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INDUSTRIAL ROBOT SAFETY

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MEC-134 EXAM PREVIEW

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Exam Preview:

1. Studies in Sweden and Japan indicate that many robot accidents do not occur under normal operating conditions but, instead during programming, program touch-up or refinement, maintenance, repair, testing, setup, or adjustment.
    a. True
    b. False
2. According to the reference material, which of the following path types matches this description: Robots programmed and controlled in this manner are programmed to move from one discrete point to another within the robot's working envelope.
    a. Pick and Place Path
    b. Point-to-Point Path
    c. Controlled Path
    d. Continuous Path
3. According to the reference material, servo robots do not have the feedback capability, and their axes are controlled through a system of mechanical stops and limit switches.
    a. True
    b. False
4. According to the reference material, Robots have three arm movements (up-down, in-out, side-to-side). In addition to these movements, what is the maximum degrees of freedom for a robot?
    a. 4
    b. 5
    c. 6
    d. 7

5. According to the reference material, pneumatic power transmission (high-pressure oil) is usually used for medium to high force or weight applications, or where smoother motion control can be achieved than with hydraulics.
    a. True
    b. False
6. Which of the following options below is NOT a robot programming method discussed in the reference material?
    a. Lead-Through Programming
    b. Walk-Through Programming
    c. Off-line Programming
    d. On-line Programming
7. Using Figure IV:4-1. Robot Arm Design Configurations, which of the following configurations would do best at transporting materials from one side of a shop/warehouse to the other?
    a. SCARA
    b. Gantry
    c. Rectangular coordinate
    d. Spherical coordinate
8. According to the reference material, electrically powered robots are the most prevalent in industry. Either AC or DC electrical power is used to supply energy to electromechanical motor-driven actuating mechanisms and their respective control systems.
    a. True
    b. False
9. To ensure safe operating practices and safe installation of robots and robot systems, it is recommended that the minimum requirements of Section 5 of the ANSI/RIA ________, Installation of Robots and Robot Systems be followed
    a. R15.06-1992
    b. R15.06-1993
    c. R15.06-1994
    d. R15.06-1995
10. According to the reference material, the operational characteristics of robots can be significantly different from other machines and equipment. Robots are capable of high-energy (fast or powerful) movements through a large volume of space even beyond the base dimensions of the robot
    a. True
    b. False

Industrial Robots and Robot System Safety

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For problems with accessibility in using figures and illustrations in this document, please contact the Office of Science and Technology Assessment at (202) 693-2095.

I. Introduction

Industrial robots are programmable multifunctional mechanical devices designed to move material, parts, tools, or specialized devices through variable programmed motions to perform a variety of tasks. An industrial robot system includes not only industrial robots but also any devices and/or sensors required for the robot to perform its tasks as well as sequencing or monitoring communication interfaces.

Robots are generally used to perform unsafe, hazardous, highly repetitive, and unpleasant tasks. They have many different functions such as material handling, assembly, arc welding, resistance welding, machine tool load and unload functions, painting, spraying, etc. See Appendix IV:4-1 for common definitions. Most robots are set up for an operation by the teach-and-repeat technique. In this mode, a trained operator (programmer) typically uses a portable control device (a teach pendant) to teach a robot its task manually. Robot speeds during these programming sessions are slow.

This instruction includes safety considerations necessary to operate the robot properly and use it automatically in conjunction with other peripheral equipment. This instruction applies to fixed industrial robots and robot systems only. See Appendix IV:4-2 for the systems that are excluded.

A. **Accidents: Past Studies**

1. Studies in Sweden and Japan indicate that many robot accidents do not occur under normal operating conditions but, instead during programming, program touch-up or refinement, maintenance, repair, testing, setup, or adjustment. During many of these operations the operator, programmer, or corrective maintenance worker may temporarily be within the robot's working envelope where unintended operations could result in injuries.
2. Typical accidents have included the following:
   - A robot's arm functioned erratically during a programming sequence and struck the operator.
   - A materials handling robot operator entered a robot's work envelope during operations and was pinned between the back end of the robot and a safety pole.
   - A fellow employee accidentally tripped the power switch while a maintenance worker was servicing an assembly robot. The robot's arm struck the maintenance worker's hand.

