Robot Palletizing Work Cell

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Introduction

- **Actual** case study, robot work cell in the US.
- System integrator plans a customer requested upgrade, add automated guided vehicles (AGVs) to robot work cell, replace forklifts.
- **Upgrade requires** a review (conformity audit) to current applicable US national safety standards.
- New robot system, operating since 2010, to transfer snack food in process, depalletize / palletize trays and pallets.
Introduction

Verify **robot and electrical safety** compliance with:

- **ANSI / RIA R15.06-2012, Safety Requirements - Industrial Robots and Robot Systems**

- **ANSI / UL1740 (Dec. 7, 2007), Safety Standard - Robots and Robotic Equipment**

- **NFPA 79 (2012) - Electrical Standard for Industrial Machinery**

- **OSHA - Machine safety**
Verify **automated guided vehicle (AGV)** compliance with:

- ANSI / ITSDF B56.5-2012, Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles

- EN 1525 (1998), Safety of industrial trucks - Driverless trucks and their systems
Introduction

- Conducted at the user’s facility, material handling of polymeric trays and pallets.

- **Trays and pallets** are filled with snack food in process.

- User’s plant safety engineers, work cell operators, and service personnel participated.

- Discussion of current **non-compliance items**, applicable safety concepts, planned AGV integration and **possible countermeasures**.
Introduction

• Validated operation of safety functions:
  - E-stops, teach (manual) mode speeds (T1/T2), enabling device, single point of control, intrusion sensing devices, energy isolation LOTO (air, electrical), simulated loss of air, ...

• Operational checks of all safety functions were not possible, due to production.

• Recommendations noted are not the only potential solutions.
Major Work Cell Components

Robotics:

- 4 axis (palletizer) robot in work cell
- Robot controller
- Teach pendant
- Vacuum gripper assembly, dual function for transfer of filled and empty trays and pallets
Major Work Cell Components

Other system components:

4 - Powered **conveyors** for snack food trays and pallets (2 infeed + 2 outfeed), plus a pallet turntable

1 - Robot **pedestal** (approx. 5 feet / 1.52 m) to facilitate robot reach at adjacent conveyors

2 - **Forklift** pick up / drop off locations for operator transfer of trays and pallets *(concept: replace forklifts with AGVs)*

1 - Operator console, HMI process control
Overall work cell, human interface:

- Work cell perimeter guarding, interlocked slide gate, 1 conveyor turntable access door, 2 outfeed tray and pallet access doors
- Forklift delivery of empty trays and pallets, transfer stacked trays and pallets with product
- Light curtains at forklift pallet drop off location and tray infeed conveyor (total 3)
- Operator clears out of position or dropped tray or pallet, and re-stacks; may need cell clean up
Product flow: infeeds, transfers, outfeeds
• **Product flow:** infeeds, transfers, outfeeds
• Work cell “request to enter” (rotary key switch) located inside safeguarded space, behind the slide gate. **No exterior access.**

- It should **not be necessary to enter a hazard zone** to access control actuators. Risk of crush and impact.

- Switch **function and positions** are not identified.
Access to Robot Controls

Recommendations:

a. Relocate “request to enter” rotary switch control outside robot work cell; and

b. Add permanent function identification and operating positions (e.g. “Request to Enter”, “On/Off”) at the selector switch enclosure.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.3.2, 5.3.3]
[UL 1740, Par. 88.2]
[NFPA 79, Par. 10.2.3.1]
Loss of air to end-effector

- Trays and pallets are retained by air powered, dual function end-effectors.

- Loss of air (90 psi / 6 bar) was simulated, separately on a tray and pallet, during auto mode.

- In each case, the payload was retained for 10-15 seconds before dropping or becoming a projectile. Risk of impact injury.
Recommendation:
- **Modify** the end-effector assembly to retain payload after a loss of air pressure - such as pneumatic “power to retain” and “power to release” (preferred); or

- Use a check valve.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.3.10]
[UL 1740, Paragraph 36.4]
Work Cell Egress

- **Egress (ability to exit):**
  - Padlock holes in fence post and slide gate may be used to lock the work cell.

