment preparation methods implemented
## Risk Assessment Preparation Cont’d

- MG Committee documentation
  - Presentation of recommendations for compliance

<table>
<thead>
<tr>
<th>Manager &amp; Area</th>
<th>Machine (s/n)</th>
<th>Hazard Site</th>
<th>Recommended Actions</th>
<th>Qty</th>
<th>Material Cost</th>
<th>Guard Fab Hours</th>
<th>Installation Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT Quagmire Bldg 1</td>
<td>PDQ Lathe</td>
<td>Chuck</td>
<td>Purchase chuck guard #1 (XYZ catalog pp 58)</td>
<td>1</td>
<td>$140</td>
<td>NA</td>
<td>4 hrs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spindle bore</td>
<td>Spindle bore Cap (B&amp;W fab drwg # 567)</td>
<td>1</td>
<td>$50</td>
<td>8 hrs</td>
<td>1 hr</td>
</tr>
<tr>
<td>Knee Mill</td>
<td>Point-of-op.</td>
<td>Risk assessment required</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td></td>
</tr>
<tr>
<td>PT Quagmire Total</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>$190</td>
<td>8hrs</td>
<td>5 hrs</td>
</tr>
</tbody>
</table>
Risk Assessment Preparation Cont’d

- Site Communication and Recommended Details
  - Importance of assisting the MG Committee obtain an accurate understanding of machine processes
  - Personnel may be asked to describe or demonstrate tasks
  - An opportunity to recommend improvements
  - Committee evaluations designed to provide improvement on several fronts if warranted
  - Advertised a “pilot program” to obtain feedback; an opportunity garner ownership
Risk Assessment Preparation Cont’d

Machine Guarding Pilot & Comment Form for Drill Presses

**Purpose:** This form is designed to gauge the impact of machine guarding from several perspectives indentified below. The machine pictured to the right shows a proposed guard:
- Shield guard – provides operator protection from the rotating chuck and point-of-operation. The guard is adjustable.

<table>
<thead>
<tr>
<th>Guard Impact (evaluate the categories below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Hazards</td>
</tr>
<tr>
<td>□ Acceptable</td>
</tr>
</tbody>
</table>

Recommendations: Recommendations: Recommendations: Recommendations:

Use back of form if necessary

**Overall Evaluation**
- □ Acceptable
- □ Unacceptable
- □ Acceptable with recommendation implementation
- □ Other:

Commentator’s Name (Print): Organization & location Phone:

Machine Guarding Committee Review: Date:
Risk Assessment Preparation Cont’d

• Establishing rank (priority) to guard/assess

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**ANSI/RIA R15.06-1999 format**
Conducting Assessments Process

- Responsibilities and Actions:
  - Purchasing/Procurement
  - Machine/Process Owner
  - Occupational Safety & Health (Safety)
  - Machine Guarding Committee
  - Management
  - Employees
Conducting Assessments Process Cont’d

**Purchasing:**
- Requests hazard documentation/risk assessment (ISO 12100:2010)
- Provides data to machine/process owner

**Machine/Process Owner:**
- Provides equipment data to safety (materials used/produced; related equipment; interaction with existing processes; supplier services; etc.)
- Risk assessment copy

**Safety:**
- Reviews data & specifications
- Performs initial risk assessment
- Distributes draft assessment to Machine Guarding Committee (MGC)

**MGC:**
- Reviews, discusses & approves draft

**Safety:**
- Acts on recommendations
- Distributes assessment to:
  - Management owners for accuracy and implementation determination
  - Maintenance for installation & maintenance schedules

**Management:**
- Reviews and distributes assessment to affected employees for comments/buy-in, hazard awareness, training
- Provides feedback to MGC
Conducting Assessments Process Cont’d

**MGC:**
- Reviews assessment comments
- Schedules meeting to finalize assessment
- Seeks management approval to publish by signature

**Management:**
- Distributes final assessment report to operators/affected personnel for buy-in
- Implements assessment requirements/recommendations
- Assure machine/equipment is functionally maintained and effective

**Employees:**
- Utilizes guards, procedures and recommendations

**Safety:**
- Files & publishes assessment report
- Maintains report

**Safety:**
Periodically reviews machine guarding effectiveness against assessment report
Machine Guarding Risk Assessment Techniques
Machine Guarding Assessment Techniques

- ANSI Z690.3-2011, “Risk Assessment Techniques”:
  - Annex A – risk assessment comparison, describes relevance of influencing factors (resources, capability, nature and degree of uncertainty, complexity and ability to provide quantitative output
  - Annex B – provides an overview of several techniques, how to use them, process descriptions, outputs, strengths and limitations
Assessment Techniques Continued