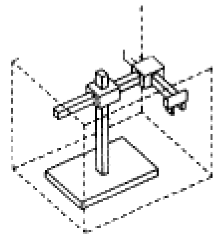
B. **Robot Safeguarding**

1. The proper selection of an effective robotic safeguarding system should be based upon a hazard analysis of the robot system's use, programming, and maintenance operations. Among the factors to be considered are the tasks a robot will be programmed to perform, start-up and command or programming procedures, environmental conditions, location and installation requirements, possible human errors, scheduled and unscheduled maintenance, possible robot and system malfunctions, normal mode of operation, and all personnel functions and duties.
2. An effective safeguarding system protects not only operators but also engineers, programmers, maintenance personnel, and any others who work on or with robot systems and could be exposed to hazards associated with a robot's operation. A combination of safeguarding methods may be used. Redundancy and backup systems are especially recommended, particularly if a robot or robot system is operating in hazardous conditions or handling hazardous materials. The safeguarding devices employed should not themselves constitute or act as a hazard or curtail necessary vision or viewing by attending human operators.

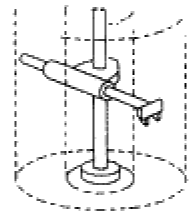
II. Types and Classification of Robots

Industrial robots are available commercially in a wide range of sizes, shapes, and configurations. They are designed and fabricated with different design configurations and a different number of axes or degrees of freedom. These factors of a robot's design influence its working envelope (the volume of working or reaching space). Diagrams of the different robot design configurations are shown in Figure IV: 4-1.

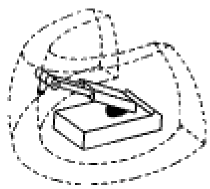
Figure IV:4-1. Robot Arm Design Configurations



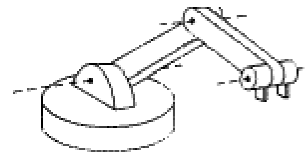
Rectangular Coordinate Robot



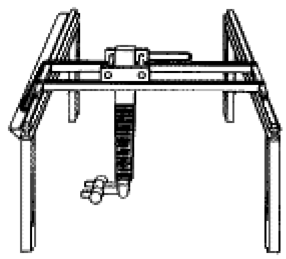
Cylindrical Coordinate Robot



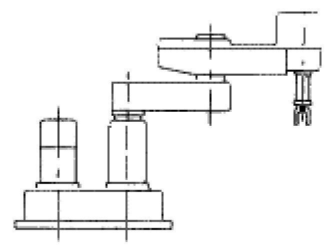
Sperical Coordinate Robot



Articulated Arm Robot



Gantry Robot



SCARA Robot

A. **Servo and Nonservo**

All industrial robots are either servo or nonservo controlled. Servo robots are controlled through the use of sensors that continually monitor the robot's axes and associated components for position and velocity. This feedback is compared to pretaught information which has been programmed and stored in the robot's memory. Nonservo robots do not have the feedback capability, and their axes are controlled through a system of mechanical stops and limit switches.

B. **Type of Path Generated**. Industrial robots can be programmed from a distance to perform their required and preprogrammed operations with different types of paths generated through different control techniques. The three different types of paths generated are Point-to-Point Path, Controlled Path, and Continuous Path.

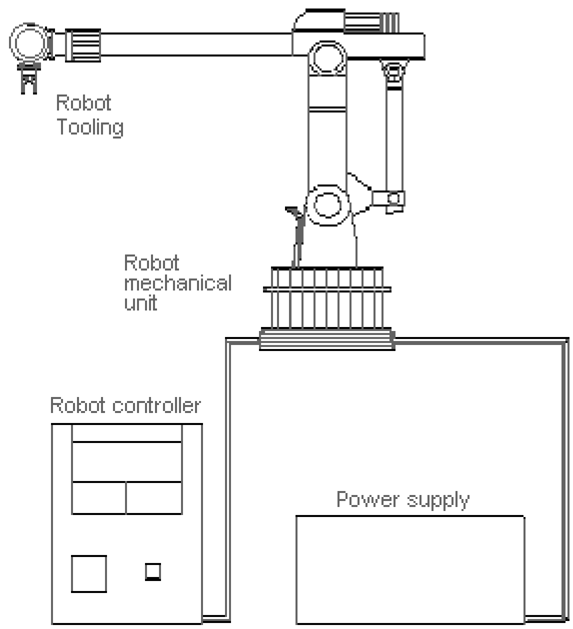
1. **Point-to-Point Path**. Robots programmed and controlled in this manner are programmed to move from one discrete point to another within the robot's working envelope. In the automatic mode of operation, the exact path taken by the robot will vary slightly due to variations in velocity, joint geometries, and point spatial locations. This difference in paths is difficult to predict and therefore can create a potential safety hazard to personnel and equipment.
2. **Controlled Path**. The path or mode of movement ensures that the end of the robot's arm will follow a predictable (controlled) path and orientation as the robot travels from point to point. The coordinate transformations required for this hardware management are calculated by the robot's control system computer. Observations that result from this type of programming are less likely to present a hazard to personnel and equipment.
3. **Continuous Path**. A robot whose path is controlled by storing a large number or close succession of spatial points in memory during a teaching sequence is a continuous path controlled robot. During this time, and while the robot is being moved, the coordinate points in space of each axis are continually monitored on a fixed time base, e.g., 60 or more times per second, and placed into the control