- If a lock is placed in the closed slide gate, and robot system restarted, a person inside work cell **cannot exit** through the locked gate.

Risk of impact and crush.
b. Exterior padlock brackets on 2 access doors, no interior release, prevents egress from inside the work cell.

- A person may be trapped inside the work cell. Risk of impact and crush.

- Relies on training and procedures.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.10.4.5]
Work Cell Egress

Recommendations:

a. **Remove** steel padlock tabs to permit slide gate and doors to be opened from inside the work cell **without a key, tool or power**; or
b. Proceed with **upgrade concept** to:

- **Remove** current slide gate and double doors

- Replace the interlocks with “safety rated” light curtains, assure lowest beam is less than 12 inches (305 mm) above the floor.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.10.5.1]
Axis Limiting Means

- Robot path is restricted only by programmed path (adjustable hardstops are not installed).

- Robot/end-effector/payload can contact the work cell perimeter fence at several locations.

- At other locations, 11.5 inch (292 mm) clearance, less than minimum 20 inch (0.5 m) clearance required by R15.06.
Axis Limiting Means

a. Position error, program error, or program change, robot can crash into or through fence and impact observer(s) outside the work cell.

b. Potential crush/trap point of a teacher inside the work cell, when the robot is in teach or manual mode.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.4.3, 5.5.2, 5.10.2]
[UL 1740, Par. 36.2]
Axis Limiting Means

Recommendations:

- **Obtain and install** OEM adjustable hardstops (screws) at Axes 1 (base), 2 and 3; and

- **Position hardstops** to provide minimum clearance (20 inches / 0.5 m) to structures and equipment not specifically supporting the robot function.

\[
\geq 20 \text{ in. (0.5 m)}
\]
Work Cell Status - Color Code

- Multi-color tower lamps are located above the work cell controller.

- **Color code** does not comply with NFPA 79 - 2012, Table 10.3.2 (machine indicator lights and icons).

- Operators were not aware of the lamp status color codes.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.3.3]
[NFPA 79, Table 10.3.2]
[UL 1740, Par. 36.1]
## Work Cell Status - Color Code

### Table 10.3.2 Machine Indicator Lights and Icons

<table>
<thead>
<tr>
<th>Color</th>
<th>Safety of Persons or Environment</th>
<th>Condition of Process</th>
<th>State of Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>RED</td>
<td>Danger</td>
<td>Emergency</td>
<td>Faulty</td>
</tr>
<tr>
<td>YELLOW (AMBER)</td>
<td>Warning/ Caution</td>
<td>Abnormal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>GREEN</td>
<td>Safe</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>BLUE</td>
<td>Mandatory action</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLEAR WHITE</td>
<td>No specific meaning assigned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAY BLACK</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NFPA 79-2012

- Drive Power Enabled
- E-stop
- Material (pallets) needed

Work cell status multi-color tower lamp with legend plate

### Recommendation:

**Add a **legend plate** near the lamp assembly.**
Work Cell Status

• All work cell status lamps are filament type, 2 lamps are not functional (burned out).

• Screw in / Edison type base is not acceptable, as it may loosen due to vibration (loss of lamp function).

[UL 1740, Par. 36.1]
[ANSI / RIA R15.06-2012, Part 1 - Par. 5.3.3 (Status indication)]
• Tower lamps are subject to process vibration and premature lamp failure.

Recommendations:
Replace the filament type lamps with a non-filament type (such as LED) and bayonet (push and turn) base.

[UL 1740, Par. 36.1]
Work Cell Status

• Status lamps perform a safety function (such as robot servo power is enabled).

Recommendations:

- Automatically check lamps on robot system start up and monitor their operation.

- A safety critical lamp failure requires user notification.

[NFPA 79 (2012), Par. 10.3.1.1]
Access to Robot in Auto Mode

- A 2 7/8 inch (73 mm) gap between HMI cabinet and fence post permits:
  - Reach into robot work cell; and
  - Access to robot/end-effector/payload in auto mode.

