Agenda

- Ross Controls Introduction
- Risk Assessment
- Fluid Power Issues
- Fluid Power Solutions
The ROSS Controls Story

- Founded in 1921 by Charlie Ross
- Design, manufacture and sale or pneumatic valves and systems for industrial equipment
- 1954 – First double valve ever developed by ROSS
- 1962 – Developed first pneumatic energy isolation device
- 2005 – DM²™
## Current Committees with ROSS Representation

<table>
<thead>
<tr>
<th>Standard</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI B11.19 Performance Criteria for Safeguarding</td>
<td>Published 2003. Updated 2010</td>
</tr>
<tr>
<td>ANSI B11.0 General Safety Requirements &amp; Risk Assessment</td>
<td>Released 2008, updated 2010</td>
</tr>
<tr>
<td>ANSI Z244 Control of Hazardous Energy - Lockout Tagout</td>
<td>Published 2003, Re-affirmed 2008</td>
</tr>
<tr>
<td>ANSI TR6 Safety Control Systems for Machine Tools</td>
<td>Published 2010</td>
</tr>
<tr>
<td>ANSI B155.1 Packaging and Packaging Related Converting Machinery</td>
<td>Published 2011</td>
</tr>
<tr>
<td>ANSI B11.151 Plastics Machinery</td>
<td>Under revision</td>
</tr>
<tr>
<td>ANSI B11.1 Mechanical Power Press</td>
<td>Published 2009</td>
</tr>
<tr>
<td>ANSI B11.2 Hydraulic and Pneumatic Presses</td>
<td>Under revision, should release in 2012</td>
</tr>
<tr>
<td>CSA Z432 Guarding of Machinery</td>
<td>Published 2004. Updated 2009</td>
</tr>
<tr>
<td>CSA Z460 Control of Hazardous Energy - Lockout - Tagout</td>
<td>Published 2005. Updated 2010</td>
</tr>
</tbody>
</table>
Risk Assessment

Standards requiring risk assessment:

- ANSI A244
- ANSI B11.0
- ANSI B11.19
- ANSI/PMMI B155.1
- RIA 15.06
- CSA Z432
- CSA Z460
- ISO 13849
- ISO 12100
Risk Assessment

• Risk Assessment
  • Task based process
  • Consider severity, frequency, & probability
  • Consider foreseeable misuse & failure modes
Risk Assessment

ANSI B11.0 & B155.1

Task Based Hazard Analysis

Determine:

• People exposed
• Tasks required
• Severity of hazard
• Exposure to the hazard
<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>
Risk Assessment – ANSI B11.0

Catastrophic – death or permanently disabling injury (unable to return to work)
Serious – severe debilitating injury or illness (able to return to work at some time)
Moderate – significant injury or illness requiring more than first aid (able to return to same job)
Minor – no injury or slight injury requiring no more than first aid (little or no lost work time)

Very Likely – near certain to occur
Likely – may occur
Unlikely – not likely to occur
Remote – so unlikely as to be near zero
Table 3 — The Hazard Control Hierarchy

<table>
<thead>
<tr>
<th>Protective Measure</th>
<th>Examples</th>
<th>Influence on Risk Factors</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elimination or Substitution</td>
<td>• Eliminate pinch points (increase clearance)</td>
<td>• Impact on overall risk (elimination) by affecting severity and probability of harm</td>
<td>Design Out</td>
</tr>
<tr>
<td></td>
<td>• Intrinsically safe (energy containment)</td>
<td>• May affect severity of harm, frequency of exposure to the hazard under consideration,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Automated material handling (robots, conveyors, etc.)</td>
<td>and/or the possibility of avoiding or limiting harm depending on which method of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Redesign the process to eliminate or reduce human interaction</td>
<td>substitution is applied.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduced energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Substitute less hazardous chemicals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guards and Safeguarding Devices</td>
<td>• Barriers</td>
<td>• Greatest impact on the probability of harm (Occurrence of hazardous events under</td>
<td>Engineering Controls</td>
</tr>
<tr>
<td></td>
<td>• Interlocks</td>
<td>certain circumstance)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Presence sensing devices (light curtains, safety mats, area scanners,</td>
<td>• Minimal if any impact on severity of harm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Two hand control and two-hand trip devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awareness Devices</td>
<td>• Lights, beacons, and strobes</td>
<td>• Potential impact on the probability of harm (avoidance)</td>
<td>Administrative Controls</td>
</tr>
<tr>
<td></td>
<td>• Computer warnings</td>
<td>• No impact on severity of harm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Signs and labels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Beepers, horns, and sirens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training and Procedures</td>
<td>• Safe work procedures</td>
<td>• Potential impact on the probability of harm (avoidance and/or exposure)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Safety equipment inspections</td>
<td>• No impact on severity of harm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Training</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lockout / Tagout / Tryout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Protective Equipment (PPE)</td>
<td>• Safety glasses and face shields</td>
<td>• Potential impact on the probability of harm (avoidance)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Ear plugs</td>
<td>• No impact on severity of harm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Gloves</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Protective footwear</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Respirators</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Risk Assessment – EN 954

