Robot Safety Standard Update

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Why Standards?

• Standards help level the market playing field when all players meet the standard(s).
• Standards provide risk management assistance by helping to limit liability for products meeting standard(s).
• Standards help meet market demands (presuming the market demands compliance with the standard(s)).
• Standards lower costs by standardizing designs & mfg.
• Globally harmonized standards allow products to be global, rather than regional designs. Equipment can be shipped between facilities of global companies.
ISO Standards Framework

- Standardization is highly structured and organized to minimize overlapping scopes.
- Standards are supposed to use the work of other standards (and not “reinvent the wheel”).

For harmonized standards (EN ISO), CEN Consultants (technical experts) review the content to judge whether the standard complies with the various EU Directives.
ANSI Standards Framework

ANSI...  
- Standards are based on market demand without oversight as to technical content.  
- Accredits an organization to be a SDO (Standards Development Organization) for a specific market/ scope.  
- Oversight of ANSI stds development is to its processes and the development procedures.

- Standard(s) do not have to use the work of other ANSI standards.

Over 240 standards about weld materials, techniques, certification, safety of weld robot systems, ...

ANSI/ RIA R15.02  Design of Robot Control Pendants - inactive
ANSI/ RIA R15.05  Performance Characteristics - inactive
ANSI/ RIA R15.06  Safety of Robots, + Integration of Robots, Robot Systems, Robot Cells
ANSI/ RIA R15.07  Robot Offline Programming - inactive
RIA TR15.106, TR15.206, and more
Standards Comparison

- **ANSI Standards and Technical Reports**
  - Are voluntary – unless adopted as a regulation (law).
  - Can be adopted by OSHA (unusual) or other jurisdiction (state, county, city… For example, UL 1740 has been adopted by some states and localities)
  - Applies to one or more of the following:
    - the manufacturer of the component (e.g., connectors, cable, fasteners, component machine such as a conveyor).
    - the integrator of the component or machine.
    - the user of the component or machine (company using the machine).
  - Compliance can be used as a
    - Means of complying with OSHA requirements of a safe workplace (since there are many more ANSI standards than regulations) but NOT presumption of compliance.
    - Civil legal defense for providing a safe workplace based on current practices.

- **OSHA Standards**
  - Are regulatory standards (required by law).
  - Are NOT comprehensive. There are VERY few OSHA machine safety standards (e.g., mechanical power presses, forging machines, cooperage machines). There is NO OSHA robot standard, however OSHA references R15.06 as being the standard applicable to robot systems.
  - Applies to the USER (the company that uses the machine).
    - There can be requirements that apply to EMPLOYEES (example lock-out).
Standards Comparison

• **ISO Standards, Technical Specifications, & Technical Reports**
  • Are voluntary unless adopted as a regulation.
  • Are meant to allow globalization of trade by unifying border requirements.
  • Are often adopted by the EU as a harmonized standard which means that the EN ISO standard provides a presumption of conformity (complies with Directives).
  • Applies to **SUPPLIER** of the component or machine:
    • the **manufacturer** of the component or machine.
    • the **integrator** of the component or machine (if the USER acts as the supplier, the USER is required to comply).
  • Compliance can be used as a
    • A LEGAL presumption of conformity with the machinery directive (if harmonized).
    • Civil legal defense of providing a safe workplace based on industry practices.

• **Country Workplace Safety Standards**
  • Are regulatory standards **(required by law)**. This is same as OSHA for the USA.
  • In Europe, each country has its own workplace safety requirements, PLUS
    • Compliance with the Directives is a legal requirement, where EN standards compliance provides the means by which to meet the Directives. Suppliers have to meet the Directives for product import and sales within the EU.
    • The USER is required to acquire & use products complying with Directives.
  • Applies to the **USER**. There can be requirements that apply to **EMPLOYEES**.
   • These standards are based on the 1999 R15.06.
   • 1999 R15.06 was torn into two parts: robot manufacturer (-1) and requirements for systems (with end-effectors) & integrators (-2).
   • USA provided input to the ISO 10218 standards development: R15.06 met between ISO meetings to review & develop input.