Risk of crush and impact.
Access to Turntable in Auto Mode

- A 5 inch (127 mm) gap between light curtain and fence post permits:
  - > 36 inch (914 mm) reach into robot work cell;
  - Access to pallet conveyor turntable rotation in auto mode.

Risk of crush and impact.
12.5 inch (317.5 mm) gap between light curtain and side work cell panel permits:

- **Undetected access** into robot work cell; and

- **Access** to robot end-effector/payload in auto.

Risk of crush and impact.
Access to Moving Hazards in Auto Mode

Recommendation:

- Install, at each gap, a supplemental panel with fasteners, that requires a tool for removal.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.10.4]
[UL 1740, Paragraph 35.2]
[OSHA - Chapter 1 - Basics of Machine Safeguarding]
Emergency movement:

- Customer has **no means or procedures** for robot emergency movement without drive power.
- **Integrator did not provide training** to move the robot without drive power in an emergency (no brake release information).
- A delay, or improper emergency movement (release of wrong axis), can result in **greater injury**.

[ANSI / RIA R15.06-2012, Part 1 - Par. 5.13]
[UL1740, Par. 36.6]
Recommendations:

• **Research and document** proper emergency movement method from the robot manufacturer.

• **Train** personnel in emergency procedures.

• **Post** emergency procedures at the work cell, where readily visible.
Interlock Safety Circuit

- 1 interlocked slide gate and 3 access doors each use a **single** proximity sensor to monitor the work cell perimeter safety function.
- Although the proximity sensors are 2 channel “safety rated” Cat. 4, **only 1 channel was used.**
- A single fault of 1 proximity sensor or 24 v dc normally closed safety circuit **may result in the loss of safety function** (i.e. not detect an open slide gate or door).
Interlock Safety Circuit

Recommendations:

- **Connect** the **second channel** of each proximity sensor to the robot controller safety circuit input; and

- **Perform** operational checks of safety functions for the slide gate and each door, under normal operation and simulated single fault conditions. **Document** the results.

[ANSI / RIA R15.06-2012, Part 2 - Par. 5.4]
• Second channel input connections. **Option**: use a “safety rated” PLC to independently monitor the status of each proximity sensor.

• Use a different (**diverse**) sensing device (e.g. magnetic) to supplement proximity sensors. Integrate with robot controller safety circuit.
Other Observations

• “Span of control” is not provided for multiple conveyor, turntable and robot “local” e-stops. Potential confusion, actuation of incorrect e-stop in an emergency.

• Tool center point (TCP), with end-effector, > 10 inches (250 mm)/sec. in Teach (manual).

• Only 1 enabling device for tasks with 2 operators (or service technicians) inside the work cell.

• No function identification for air lock out valve.
• Product flow: infeeds, transfers, outfeeds

- Infeed pallet light curtain
- Light curtain
- Outfeed pallet light curtain
- Infeed product conveyor
- Teach Pendant
- Infeed empty pallets
- Infeed tray light curtain
- Pallet conveyor turntable
- Work cell status lamps
- Robot controller
- Outfeed stacked trays
- AGV
- 4 axis robot with dual function end-effector
- Outfeed tray light curtain
- Infeed tray conveyor
AGV Safety Concepts

AGV safety concepts / practical implementation:

- Operating environment (personnel access for periodic cleaning)
- Battery charging station (location)
- Quality Control inspection station (location and personnel access)
- Pedestrian (QC, operators, service/maintenance) access into AGV pathways
- Planned AGV path travel and clearance
- Identification of AGV pathways (floor markings)
- AGV awareness signs for personnel
Overview of non-conformance items

• **A recent** system integration does not assure compliance with applicable robot safety requirements.

• Other hazards were found / corrected or protected.

• Other countermeasures are possible.
Summary

A third party conformity audit (or risk assessment), can facilitate acceptance by:

• Users

• Insurance groups

• Labor organizations

• Local, state and federal authorities having jurisdiction (AHJs)
Questions

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