system's computer memory. When the robot is placed in the automatic mode of operation, the program is replayed from memory and a duplicate path is generated.

C. **Robot Components**. Industrial robots have four major components: the mechanical unit, power source, control system, and tooling (Figure IV: 4-2).

1. **Mechanical Unit**. The robot's manipulative arm is the mechanical unit. This mechanical unit is also comprised of a fabricated structural frame with provisions for supporting mechanical linkage and joints, guides, actuators (linear or rotary), control valves, and sensors. The physical dimensions, design, and weight-carrying ability depend on application requirements.

Figure IV:4-2. Industrial Robots: Major Components



2. **Power Sources**

a. Energy is provided to various robot actuators and their controllers as pneumatic, hydraulic, or electrical power. The robot's drives are usually mechanical combinations powered by these types of energy, and the selection is usually based upon application requirements. For example, pneumatic power (low-pressure air) is used generally for low weight carrying robots.
b. Hydraulic power transmission (high-pressure oil) is usually used for medium to high force or weight applications, or where smoother motion control can be achieved than with pneumatics. Consideration should be given to potential hazards of fires from leaks if petroleum-based oils are used.
c. Electrically powered robots are the most prevalent in industry. Either AC or DC electrical power is used to supply energy to electromechanical motor-driven actuating mechanisms and their respective control systems. Motion control is much better, and in an emergency an electrically powered robot can be stopped or powered down more safely and faster than those with either pneumatic or hydraulic power.

D. **Control Systems**

1. Either auxiliary computers or embedded microprocessors are used for practically all control of industrial robots today. These perform all of the required computational functions as well as interface with and control associated sensors, grippers, tooling, and other associated peripheral equipment. The control system performs the necessary sequencing and memory functions for on-line sensing, branching, and integration of other equipment. Programming of the controllers can be done on-line or

at remote off-line control stations with electronic data transfer of programs by cassette, floppy disc, or telephone modem.

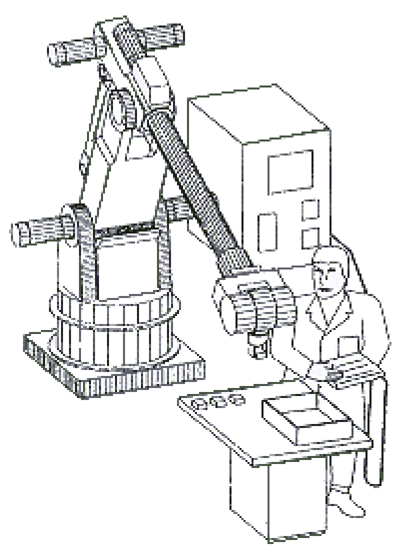
2. Self-diagnostic capability for troubleshooting and maintenance greatly reduces robot system downtime. Some robot controllers have sufficient capacity, in terms of computational ability, memory capacity, and input-output capability to serve also as system controllers and handle many other machines and processes. Programming of robot controllers and systems has not been standardized by the robotics industry; therefore, the manufacturers use their own proprietary programming languages which require special training of personnel.

E. **Robot Programming By Teaching Methods**. A program consists of individual command steps which state either the position or function to be performed, along with other informational data such as speed, dwell or delay times, sample input device, activate output device, execute, etc.

When establishing a robot program, it is necessary to establish a physical or geometrical relationship between the robot and other equipment or work to be serviced by the robot. To establish these coordinate points precisely within the robot's working envelope, it is necessary to control the robot manually and physically teach the coordinate points. To do this as well as determine other functional programming information, three different teaching or programming techniques are used: lead-through, walk-through, and off-line.