• TS (Technical Specification) 15066 is in process. It is a about collaborative robots and their use. It is a TS because more application knowledge is needed before publishing a collaborative robot standard.
• The need of a “robotic device” document has been identified.
Update to CAN CSA Z434 is expected to be published in 2013.
- Consists of ISO 10218-1, ISO 10218-2, Canadian deviations (additions), & User requirements interspersed throughout.
- There are additional addendums to aid in the use of the new standard.

CSA Z434 will contain all ISO requirements (clearly shown) as the Canadian deviations and additions.
- This means that robot standards for Canada CSA, USA ANSI, ISO, and EN ISO are harmonized to be almost the same.
  AND
- Because both the Z434 and R15.06 are adoptions of ISO 10218-1 and ISO 10218-2, it is easy to compare and see differences.
• UL 1740 was developed as a certification standard for R15.06-1999. As such it has requirements that are in addition to R15.06-1999.
  • The revision process is starting soon or in process.
  • The HOPE is that the next revision will be harmonized with ISO/RIA/CSA.
  • This could mean EITHER
    • Harmonize globally for robots (part 1) and accept certification (from other NRTLs) to ISO 10218 since it is the same as ANSI RIA R15.06 – 2012.
  OR
  • ONLY address specific US electrical requirements
• 2012 R15.06 has been approved by RIA balloting, but is still in the ANSI review & approval process.
  • NEW R15.06 is a NATIONAL adoption of ISO 10218-1 & -2.
    • An update to ANSI RIA R15.06 – 1999
      • ISO 10218-1 and -2, which started using 1999 R15.06 as the base.
  • ANSI RIA R15.06 – 2012 = ISO 10218-1 + ISO 10218-2 + R15.06 (Foreword + Introduction + Bibliography).
    • -1: Robot arm and its controller ONLY! No end-effector
      • Stakeholder – Robot Manufacturer
      • Equivalent to Clause 4 ONLY of 1999 R15.06.
    • -2: Industrial robot system & integration
      • Stakeholders – Integrator, Installer, and also the User but only if/when the User acts as the designer, integrator or modifier.
      • Equivalent to Clauses 5 & 6 of 1999 R15.06.
1999 -> 2012 R15.06 Transition

• ANSI RIA R15.06–1999 can be used until the end of 2014.
  • During this ~ 2 year transition, there is a choice of using EITHER the 1999 R15.06 (R2009) or new 2012 R15.06.
  • The overlap with the 1999 (R2009) R15.06 allows:
    • A transition for on-going projects and for constituents to become comfortable with a new standard after 13 years with 1999 R15.06.
    • The R15.06 committee to publish needed accompanying documents.
      • RIA TR 15.306 – a risk assessment methodology, however other methodologies are acceptable so long as the outcome is at least as stringent as the TR15.306 methodology. Update of the methodology in R15.06-1999.
      • RIA TR 15.406 – safeguarding (w/ ISO safeguarding information). This is an update to the materials that were included in R15.06-1999.
      • USER requirements.
      • Collaborative robots/ collaborative application guidance.
      • Manual Work Stations (when is a work station a hindering device which act prevents entry to a cell)
      • Possibly a Prescribed Methodology with a risk assessment required for the application and environment (like the 1999 R15.06 Prescribed Methodology).
Due to the NEW R15.06, the following Standards and Technical Reports will be withdrawn at the end of 2014 (when the 1999 R15.06 is withdrawn):

- **ANSI RIA R15.06–1999**: Robot Mfg, Integration and Use Safety.
- **RIA TR 15.106–2006**: Teaching Multiple Robots.
  - Applicable ONLY when using the 1999 R15.06.
  - Applicable ONLY when using the 1999 R15.06.
- **ANSI / RIA / ISO 10218-1: 2007**
  - Applicable ONLY when using the 1999 R15.06.
## Terminology Changes