S - Severity of Injury

<table>
<thead>
<tr>
<th>S1</th>
<th>S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight (reversible)</td>
<td>Serious (non-reversible)</td>
</tr>
</tbody>
</table>

Take the worst case injury into account. If this is no more than a slight cut or bruise, then select S1. If the consequences are more severe, up to and including death, then select S2.

F - Frequency & Duration of Exposure

<table>
<thead>
<tr>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seldom</td>
<td>Frequent to continuous and/or long exposure</td>
</tr>
</tbody>
</table>

Select F2 if a person is exposed to the hazard frequently. It is irrelevant whether it is the same person or a different person. Select F1 if access is only required from time to time and the exposure time is short.

P – Possibility of Avoiding the Hazard

<table>
<thead>
<tr>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible under specific conditions</td>
<td>Less possible</td>
</tr>
</tbody>
</table>

Determine the possibility of avoiding the hazard if the monitoring & control devices used (such as light curtains) failed. This is generally related to the speed at which the hazard moves, proximity to the hazard, level of training, and expertise of operators. If, in your opinion, the operator could recognize the hazard and avoid injury, select P1. Otherwise, select P2.

Legend

- **Preferred Category.** Some risk levels offer two selection possibilities. If the equipment is clean and dry and the levels of maintenance and inspection of the safety related system are high, select the lower category. Otherwise, select the higher.

- **Possible Lower Category.** In some applications the designer can select a lower category by using other safeguard measures, such as hard guarding.

- More than required for the relevant risk
## Control Integrity – EN 954

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category B</td>
<td>Basic industrial product</td>
</tr>
<tr>
<td>Category 1</td>
<td>Uses well tried components and well tried safety principles</td>
</tr>
<tr>
<td>Category 2</td>
<td>Function is checked at suitable intervals (start up &amp; prior to initiation of hazardous situation)</td>
</tr>
<tr>
<td>Category 3</td>
<td>A single fault does not lead to the loss of the safety function &amp; must be detected at or before the next demand of the safety function; multiple faults can lead to the loss of the safety function</td>
</tr>
<tr>
<td>Category 4</td>
<td>Multiple faults CANNOT lead to the loss of the safety function</td>
</tr>
</tbody>
</table>
ISO 13849-1:2006 Annex A

Risk Assessment – ISO 13849

Low contribution to Risk Reduction

- S1 - Slight Injury
- S2 - Serious Injury
- F1 - Seldom or Short
- F2 - Frequent or Long
- P1 - Avoidable
- P2 - Unavoidable

High contribution to Risk Reduction
Risk Assessment – ISO 13849

- Performance Level Factors
  - MTTFd - Mean time to dangerous failure
  - DC - Diagnostic Coverage
  - CCF - Common Cause Failure
- Every part of the safety system must be scored
### Risk Reduction Comparison