- Techniques are subjective, qualitative approach to identify, document and abate or manage machine hazards
- Technique chosen dependent on:
  - The observation of tasks being performed (complexity)
  - Hazards personnel may be exposed to (need to provide specific information or guidance)
  - Best method to accurately identify hazards
  - Providing the best method to document/display recommendations
Assessment Techniques Continued

• The goal of this process is to:
  ‣ Recommend safeguards that will reduce risks to acceptable/tolerable levels or
  ‣ Identify conditions or recommendations requiring management acknowledgement for consideration as an acceptable risk or a risk that requires more attention to resolve.
Assessment Techniques Continued

• Assessment spinoffs:
  ‣ Job Safety Analyses (JSAs)
  ‣ OSHA Voluntary Protection Program (VPP)
  ‣ ISO 18001: Occupational Health and Safety Management
  ‣ ISO 9000 Quality Management System
  ‣ Formal equipment evaluation
  ‣ Operating and maintenance instructions
  ‣ Personnel training, “tool box” meetings and other similar applications.
Assessment Techniques Continued

• Criteria used:
  ‣ Establish a baseline, assuming no safety controls exist by assigning values for appropriate risk category & parameter
  ‣ Risk category and color codes:
    • Negligible
    • Acceptable
    • Moderate
    • Substantial
    • Intolerable

• Parameters:
  • Event outcome
  • Task frequency
  • Severity
  • Likelihood of occurrence
  • Degree of equipment damage
  • Production effects
  • Regulatory compliance
Assessment Techniques Continued

- Parameter examples:

<table>
<thead>
<tr>
<th>Risk Category → Parameter ↓</th>
<th>Negligible</th>
<th>Acceptable</th>
<th>Moderate</th>
<th>Substantial</th>
<th>Intolerable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury Severity</td>
<td>None</td>
<td>None</td>
<td>First Aid</td>
<td>Medical Treatment</td>
<td>Lost Time, Full Recovery</td>
</tr>
<tr>
<td>Production Effects</td>
<td>None</td>
<td>Slight recoverable delay</td>
<td>Production interruption</td>
<td>Production shutdown</td>
<td>Production shutdown</td>
</tr>
<tr>
<td>Equipment Damage</td>
<td>No damage</td>
<td>Little to no damage</td>
<td>Damage requiring intervention to resume</td>
<td>Damage that prevents operation</td>
<td>Extensive damage requiring equipment replacement</td>
</tr>
</tbody>
</table>
**Assessment Techniques Continued**

- **Example:**

<table>
<thead>
<tr>
<th>Job Step/Task</th>
<th>Hazard</th>
<th>Frequency</th>
<th>Severity</th>
<th>Likelihood</th>
<th>Outcome</th>
<th>Abatement Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine maintenance tasks</td>
<td>Crushing injuries upon contact</td>
<td>Once per month</td>
<td>[Red]</td>
<td>[Red]</td>
<td></td>
<td>Work cell is provided with interlocks that disengages power to all equipment when access is attempted. An emergency stop function results.</td>
</tr>
</tbody>
</table>

**Risk Key:**

<table>
<thead>
<tr>
<th>Risk Designation:</th>
<th>Negligible</th>
<th>Acceptable</th>
<th>Moderate</th>
<th>Substantial</th>
<th>Intolerable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Code:</td>
<td>GREEN</td>
<td>LIGHT GREEN</td>
<td>YELLOW</td>
<td>ORANGE</td>
<td>RED</td>
</tr>
</tbody>
</table>
### Assessment Techniques Continued

Military Standard (MIL-STD) 882

<table>
<thead>
<tr>
<th>Probability of Occurrence of Harm</th>
<th>Severity of Harm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Catastrophic</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>
</tbody>
</table>

**Table Definitions:**

<table>
<thead>
<tr>
<th>Probability of Occurrence of Harm</th>
<th>Severity of Harm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Likely – Near certain to occur</td>
<td>Catastrophic: Death or permanent disabling injury or illness. (Unable to return to work). Extensive damage requires equipment replacement</td>
</tr>
<tr>
<td>Likely – May occur</td>
<td>Serious: Permanent and non-reversible injury or illness (able to return to work at some point). Severe damage requiring extensive rework.</td>
</tr>
<tr>
<td>Unlikely – Not likely to occur</td>
<td>Moderate: Permanent and non-reversible minor injury or illness requiring more than first aid (able to return to same job). Damage requiring attention.</td>
</tr>
<tr>
<td>Remote – So unlikely as to be near zero</td>
<td>Minor: No injury or slight injury no more than first aid (little or no lost time). Little to no damage.</td>
</tr>
</tbody>
</table>