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robot</td>
<td>Robot, <strong>NO end effector</strong></td>
</tr>
<tr>
<td>Robot system</td>
<td>Robot(s) w/ end effector and any task equipment</td>
</tr>
<tr>
<td>Robot cell</td>
<td>Robot system(s) &amp; all within safeguarded space</td>
</tr>
<tr>
<td>Slow speed</td>
<td>Reduced speed</td>
</tr>
<tr>
<td>Safety stop</td>
<td>Protective stop</td>
</tr>
<tr>
<td>Teach mode*</td>
<td>MANUAL reduced speed MODE *</td>
</tr>
<tr>
<td>APV</td>
<td>MANUAL high speed MODE</td>
</tr>
</tbody>
</table>

*teach is a task using manual mode*
Terminology

- Monitored standstill function (Part 1, 5.5.3) = Stop Cat 2 per NFPA79 (IEC 60204)
  - Power is ON and motion is monitored to be “standstill”
  - Equivalent to Drive STO (Safe-Torque-Off of drives).

- **Operator = ALL PERSONNEL**, not simply production personnel (see RIA R15.06-2013 Introduction)
(Safety-rated) Terminology Additions

- **Safety-rated**
  
  *Definition in Part 1, 3.19: characterized by having a prescribed safety function with a specified safety-related performance.*

- Safety-rated *monitored speed* (3.19.1)
- Safety-rated *reduced speed* (3.19.2)
- Safety-rated *soft axis and space limiting* (3.19.3)
- Safety-rated *soft limit* (3.19.3)
- Safety-rated *output* (3.19.4)
- Safety-rated *zone output* (3.19.5)
- Safety-rated *monitored stop* (3.19.6)

These safety-rated features are optional, the standard states the requirements WHEN/ IF the feature is provided.
(Collaborative) Terminology Additions

- **Collaborative**… *Part 1, 5.10 & Part 2, 5.11*

  **Collaborative Robot**, Definition: *Part 1, 3.4 & Part 2, 3.2*
  - robot designed for **direct** interaction with a human within a defined **collaborative workspace** (3.3)

- **Collaborative Workspace**, Definition: *Part 1, 3.5 & Part 2, 3.3*
  - workspace within the safeguarded space where the robot and a human can perform tasks simultaneously during production operation

**NOTE:** It is an OPTION for robots to be equipped and ready for collaborative operation and collaborative applications.

And the requirements for collaborative are still being determined (hence ISO TS 15066).
### ISO (and now R15.06) Language

- **Shall** = mandatory
- **Should** = recommendation or good practice
  - can be **very strong** or advisory
- **May** = allowed / have permission
- **Can** = possible or a capability (statement of fact).

- Notes used throughout the document are informative, intended to provide explanations and additional information.

*Described in the R15.06 Introduction*
GREAT progress towards global harmonization.

Part 1: MORE safety embedded into robots (some are OPTIONS).

- With the new embedded safety technology, robot systems can be integrated to a smaller workspace, comply with safety requirements, and result in cost savings while personnel are safeguarded.
  - Case studies have shown large savings in space and cost.
  - Easier to provide safe integration of enabling circuitry, associated equipment, …

Standards Lag Technology and Innovation. While standards writers try to allow for new technology, it is difficult to envision requirements for something that is not yet known.

- NOTE: New R15.06 allows for wireless controls (excluded by error in language in 1999) and it allows collaborative operation (of which some forms of collaborative operation are brand new innovations that the market has not addressed yet).
Benefits of R15.06 Revision