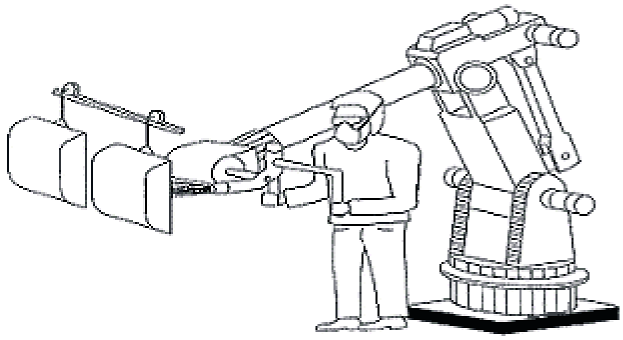
1. **Lead-Through Programming or Teaching**. This method of teaching uses a proprietary teach pendant (the robot's control is placed in a "teach" mode), which allows trained personnel physically to lead the robot through the desired sequence of events by activating the appropriate pendant button or switch. Position data and functional information are "taught" to the robot, and a new program is written (Figure IV:4-3). The teach pendant can be the sole source by which a program is established, or it may be used in conjunction with an additional programming console and/or the robot's controller. When using this technique of teaching or programming, the person performing the teach function can be within the robot's working envelope, with operational safeguarding devices deactivated or inoperative.

Figure IV:4-3. Robot Lead-Through Programming or Teaching



2. **Walk-Through Programming or Teaching**. A person doing the teaching has physical contact with the robot arm and actually gains control and walks the robot's arm through the desired positions within the working envelope (Figure IV:4-4).

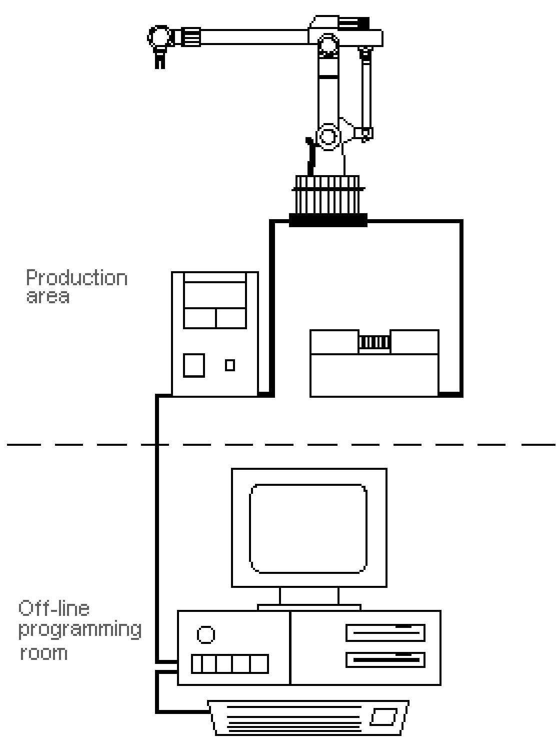
Figure IV:4-4. Walk-Through Programming or Teaching



During this time, the robot's controller is scanning and storing coordinate values on a fixed time basis. When the robot is later placed in the automatic mode of operation, these values and other functional information are replayed and the program run as it was taught. With the walk-through method of programming, the person doing the teaching is in a potentially hazardous position because the operational safeguarding devices are deactivated or inoperative.

Off-Line Programming. The programming establishing the required sequence of functional and required positional steps is written on a remote computer console (Figure IV:4-5). Since the console is distant from the robot and its controller, the written program has to be transferred to the robot's controller and precise positional data established to achieve the actual coordinate information for the robot and other equipment. The program can be transferred directly or by cassette or floppy discs. After the program has been completely transferred to the robot's controller, either the lead-through or walk-through technique can be used for obtaining actual positional coordinate information for the robot's axes.