#### Table 4 — Approximate Relationships Between Levels in ANSI B11.TR6 and Other Relevant Standards

<table>
<thead>
<tr>
<th>Risk Reduction</th>
<th>System Architecture</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI B11.TR6</td>
<td>ANSI B11.0</td>
<td>R1/ R2A</td>
<td>Ethanol</td>
<td>CATEGORY</td>
<td>SIL</td>
<td>Performance Level</td>
<td></td>
</tr>
<tr>
<td>Highest: Requirements of B and the use of well-verified safety principles shall apply. Safety-related parts shall be designed, so that a single fault in any of these parts does not lead to a loss of the safety function, and the single fault is detected at or before the next demand upon the safety function, but that if this detection is not possible, an accumulation of undetected faults shall not lead to loss of the safety function.</td>
<td>Highest: Redundancy w/ continuous self-checking (e.g., Dual channel w/ continuous monitoring)</td>
<td>R1 / R2A (Control reliable)</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate / High: Requirements of B and the use of well-verified safety principles shall apply. Safety-related parts shall be designed, so that a single fault in any of these parts does not lead to a loss of the safety function, and whenever reasonably practicable, the single fault is detected.</td>
<td>Intermediate / High: Redundancy w/ self-checking upon start-up (e.g., Dual channel w/ monitoring at cycle/start-up)</td>
<td>R2A / R2B (Control reliable / Single channel with monitoring)</td>
<td>3</td>
<td>3 to 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low / Intermediate: Requirements of B and the use of well-verified safety principles shall apply. Safety function shall be checked at suitable intervals by the machine control system.</td>
<td>Low / Intermediate: Redundancy that may be manually checked (e.g., Dual channel w/ optional manual monitoring)</td>
<td>R2B / R2C (Single channel with monitoring / Single channel)</td>
<td>2</td>
<td>2 to 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest: Requirements of B shall apply. Well-verified components and well-verified safety principles shall be used.</td>
<td>Lowest: Single channel</td>
<td>R3A (Single channel)</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B: SRP/CS and/or their protective equipment, as well as their components, shall be designed, constructed, selected, assembled and combined in accordance with relevant standards so that they can withstand the expected influence. Basic safety principles shall be used.
OSHA Insight

OSHA Instruction CPL 02-00-147 (Highlights)

- Directive to inspectors to address ANSI Z244.1
- Machine guarding becomes an important economical alternative to LOTO
- Hazardous energy that is present must be released
- Apply this safeguard through a risk assessment process
- Control reliability would provide alternative safeguarding measures
Fluid Power

Risk Assessment

• Function of:
  ◦ Severity
  ◦ Frequency
  ◦ Avoidability
Fluid Power Risk Assessment

Severity  (Assume no guarding)

- Function of:
  - Pressure & force
  - Tooling interface
  - Speed
  - Mass
Fluid Power Risk Assessment

• What is considered severe?

• Per EN 13736 & B11.2 there is a risk of injury if:
  Force > 150 N (33.8 lbf)
  Weight of tooling > 15 kg (33 lbs)

• Requires redundancy &/or monitored restraint

<table>
<thead>
<tr>
<th>Bore &quot;</th>
<th>Area</th>
<th>Force (100)</th>
<th>Force (80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.313</td>
<td>0.0767</td>
<td>7.7</td>
<td>6.1</td>
</tr>
<tr>
<td>0.438</td>
<td>0.1503</td>
<td>15.0</td>
<td>12.0</td>
</tr>
<tr>
<td>0.563</td>
<td>0.2485</td>
<td>24.9</td>
<td>19.9</td>
</tr>
<tr>
<td>0.750</td>
<td>0.4418</td>
<td><strong>44.2</strong></td>
<td><strong>35.3</strong></td>
</tr>
<tr>
<td>0.875</td>
<td>0.6013</td>
<td>60.1</td>
<td>48.1</td>
</tr>
<tr>
<td>1.063</td>
<td>0.8866</td>
<td>88.7</td>
<td>70.9</td>
</tr>
</tbody>
</table>
Fluid Power Risk Assessment

- Frequency
  - Manual operation (Loading or unloading)
  - Jam clearing – How often?
  - Maintenance
Fluid Power Risk Assessment

- Avoidability
  - What is the operational speed?
  - Will there be awareness?
  - With safeguarding:
    - What is the stopping time?
    - Has the safe distance calculation been completed?
    - Has depth of penetration been considered?
Fluid Power Risk Assessment

- Must consider valve failure modes
  - Failure to shift
  - Failure to return
  - Seal leakage
  - Sudden pressure loss
  - Sudden pressurization
  - Slow shifting
Fluid Power Risk Assessment

- Consider contamination effects
Fluid Power Risk Assessment

• Design with desired outcome in mind
  • What happens when solenoid power is removed?

