INDSTRIAL ROBOTS AND ROBOT SYSTEMS

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1. INTRODUCTION

This data sheet is intended to provide information for safeguarding workers who may come in contact with robots and robot systems. This data sheet does not address robot systems such as personal robots, automatic guided vehicle systems (AGVS), automated storage and retrieval systems, automatic conveyor and shuttle systems, mobile robots and numerically controlled machine tools.

Use of robots in industry is on the increase – mainly for repetitive tasks and for jobs posing health and safety risks to humans.

Injuries to personnel working with robots have been attributed to: (i) being struck by a robot, (ii) being caught between a robot arm and other machine or object, (iii) being struck by objects or tools used by a robot when either released accidentally or not released as programmed, and (iv) being injured during legitimate work activity of robot (e.g. during operation such as welding, cutting, spray paining etc.)

The risk of injury is greatest while a person is working inside the work envelope of a robot. This occurs most frequently while (i) teaching the robot, (ii) maintaining the robot, or (iii) clearing a jam.

A risk of injury also exists outside the work envelope when a worker is within the range of parts or material that could be released by a robot.

The information provided in this data sheet is to a large extent based on the ANSI/RIA, R15.06-1986 American National Standard for Industrial Robot Systems – Safety Requirements.

2. INSTALLATION OF ROBOT SYSTEMS

2.1 The robots shall be installed, anchored, and wired in accordance with the manufacturer's instructions & specifications, and applicable codes. The robots shall be compatible with working environment, such as explosive mixtures, dust, corrosive conditions, humidity, temperature, electromagnetic interference (EMI), and radio frequency interference (RFI).

2.2 Clearance shall be provided to avoid pinch points. The robot system shall be installed to avoid interference with buildings, structures, utilities, and other machines and equipment.

2.3 Robot installations shall be segregated from equipment and facilities such as pressure vessels, flammable liquid tanks, compressed gas bottles, high voltage equipment, etc., so that such equipment and facilities are not put at risk by robot action.

2.4 Limiting devices, when used, shall be positioned to establish restricted work envelopes for restraint of the motion of the robots. The limiting devices shall not cause additional hazards in the restricted work envelope.

2.5 The restricted work envelope shall be conspicuously identified, by means of signs, line markings on the floor, etc. It should be noted that guarding should be accomplished by barriers, railings or the equivalent.

2.6 Prior to commencement of operations, the employer shall cause an evaluation of all potential hazards arising from the robot installation to be made. This procedure shall be repeated for each application to ensure that all necessary safeguards are provided to protect the workers from any such hazard.

3. SAFETY REQUIREMENTS OF ROBOT SYSTEMS

3.1 Robots and Robot Systems shall be designed with failure to safety in mind (fail-safe design). Robot components shall be designed and constructed, so that any breakage, failure, or release of stored energy will not endanger a worker. Safeguards and safety systems shall be designed so that any interruptions of the power supply to them shall cause the robot and robot system to default to the hazard-free conditions appropriate under the circumstances.

3.2 Every robot system shall have emergency stop devices as needed.

3.3 Each operator station of a robot system shall be provided with a readily accessible emergency stop device.

3.4 Following the activation of an emergency stop, restarting the robot shall require a deliberate action by the operator from outside the restricted work envelope.

3.5 An amber light which will be lit, any time the robot is energized shall be installed on the robot.

3.6 Means shall be provided for the controlled release of stored energy. Clear identification shall be provided for each source of stored energy (e.g. capacitors, hydraulic pressure accumulators, springs, counterbalances, and flywheels).

3.7 Every robot shall be protected against electromagnetic and radio frequency interferences that may result in hazardous motion of the robot.

3.8 The shutdown of associated equipment shall not result in hazardous motion of the robot.

3.9 Mechanical (hard) stops shall be provided. They shall be capable of stopping the motion of the robot under rated load and maximum speed conditions.

3.10 Emergency braking (upon activation of emergency stop) of the robot shall be achieved by positive braking systems rather than simple power cut-off.

3.11 All robots shall have a slow speed. The robot shall be designed and constructed so that in the event of any single, reasonably foreseeable malfunction, the operation shall default to slow speed or the hazard-free condition appropriate under the circumstances.

3.12 Isolating means and physical lock-out devices shall be provided for all sources of energy to the robot and to all associated equipment.