Figure IV:4-5. Off-Line Programming or Teaching



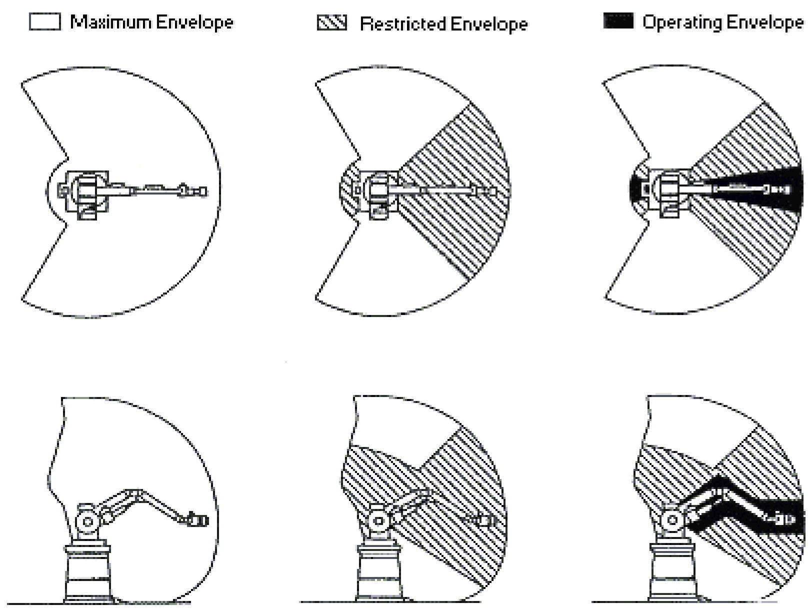
When programming robots with any of the three techniques discussed above, it is generally required that the program be verified and slight modifications in positional information made. This procedure is called program touch-up and is normally carried out in the teach mode of operation. The teacher manually leads or walks the robot through the programmed steps. Again, there are potential hazards if safeguarding devices are deactivated or inoperative.

3. **Degrees of Freedom**. Regardless of the configuration of a robot, movement along each axis will result in either a rotational or a translational movement. The number of axes of movement (degrees of freedom) and their arrangement, along with their sequence of operation and structure, will permit movement of the robot to any point within its envelope. Robots have three arm movements (up-down, in-out, side-to-side). In addition, they can have as many as three additional wrist movements on the end of the robot's arm: yaw (side to side), pitch (up and down), and rotational (clockwise and counterclockwise).

III. Hazards

The operational characteristics of robots can be significantly different from other machines and equipment. Robots are capable of high-energy (fast or powerful) movements through a large volume of space even beyond the base dimensions of the robot (see Figure IV:4-6). The pattern and initiation of movement of the robot is predictable if the item being "worked" and the environment are held constant. Any change to the object being worked (i.e., a physical model change) or the environment can affect the programmed movements.

Figure IV:4-6. A Robot's Work Envelope



Some maintenance and programming personnel may be required to be within the restricted envelope while power is available to actuators. The restricted envelope of the robot can overlap a portion of the restricted envelope of other robots or work zones of other industrial machines and related equipment. Thus, a worker can be hit by one robot while working on another, trapped between them or peripheral equipment, or hit by flying objects released by the gripper.

A robot with two or more resident programs can find the current operating program erroneously calling another existing program with different operating parameters such as velocity, acceleration, or deceleration, or position within the robot's restricted envelope. The occurrence of this might not be predictable by maintenance or programming personnel working with the robot. A component malfunction could also cause an unpredictable movement and/or robot arm velocity.

Additional hazards can also result from the malfunction of, or errors in, interfacing or programming of other process or peripheral equipment. The operating changes with the process being performed or the breakdown of conveyors, clamping mechanisms, or process sensors could cause the robot to react in a different manner.

I. **Types of Accidents**. Robotic incidents can be grouped into four categories: a robotic arm or controlled tool causes the accident, places an individual in a risk circumstance, an accessory of the robot's mechanical parts fails, or the power supplies to the robot are uncontrolled.

   1. **Impact or Collision Accidents**. Unpredicted movements, component malfunctions, or unpredicted program changes related to the robot's arm or peripheral equipment can result in contact accidents.
   2. **Crushing and Trapping Accidents**. A worker's limb or other body part can be trapped between a robot's arm and other peripheral equipment, or the individual may be physically driven into and crushed by other peripheral equipment.
   3. **Mechanical Part Accidents**. The breakdown of the robot's drive components, tooling or end-effector, peripheral equipment, or its power source is a mechanical accident. The release of parts, failure of gripper mechanism, or the failure of end-effector power tools (e.g., grinding wheels, buffing wheels, deburring tools, power screwdrivers, and nut runners) are a few types of mechanical failures.
   4. **Other Accidents**. Other accidents can result from working with robots. Equipment that supplies robot power and control represents potential electrical and pressurized fluid hazards. Ruptured hydraulic lines could create dangerous high-pressure cutting streams or whipping hose hazards. Environmental accidents from arc flash, metal spatter, dust, electromagnetic, or radio-frequency interference can also occur. In addition, equipment and power cables on the floor present tripping hazards.