**Risk:**

- High – Requires engineered controls to abate hazard
- Medium – Requires engineered controls and administrative controls as required to abate hazard
- Low – Requires at minimum administrative controls as required to abate hazard
- Negligible - Administrative controls may be adequate
Assessment Techniques Continued

**MIL-STD 882 example**

<table>
<thead>
<tr>
<th>No.</th>
<th>Process Step and Hazards/ Rationale: Safeguards and/or Concerns</th>
<th>Risk Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Probability</td>
</tr>
<tr>
<td>1.</td>
<td>Operator’s hands/fingers become entangled in power transmission belts and pulleys</td>
<td>Remote</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk Level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>

**Risk Estimation Rationale:**

- Guards are installed on ballscrews (bellows), transmission belts and pulleys (metal guard)
- Hazard locations are labeled per ANSI standards
- Machine pre-operation checklist requires guarding verification
Assessment Reports

• A report is generated and submitted to area management covering the following topics:
  ‣ Process description
  ‣ Hazard discussion
  ‣ Risk assessment results
  ‣ Recommendations/requirements
  ‣ List of equipment and methods for implementation of recommendations/requirements

• A living document designed to demonstrate safety and verify effectiveness
Assessment Techniques Continued

• Should risk assessment outcome exceed acceptable category, management must:
  ‣ Decide if recommended assessment rationale and controls are acceptable and;
  ‣ Assume risk for task performance based on the risk assessment rationale and recommended abatement methods
Machine Mods Resulting from Assessment

- Machinery Modification
  - Machine’s manufacturer should be consulted to assure anticipated modifications will not void the warranty and will not create unforeseen hazards or production issues.
  - Any machinery modification should be subject to a risk assessment to assure personnel safety and regulatory compliance is not compromised.
  - New use and care requirements as a result of modifications must be incorporated into operating and maintenance procedures.
Tool Box Applications for RA

- Incorporation of mechanical power press guard opening criteria for universal applications: 29 CFR 1910.217 Table 0-10
  - Guard opening Scale

<table>
<thead>
<tr>
<th>Distance of Opening from POO (inches)</th>
<th>Maximum width of opening (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ to 1 ½</td>
<td>¼</td>
</tr>
<tr>
<td>1 ½ to 2 ½</td>
<td>3/8</td>
</tr>
<tr>
<td>2 ½ to 3 ½</td>
<td>½</td>
</tr>
<tr>
<td>3 ½ to 5 ½</td>
<td>5/8</td>
</tr>
<tr>
<td>5 ½ to 6 ½</td>
<td>¾</td>
</tr>
<tr>
<td>6 ½ to 7 ½</td>
<td>7/8</td>
</tr>
<tr>
<td>7 ½ to 12 ½</td>
<td>1 ¼</td>
</tr>
<tr>
<td>12 ½ to 15 ½</td>
<td>1 ½</td>
</tr>
<tr>
<td>15 ½ to 17 ½</td>
<td>1 7/8</td>
</tr>
<tr>
<td>17 ½ to 31 ½</td>
<td>2 1/8</td>
</tr>
</tbody>
</table>

Rockford Systems Inc.
Rockford, IL
Tool Box Applications for RA Continued

• Use of pendants with e-stops
  ‣ Robot teach pendant rationale (ANSI/RIA 15.06, Industrial Robot and Robot Systems Safety Requirements)

• Incorporation of machine “slow” speed control speed < 250 mm/sec (10 in/sec) (ANSI/RIA 15.06)
  ‣ Machine speed/hazard avoidance applied to machine travel
  ‣ Reduced tool changing speeds

• Use of control reliable systems
  ‣ Capability of controls/safeguarding to achieve a safe state in the event of a failure of their safety-related functions
Tool Box Applications for RA Continued

• Use of distance criteria per ANSI B11.19-2010
• Occupying hands through use of controls & devices:
  ‣ Two-hand controls
  ‣ Push-to-run devices
  ‣ Teach pendants
• Implement necessary heights for physical guards criteria
• Operator surveillance
  ‣ Defensive action and control
  ‣ Machine speed/hazard avoidance (distance formulas)
Tool Box Applications for RA Continued

- International Organization for Standardization (ISO) 12100:2010, General Principles for Design – Risk Assessment and Risk Reduction:
  - Provides a framework for safe machines design
  - Allows manufacturers to demonstrate machine’s ability to perform intended functions during life cycle where risk has been adequately reduced
  - Establishes strategy to accomplish objectives
  - “Functional Safety” demonstration
Tool Box Applications for RA Continued