3.13 Actuating controls shall be designed to eliminate potential hazards to workers. For example,

- Master control panel shall be arranged so that the robot is easily visible to any operator using this panel.
- Controls and equipment requiring access during automatic operation shall be located outside the restricted work envelope.
- Start controls shall be guarded, located or constructed so as to protect against inadvertent operation.
- Each robot that can be controlled from a remote location shall be provided with an effective means that, when used, prevents that robot's motion from being initiated from any location other than at the individual robot.
- Actuating controls shall be clearly labeled to identify their function.
- Actuating controls shall be designed and arranged to ensure against automatic restart following restoration of power after a power failure or activation of an emergency stop.
- Restarting after a power failure shall be per section 3.4.

3.14 Mis-mating of electrical connectors shall be prevented where such mis-mating may cause hazardous motion. Separation of electrical connectors shall be prevented where such separation may cause hazardous motion.

3.15 A robot shall be capable of being moved about each axis and in each plane without using robot drive power.

3.16 The configuration and construction of end-effectors shall be such that a loss or abnormal change in electrical, hydraulic, pneumatic, or vacuum power will not result in a hazardous condition. If this is not feasible, then other methods of safeguarding shall be provided to protect against a hazardous condition.

4. SAFEGUARDING

4.1 An effective safety system shall be provided to protect persons who could be exposed to potential hazards associated with a robot's operation. A combination of methods may be used to develop an effective safety system. Redundancy and backup systems are also recommended.

4.2 The user of a robot system shall ensure that safeguards are provided and used. The means and degree of safeguarding, including any redundancies, shall correspond directly to the type and level of hazard presented by the robot system consistent with the robot application. Safeguarding devices may include but not be limited to barriers, interlocked barrier guard, perimeter guards, complete enclosures, awareness barriers, awareness signals and presence-sensing devices. An awareness device may be used as the method of safeguarding only where a hazard analysis indicates that other methods of guarding are not feasible or are not warranted.

4.3 The presence detectors that are most commonly used in robotics safety are pressure sensitive mats and light curtains. Presence-sensing devices shall be fail-safe so that the occurrence of a failure within the device will leave it unaffected or convert into a mode in which its failed state would not result in an accident.

4.4 Safeguarding the Operator: The safeguards shall either prevent the operator from being in the restricted work envelope during robot motion, or prevent or inhibit robot motion while any part of an operator's body is within the restricted work envelope.

4.5 **Safeguarding the Teacher:**

4.5.1 The teacher shall be trained regarding the particular installation, including the control program and the recommended teach procedures.

4.5.2. Before teach a robot, the teacher shall visually check the robot and work envelope to assure that conditions that may cause hazards do not exist. The teach controls of the pendant shall be function tested to ensure proper operation.

4.5.3 Before entering the restricted work envelope, the teacher shall ensure that all safeguards are in place and functioning as intended in the teach mode.

4.5.4 Only the teacher shall be allowed in the restricted work envelope, during teaching.

4.5.5. When teach mode is selected, the following conditions shall be met:

(1) the robot system shall be under the sole control of the teacher.
(2) When under drive power, the robot shall operate at slow speed only. When a speed greater than slow speed is provided for the verification of a program, it shall require a deliberate action by the teacher to select a speed and shall require a constant actuation of the controls to continue robot motion.
(3) The robot shall not respond to any remote interlocks or signals that would cause motion.
(4) Movement of other equipment in the work envelope shall be under the sole control of the teacher if such movement would present a hazard.

4.5.6 The teacher shall be required to leave the restricted work envelope prior to initiating automatic mode.

4.6 **Safeguarding Maintenance and Repair Personnel**:

4.6.1 Personnel who perform maintenance or repair on robots or robot systems shall be trained in the procedures necessary to safety perform the required tasks.

4.6.2 Personnel who maintain and repair robot systems shall be safeguarded from injury due to unexpected or unintended motion.

4.6.3 The most effective means of safeguarding is to shut the robot system off. A procedure shall be followed that includes lockout of source of power and releasing or blocking of potentially hazardous stored energy.

4.6.4 When a lockout procedure can not be used, equally effective alternative safeguarding procedures shall be established and used to prevent injury.

5. TRAINING

5.1 Hazard analysis of each mode of operation is the foundation for any training program. A person who has to enter the robot work envelope shall be made aware of all potential hazards. No person shall be allowed to work with a robot until that person is adequately trained to do such work in a safe manner.

5.2 Training program shall be documented and shall include:

(1) Instruction on operation of entire system, including robot control system.
(2) Instruction in safety procedures and the safety recommendations of the manufacturers as they apply to each individual installation and application of the particular robot in use.