II. **Sources of Hazards**. The expected hazards of machine to humans can be expected with several additional variations, as follows.

   1. **Human Errors**. Inherent prior programming, interfacing activated peripheral equipment, or connecting live input-output sensors to the microprocessor or a peripheral can cause dangerous, unpredicted movement or action by the robot from human error. The incorrect activation of the "teach pendant" or control panel is a frequent human error. *The greatest problem, however, is over familiarity with the robot's redundant motions* so that an individual places himself in a hazardous position while programming the robot or performing maintenance on it.
   2. **Control Errors**. Intrinsic faults within the control system of the robot, errors in software, electromagnetic interference, and radio frequency interference are control errors. In addition, these errors can occur due to faults in the hydraulic, pneumatic, or electrical subcontrols associated with the robot or robot system.
   3. **Unauthorized Access**. Entry into a robot's safeguarded area is hazardous because the person involved may not be familiar with the safeguards in place or their activation status.
   4. **Mechanical Failures**. Operating programs may not account for cumulative mechanical part failure, and faulty or unexpected operation may occur.
   5. **Environmental Sources**. Electromagnetic or radio-frequency interference (transient signals) should be considered to exert an undesirable influence on robotic operation and increase the potential for injury to any person working in the area. Solutions to environmental hazards should be documented prior to equipment start-up.
   6. **Power Systems**. Pneumatic, hydraulic, or electrical power sources that have malfunctioning control or transmission elements in the robot power system can disrupt electrical signals to the control and/or power-supply lines. Fire risks are increased by electrical overloads or by use of flammable hydraulic oil. Electrical shock and release of stored energy from accumulating devices also can be hazardous to personnel.
   7. **Improper Installation**. The design, requirements, and layout of equipment, utilities, and facilities of a robot or robot system, if inadequately done, can lead to inherent hazards.

IV. Investigation Guidelines

I. **Manufactured, Remanufactured, and Rebuilt Robots**

1. All robots should meet minimum design requirements to ensure safe operation by the user. Consideration needs to be given to a number of factors in designing and building the robots to industry standards. If older or obsolete robots are rebuilt or remanufactured, they should be upgraded to conform to current industry standards.
2. Every robot should be designed, manufactured, remanufactured, or rebuilt with safe design and manufacturing considerations. Improper design and manufacture can result in hazards to personnel if minimum industry standards are not conformed to on mechanical components, controls, methods of operation, and other required information necessary to insure safe and proper operating procedures. To ensure that robots are designed, manufactured, remanufactured, and rebuilt to ensure safe operation, it is recommended that they comply with Section 4 of the ANSI/RIA R15.06-1992 standard for *Manufacturing, Remanufacture, and Rebuild of Robots.*

II. **Installation**

1. A robot or robot system should be installed by the users in accordance with the manufacturer's recommendations and in conformance to acceptable industry standards. Temporary safeguarding devices and practices should be used to minimize the hazards associated with the installation of new equipment. The facilities, peripheral equipment, and operating conditions which should be considered are:
   - Installation specifications;
   - Physical facilities;
   - Electrical facilities;
   - Action of peripheral equipment integrated with the robot;
   - Identification requirements;
   - Control and emergency stop requirements; and
   - Special robot operating procedures or conditions.
2. To ensure safe operating practices and safe installation of robots and robot systems, it is recommended that the minimum requirements of Section 5 of the ANSI/RIA R15.06-1992, Installation of Robots and Robot Systems be followed. In addition, OSHA's Lockout/Tagout standards (29 CFR 1910.147 and 1910.333) must be followed for servicing and maintenance.

V. Control and Safeguarding Personnel

For the planning stage, installation, and subsequent operation of a robot or robot system, one should consider the following.

1. **Risk Assessment**. At each stage of development of the robot and robot system a risk assessment should be performed. There are different system and personnel safeguarding requirements at each stage. The appropriate level of safeguarding determined by the risk assessment should be applied. In addition, the risk assessments for each stage of development should be documented for future reference.
2. **Safeguarding Devices**. Personnel should be safeguarded from hazards associated with the restricted envelope (space) through the use of one or more safeguarding devices:
   - Mechanical limiting devices;
   - Nonmechanical limiting devices;
   - Presence-sensing safeguarding devices;
   - Fixed barriers (which prevent contact with moving parts); and
   - Interlocked barrier guards.
3. **Awareness Devices**. Typical awareness devices include chain or rope barriers with supporting stanchions or flashing lights, signs, whistles, and horns. They are usually used in conjunction with other safeguarding devices.