- Control of simultaneous motion.
- Collaborative robots / operation.
  - ISO is developing a TS on the topic because it is so new.
- Wireless pendants allowed and expected to become available.
  - Currently battery requirements for typical use presently make the pendants too heavy.
- Robot mfg’ers have a GLOBAL design (savings through the whole supply chain).
- Robot integrators can have GLOBAL solutions.
- Users can have GLOBAL solutions that can be much more easily moved between country locations.
Part 2 is more realistic compared to 1999
  - Clearance requirement changes.
    - Clearance must be 20” (not 18”).
    - Clearance only required if personnel will be exposed to pinching/ crushing/ trapping hazard(s) when performing tasks (including teach and minor servicing).
      - Note: With High Speed Manual:
        Clearance is required regardless of task locations.
Benefits of R15.06 Revision

- Risk Assessment is REQUIRED.
  - Plus integrators shall provide the risk assessment RESULTS to the end-user.
  - Risk assessment allows tailoring the system to the safety needs (safe and lean)
- Safety Distance may be based on worst anticipated loads, speeds, and extension – not worst possible.
  - Smaller safety distances possible
  - Real-life validations and on-going monitoring
Why be interested in the revision?

- Optional Safety-rated Soft Axis & Space Limiting
  - Concept of the Programmable Safety Control embedded in the robot control.
    - Separate from application programming, high security. Think of it as CONFIGURATION.
  - Can be used to provide clearance.
    - Possible to setup very tight restricted spaces, which will reduce hazards and exposures to all personnel.
  - Can replace hard stop requirements.
    - Tighter control of Restricted Space.
    - Smaller footprints and decreased floor space
  - Option on new or recent gen robots ONLY.
  - Cat 2 Stops (per NFPA79 / IEC 60204) provide for longer life and higher reliability due to not cycling the contactors
    - Fewer interventions means less exposure to hazards
    - Higher thru-put by not removing power & restarting.
Robot Zone Model

Tool Zone Model

Safe Operating Zone

by Todd Dickey of Honda Engineering NA & Troy Uahunui of Toyota Eng & Mfging
Stop Categories

• Protective stops can be category 0, 1 or 2 per NFPA79 / IEC 60204 (Part 2, 5.3.8.3)
  • Cat 2 stops: hazards are stopped but drive power remains on.
  • Speeds cycle time and reduces contactor and servo wear & maintenance (and resulting downtime).
• In Information for Use, required to describe span of control of e-stops and protective stops.
Span of Control of Estop

Source: NRSC 2011 “Globalization of Robot Safety Standards 2010” by Todd Dickey of Honda Engineering NA & Troy Uahinui of Toyota Eng & Mfging
Detachable or Cableless Pendants

- Pendant Estop function required.
- Visual indication required when pendant is active.
- Loss of communication shall result in a protective stop for all robots.
  - In the manual mode only
  - Restart requires separate deliberate action
Detachable or Cableless Pendants

- Care shall be taken to avoid confusion between active and inactive stop devices by providing for appropriate storage or design. → Mr. Integrator
  - Prevent situation when an “off” pendant has Estop visible & in a panic situation someone might think the Estop functions.
- Ultimately, the USER is responsible.
  So the USER responsible for proper storage/ use to prevent confusion.
Collaborative Robots

• Robot in **AUTO mode**.
• Visual indication required when collaborative operation is selected & active.
• Robot has certain controlled performance (see section in standard).
Collaborative Robots

• Collaborative “controlled performance” with 4 types of Collaborative Operation identified…
  1. Robot shall stop when a human enters / is (remains) in the collaborative workspace.
     • Operator may interact with robot.
     • Automatic operation may resume when the human leaves the collaborative workspace (requires safeguarding).
  2. Hand-guiding operation is allowed with various requirements to ensure safety.
• Collaborative “controlled performance” continued…
  3. Distance / speed monitoring (also called separation monitoring).
    • Addressed in new TS 15066

4. Power and force limiting
   • Addressed in new TS 15066
Operational Modes

- Automatic
- Manual
  - Reduced speed *(not Teach mode)*
  - High-speed *(not APV)*
What’s DIFFERENT in this REVISION?

- Enhanced enabling device language.
  - Interlocking devices for a shared hazard shall have the same span of control.
  - Overlapping restricted spaces, robots to have interlocked enabling devices.
- Two handed operation of a single device.
- Designs must include allowance for additional enabling devices if warranted by the process.
What’s DIFFERENT in this REVISION?