• ISO 12100:2010 step-by-step strategy (in order)
  ‣ Determine limits of machine for intended use and foreseeable misuse
  ‣ Identify hazard and associated hazardous conditions
  ‣ Establish risk for each hazard and associated hazardous condition
  ‣ Evaluate risks and identify risk reduction measures
  ‣ Eliminate hazards or reduce risks

• B&W NOG-L requests information to assure safety and help assure warranty preservation
  ‣ Form letter used to request assessment
Valuable Tool Box Instruments

- Ergonomics: reach limits
  - ANSI B11.19, Performance Criteria for Safeguarding
  - ANSI/RIA 15.06-1999, Industrial Robots and Robot Systems – Safety Requirements
  - CAN/CSA Z434-03(R2013) - Industrial Robots and Robot Systems - General Safety Requirements
Valuable Tool Box Instruments Cont’d

• Machine speeds/physical guards/fixed position:
  ‣ ANSI/RIA 15.06-1999, Industrial Robot and Robot Systems Safety Requirements
  ‣ ANSI B11.19, Performance Criteria for Safeguarding
  ‣ BS EN ISO 13855:2010, Safety of machinery - Positioning of safeguards with respect to the approach speeds of parts of the human body
Valuable Tool Box Instruments Cont’d

- Safe Distance Safeguarding Program for Power Press Brakes
  - OSHA Instruction CPL 2-1.25, Guidelines for Point of Operation of Power Press Brakes
  - Press Brake Safety Compliance Kit, Sheet Metal and Air Conditioning Contractors’ National Association
  - Washington State Department of Labor & Industries WAC 296-806-46508; 46504
Valuable Tool Box Instruments Cont’d

• Minor Servicing and maintenance (routine, repetitive, integral to use)
  ‣ 29 CFR 1910.147 (a)(2)(ii)(B)
  ‣ OSHA Directive CPL02-00-147, The Control of Hazardous Energy – Enforcement Policy and Inspection Procedure
Valuable Tool Box Instruments Cont’d

- General Regulations:
  - OSHA 29 CFR 1910 Subpart O, Machinery and Machine Guarding
  - OSHA 29 CFR 1910 Subpart S, Electrical
Valuable Tool Box Instruments Cont’d

- General Standard References:
  - ANSI B11.0-2010, Safety of Machinery – General Requirements and Risk Assessment
  - ANSI B11.19-2010, Performance Criteria for Safeguarding
  - ANSI/ASSE/ISO Risk Management Standards Z690.1, .2, .3; national adoption of ISO 31000
  - ANSI/ASSE Z590.3-2011, Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes
Valuable Tool Box Instruments Cont’d

• General Standard References Continued:
  - ANSI B11 Series, Standards for Machine Tools Safety Requirements for specified machines
  - NFPA 79, Electrical Standard for Industrial Machinery
Valuable Tool Box Instruments Cont’d

- Guide References (Hazard descriptions, device selection, use and application):
  - *Guidelines for Safe Machinery, Six Steps to a Safe Machine*; SICK Sensor Intelligence
  - *OSHA 3170-2R 2007, Safeguarding Equipment and Protecting Employees from Amputations*
  - Province of Manitoba Workplace Safety and Health Division/Work Safe BC, *Guideline For Safe Machinery and Equipment*. Winnipeg, Manitoba
Valuable Tool Box Instruments Cont’d

• Guide References (Hazard descriptions, device selection, use and application) continued:
  
  ‣ *Guide to Safeguarding Common Machinery and Plant*; Workplace Health and Safety Queensland; Government of Queensland Australia
  
  ‣ *Machine Guarding Major Workplace Hazards*; Government of South Australia
  
Valuable Tool Box Instruments Cont’d

- Guide References (Machine Inspection and Guarding Options):
  - Rockford Systems, Inc. safeguarding catalogs by machine category
  - Lovegreen Risk Management LLC, Machine Safety Surveys
  - Flexbar Machine Corporation Machine Safety Guard System Catalog
  - Siemens Safety Integral Safety Applications
  - Rockwell Automation Safety Products Catalog
  - Ormron Scientific Technologies Inc. Machine & Process Safeguarding (Two volumes)
Conclusions

- Must have resources and management support
- Risk assessment methods and processes must be established to assure uniformity
- Must be creative in some situations
- Need to be a good listener to identify needed details
- Need to be a salesperson
- Hopefully this presentation will provide some insight and assistance in developing or enhancing risk assessment processes for machine guarding
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