4. **Safeguarding the Teacher**. Special consideration must be given to the teacher or person who is programming the robot. During the teach mode of operation, the person performing the teaching has control of the robot and associated equipment and should be familiar with the operations to be programmed, system interfacing, and control functions of the robot and other equipment. When systems are large and complex, it can be easy to activate improper functions or sequence functions improperly. Since the person doing the training can be within the robot's restricted envelope, such mistakes can result in accidents. Mistakes in programming can result in unintended movement or actions with similar results. For this reason, a restricted speed of 250 mm/§ or 10 in/§ should be placed on any part of the robot during training to minimize potential injuries to teaching personnel.

   Several other safeguards are suggested in the ANSI/RIA R15.06-1992 standard to reduce the hazards associated with teaching a robotic system.

5. **Operator Safeguards**. The system operator should be protected from all hazards during operations performed by the robot. When the robot is operating automatically, all safeguarding devices should be activated, and at no time should any part of the operator's body be within the robot's safeguarded area.

   For additional operator safeguarding suggestions, see the ANSI/RIA R15.06-1992 standard, Section 6.6.

6. **Attended Continuous Operation**. When a person is permitted to be in or near the robots restricted envelope to evaluate or check the robots motion or other operations, all continuous operation safeguards must be in force. During this operation, the robot should be at slow speed, and the operator would have the robot in the teach mode and be fully in control of all operations.

   Other safeguarding requirements are suggested in the ANSI/RIA R15.06-1992 standard, Section 6.7.

7. **Maintenance and Repair Personnel**. Safeguarding maintenance and repair personnel is very difficult because their job functions are so varied. Troubleshooting faults or problems with the robot, controller, tooling, or other associated equipment is just part of their job. Program touchup is another of their jobs as is scheduled maintenance, and adjustments of tooling, gages, recalibration, and many other types of functions.

   While maintenance and repair is being performed, the robot should be placed in the manual or teach mode, and the maintenance personnel perform their work within the safeguarded area and within the robots restricted envelope. Additional hazards are present during this mode of operation because the robot system safeguards are not operative.

   To protect maintenance and repair personnel, safeguarding techniques and procedures as stated in the ANSI/RIA R15.06-1992 standard, Section 6.8, are recommended.

8. **Maintenance**. Maintenance should occur during the regular and periodic inspection program for a robot or robot system. An inspection program should include, but not be limited to, the recommendations of the robot manufacturer and manufacturer of other associated robot system equipment such as conveyor mechanisms, parts feeders, tooling, gages, sensors, and the like.

   These recommended inspection and maintenance programs are essential for minimizing the hazards from component malfunction, breakage, and unpredicted movements or actions by the robot or other system equipment. To ensure proper maintenance, it is recommended that periodic maintenance and inspections be documented along with the identity of personnel performing these tasks.

9. **Safety Training**. Personnel who program, operate, maintain, or repair robots or robot systems should receive adequate safety training, and they should be able to demonstrate their competence to perform their jobs safely. Employers can refer to OSHA's publication 2254 (Revised), "Training Requirements in OSHA Standards and Training Guidelines."

10. **General Requirements**. To ensure minimum safe operating practices and safeguards for robots and robot systems covered by this instruction, the following sections of the ANSI/RIA R15.06-1992 must also be considered:

    - Section 6 - Safeguarding Personnel;
    - Section 7 - Maintenance of Robots and Robot Systems;
    - Section 8 - Testing and Start-up of Robots and Robot Systems; and
    - Section 9 - Safety Training of Personnel.

    Robots or robotic systems must comply with the following regulations: Occupational Safety and Health Administration, OSHA 29 CFR 1910.333, Selection and Use of Work Practices, and OSHA 29 CFR 1910.147, The Control of Hazardous Energy (Lockout/Tagout).

VI. Bibliography

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Appendix IV:4-1. Glossary for Robotics and Robotic Systems

Actuator
A power mechanism used to effect motion of the robot; a device that converts electrical, hydraulic, or pneumatic energy into robot motion.

Application Program
The set of instructions that defines the specific intended tasks of robots and robot systems. This program may be originated and modified by the robot user.

Attended Continuous Operation
The time when robots are performing (production) tasks at a speed no greater than slow speed through attended program execution.