5.3 To ensure against deterioration of the effectiveness of the training program, the employer shall make provisions for periodic auditing and refresher training.

6. References

1. ANSI/RIA R 15.06 – 1986
   American National Standard for industrial robots and robot systems – safety requirements.
2. National Safety Council
   Robots, Data Sheet, 1-717-85

3. United Sates Department of Labor, Occupational Safety and Health Administration, Guidelines for Robotic Safety, OSHA Instruction; publication 8-1.3
4. The Machine Tool Trades Associations, Safeguarding Industrial Robots, Part 1, Basic Principles.
5. NIOSH, Safe Maintenance guide for Robotic Workstation

7. GLOSSARY OF TERMS

BARRIER: A physical means of separating persons from the restricted work envelope.

CONTROL PROGRAM: The inherent set of control instructions that defines the capabilities, actions and responses of a robot system. This program is normally supplies by the robot manufacturer and is usually not intended to be modified by the user.

DRIVE POWER: The energy source or sources for the robot actuators that produce motion.

EMERGENCY STOP: A circuit using hardware-based components that overrides all other robot controls, removes drive power from robot actuators, and causes all moving parts to stop.

END-EFFECTOR: An accessory device or tool specifically designed for attachment to the robot, wrist or tool mounting plate to enable the robot to perform its intended task.

FIXED BARRIER GUARD: A fence or barrier that requires tools for removal. It prevents access through, over, under or around the fence.

HAZARDOUS MOTION: Unintended or unexpected robot motion that may cause injury.

INDUSTRIAL ROBOT: A re-programmable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.

INDUSTRIAL ROBOT SYSTEM: A system that includes industrial robots, end effectors, any equipment, devices and sensors required for the robot to perform its tasks as well as communication interfaces for sequencing or monitoring the robot.

INTERLOCK: An arrangement whereby the operation of one control or mechanism brings about, or prevents, the operation of another. Each interlock device shall be of such a design as to fail or malfunction to an intrinsically safe condition, such as an open circuit condition.

INTERLOCK BARRIER GUARD: A physical barrier around the robot work envelope incorporating gates equipped with interlocks. These interlocks are designed so that all automatic operations of the robot and associated machinery will stop when any gate within the same restricted work envelope is opened. Restarting the operation requires closing the gate and reactivating a control switch located outside of the barrier.

LIMITING DEVICE: A device that restricts the work envelope by stopping or causing to stop all robot motion and that is independent of the control program and the application programs.

PENDANT: Any portable control device, including teach pendants, that permits an operator to control the robot from within the work envelope of the robot.

PRESENCE-SENSING SAFEGUARDING DEVICE: A device designed, constructed, and installed to create a sensing field or area to detect an intrusion into such field or area by personnel, robots, or other objects. This device shall stop all motion of the robot if any part of a worker's body enters the protected zone.

PROGRAMMING: To provide the application programs required for robots to perform intended tasks.

> **APPLICATION PROGRAM**: The set of instructions that defines the specific intended tasks of robots and robot systems to make them re-programmable and multifunctional. These programs can be originated and modified by the robot user.

PROXIMITY DETECTOR: A device that may be used to sense that an object is close to a robot or to measure how far an object is from a robot.

ROBOT: See Industrial Robot.

ROBOT SYSTEM: See Industrial Robot System

SAFEGUARD: A barrier guard, device, or procedure designed for the protection of personnel.

SLOW SPEED: A mode of operations in which the speed of any part of a robot does not exceed 250 millimetres per second (10 inches per second).

TEACHING: The generation and storage of a series of positional data points effected by moving the robot arm through a path of intended motions.

WARNING DEVICE: An audible or visible device used to alert personnel to potential safety hazards.

WARNING SYSTEMS: Audible and visible warning systems. [Note: Warning systems are not acceptable primary safeguarding methods but may be used to enhance the effectiveness of primary safeguards].

WORK ENVELOPE: The volume of space enclosing the maximum designed reach of the robot manipulator including the end-effector, the workpiece, and the robot itself.

OPERATING WORK ENVELOPE: That portion of the work envelope that is actually used by the robot while performing its programmed motions.

RESTRICTED WORK ENVELOPE: That portion of the work envelope to which a robot is restricted by limiting devices that establish limits that will not be exceeded in the event of any reasonably foreseeable failure of the robot or its controls. The maximum distance that the robot can travel after the limiting device is actuated shall be considered the basis for defining the restricted work envelope of the robot.