• Safety distance is based on worst anticipated stopping times.
• Clearance
  • 500 mm (20in) – not 18”
  • Required if risk assessment determines need due to personnel being exposed to pinch/ trapping hazards for low speed manual tasks.
  • If system has high speed manual capability/ use, then clearance is required (like 1999 version).
What’s DIFFERENT in this REVISION?

• New: control of simultaneous motion from single pendant.
• New requirement of providing access (paths & means free of hazards) to perform tasks.
  • Permanent means of access for frequent tasks required.
• New: collaborative operation discussed
  • NOTE: For collaborative operation, it might be best for the robot to have some optional features that are described in the new standard. Discuss the application needs with your supplier before buying your robot!
What’s DIFFERENT in this REVISION?

• Protective stop may be Cat 0, 1, or 2 *mentioned earlier*

• Span of Control introduced. Information for Use shall information about span of control for all devices *with a span of control*
  • Estops, Protective stops, Enabling devices, Protective devices, and more.

• Users get MORE information to aid in the safe use and maintenance.
What’s DIFFERENT in this REVISION?

- Risk assessment
  - Risk Assessment is required.
  - Integrators required to provide **results** of risk assessment.

- Hi-Speed APV → High Speed Manual
  - In the 1999 version, this was called hi-speed APV. If a robot had this capability readily available, there were a number of conditions to its use.
  - 2012 standard: conditions are interspersed in standard. Clearly stated that this mode is intended for program verification only, and shall not be used for production. All manual jogging shall be at reduced speed.
What’s DIFFERENT in this REVISION?

• High Speed Manual Mode
  • Shall only be provided in exceptional circumstances where the application requires the robot system to be operated in the manual high-speed mode.
  • The speed of the selected TCP may exceed 250 mm/s [10 in/sec].
  • The robot system shall conform with Part 1 mode requirements and be provided with a pendant conforming to Part 1.
  • 20” clearance REQUIRED w/High-speed manual.
  • The information for use shall include that the pendant’s enabling device be functionally tested for proper operation prior to initiating motion.
What’s DIFFERENT in this REVISION?

• Controls Safety Performance / Functional Safety
  • Previous “control reliability” language for required functional safety remains the same PLUS Control Reliability is considered equivalent to ISO 13849-1, PL d structure category 3 OR IEC 62061, SIL 2 with a life of 20 years.
  • These functional safety standards (ISO 13849 and IEC 62061) provide a way to objectively quantify “control reliability” & validate the safety solution’s safety integrity.
  • NOTE: if the risk assessment determines that another safety performance is appropriate, then it is the requirement.
Control System Safety Integrity

- Control Reliable is a concept
  - Cannot quantify, can only claim compliance & argue.
- ISO 13849-1 and IEC 62061 provide performance metrics
  - Can quantify performance
  - Can determine requirements
  - Can validate compliance
Control System Safety Integrity

- Revision includes ISO 13849-1 requirement (PL d structure category 3 unless another is determined as a result of the risk assessment) AND the previous control reliability language.
- ISO 13849-1’s terms provide greater precision and more accurate mapping to the requirements of “control reliable”.
What’s Next?

• R15 Technical Reports
• ISO TS (Technical Specification) 15066
  • Collaborative Operation
• New ISO Projects
  • Robots for personal care
  • Mobile service robots
  • Vocabulary
  • OTHER…
Issues

• While harmonization is reducing differences, there will always be regional / country specific requirements
  • Electrical codes/ regulations, differences in voltage / current, technical expertise, expectations…
• Sometimes confusion of security vs. safety internationally (same word in many languages).
• While standards writers try to think towards the future, it is difficult to write safety requirements for an application or use or need that does not yet exist or hardly exists.
  • Innovation leads, standards lag. Hopefully standards enable new technology and ideas – at least, this is the goal.
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