• Consider valve faults and failures
  • Does the cylinder continue moving?
  • Does it not return?
  • Does a load fall?
Two primary desired results:

1. Remove fluid power pressure to prevent movement and a hazard (remove motive force)

2. Trap fluid power to prevent movement and a hazard or use mechanical means
Fluid Power Exhaust

- Remove fluid power pressure
  - Single component
  - Zone
  - Entire machine

What is the risk level & required control integrity?
Fluid Power Exhaust

- Press clutch/brakes require safety valves
  - Dual channel
  - Monitored for fault & diminished performance
Fluid Power Exhaust Circuit
Cylinder Example:
  Force with pneumatic energy?

Vertical or Horizontal?
  Gravity – Weight of Tooling?
  Speed – Inertia to stop?
  Tooling – Crushing?  Piercing?  Cutting?

Stop or retract?
Fluid Power Cylinder Issues

- 4/2 Spring Return valve used for clamping
  - Valve is supplying pressure
  - Cylinder is jammed by a stuck part
  - Part is freed and cylinder moves rapidly to complete its stroke
Fluid Power Cylinder Issues

Jam Example
Double-Acting Cylinder Retracted

Pinched

ROSS
Consider it DONE!
Valve stuck in solenoid on position
No power to solenoid
Cat 1
Cat 4
Control Circuit Logic
Fluid Power Cylinder Issues

• 5/3 Closed Center Valves
  ◦ Trap pressure on both sides of the cylinder
  ◦ Rod side has less area and force
  ◦ Center function is often untested during normal operation of the machine
  ◦ Must be a spool and sleeve type of valve
  ◦ More susceptible to sticking
Fluid Power Cylinder Issues

Vertical Cylinder Example Solution Options:

5/3 Open Center – exhausts both sides
Control reliable exhaust valve – in case 5/3 fails

PO Check – hold load
Monitored PO Check – hold load and monitor
Redundant Monitored PO Check
Mechanical Brake
Load Holding

- Pilot operated check valves
  - Trap pressure downstream when pilot signal is removed
  - Signal can be both pneumatic and electric
  - Removal of trapped pressure
    - Electrical signal
    - Manual signal
    - Tied to lockout valve
  - Available with monitoring feedback
To trapped pressure release valve

Control Valve

Pilot-Operated Check
- Used to trap pressure and maintain cylinder position
- Available with monitoring
Load Holding

- Mechanical Methods
  - Hold platen or tooling
  - Use spring loaded pins or cylinders
  - Typically pneumatically actuated
Load Holding

Cylinder brakes are applied by removing the air pressure

- Rod brake – stops a moving load
- Rod lock – holds load in place
Load Holding

- Mechanical devices are spring return but air actuated
- Not removing the air nullifies the mechanical system
- Control reliable valve ensures air removal
Cylinder Return Function

5/2 CROSSMIRROR

- Dual crossflow spool valve
- Faults to known output condition
- Check valve on inlet
- Fault indicator
Hoze Failure

• Senses hose failure & reduces flow to a safe level
• Prevents hose whip injury & damage

ANSI GSR - 2008 7.11 Machine design shall minimize potential hazards from: Sudden hazardous movement of a hose resulting from leakage or component failure

EU 983-1996/5.3.4.3.2 requires all hoses tubing to be guarded or protected in case of failure

30 CFR 56.13021 & 57.03021 US Mine Safety & Health Administration requires guarding or protection on all hoses ¾” or larger
Safety Valves

What can be done to address pneumatic hazards?

- Remove the motive force – exhaust down stream air
- Selectively trap pressure if needed
  - Provide way to remove pressure
- Use mechanical devices when required
- Maintain the Control Integrity of the safety system
Fluid Power Risk Assessment

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