Attended Program Verification
The time when a person within the restricted envelope (space) verifies the robot's programmed tasks at programmed speed.

Automatic Mode
The robot state in which automatic operation can be initiated.

Automatic Operation
The time during which robots are performing programmed tasks through unattended program execution.

Awareness Barrier
Physical and/or visual means that warns a person of an approaching or present hazard.

Awareness Signal
A device that warns a person of an approaching or present hazard by means of audible sound or visible light.

Axis
The line about which a rotating body (such as a tool) turns.

Barrier
A physical means of separating persons from the restricted envelope (space).

Control Device
Any piece of control hardware providing a means for human intervention in the control of a robot or robot system, such as an emergency-stop button, a start button, or a selector switch.

Control Program
The inherent set of control instructions that defines the capabilities, actions and responses of the robot system. This program is usually not intended to be modified by the user.

Coordinated Straight Line Motion
Control wherein the axes of the robot arrive at their respective end points simultaneously, giving a smooth appearance to the motion. Control wherein the motions of the axes are such that the Tool Center Point (TCP) moves along a prespecified type of path (line, circle, etc.)

Device
Any piece of control hardware such as an emergency-stop button, selector switch, control pendant, relay, solenoid valve, sensor, etc.

Drive Power
The energy source or sources for the robot actuators.

Emergency Stop
The operation of a circuit using hardware-based components that overrides all other robot controls, removes drive power from the robot actuators, and causes all moving parts to stop.

Enabling Device
A manually operated device that permits motion when continuously activated. Releasing the device stops robot motion and motion of associated equipment that may present a hazard.

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. (Examples may include gripper, spot-weld gun, arc-weld gun, spray- paint gun, or any other application tools.)

Energy Source
Any electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other source.

Envelope (Space), Maximum
The volume of space encompassing the maximum designed movements of all robot parts including the end-effector, workpiece, and attachments.

Restricted Envelope (Space)
That portion of the maximum envelope to which a robot is restricted by limiting devices. The maximum distance that the robot can travel after the limiting device is actuated defines the boundaries of the restricted envelope (space) of the robot.

Note:
The safeguarding interlocking logic and robot program may redefine the restricted envelope (space) as the robot performs its application program. (See Appendix D of the ANSI/RIA R15.06-1992 Specification).

Operating Envelope (Space)
That portion of the restricted envelope (space) that is actually used by the robot while performing its programmed motions.

Hazard
A situation that is likely to cause physical harm.

Hazardous Motion
Any motion that is likely to cause personal physical harm.

Industrial Equipment
Physical apparatus used to perform industrial tasks, such as welders, conveyors, machine tools, fork trucks, turn tables, positioning tables, or robots.

Industrial Robot
A reprogrammable, 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, the end-effectors, and the devices and sensors required for the robots to be taught or programmed, or for the robots to perform the intended automatic operations, as well as the communication interfaces required for interlocking, sequencing, or monitoring the robots.

Interlock
An arrangement whereby the operation of one control or mechanism brings about or prevents the operation of another.

Joint Motion
A method for coordinating the movement of the joints such that all joints arrive at the desired location simultaneously.

Limiting Device
A device that restricts the maximum envelope (space) by stopping or causing to stop all robot motion and is independent of the control program and the application programs.

Maintenance

The act of keeping the robots and robot systems in their proper operating condition.

Mobile Robot
A self-propelled and self-contained robot that is capable of moving over a mechanically unconstrained course.

Muting
The deactivation of a presence-sensing safeguarding device during a portion of the robot cycle.

Operator
The person designated to start, monitor, and stop the intended productive operation of a robot or robot system. An operator may also interface with a robot for productive purposes.

Pendant
Any portable control device, including teach pendants, that permits an operator to control the robot from within the restricted envelope (space) 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 the field or area by personnel, robots, or other objects.

Program

1. (noun) A sequence of instructions to be executed by the computer or robot controller to control a robot or robot system.
2. (verb) to furnish (a computer) with a code of instruction.
3. (verb) to teach a robot system a specific set of movements and instructions to accomplish a task.

Rebuild
To restore the robot to the original specifications of the manufacturer, to the extent possible.

Remanufacture
To upgrade or modify robots to the revised specifications of the manufacturer and applicable industry standards.

Repair
To restore robots and robot systems to operating condition after damage, malfunction, or wear.

Robot Manufacturer
A company or business involved in either the design, fabrication, or sale of robots, robot tooling, robotic peripheral equipment or controls, and associated process ancillary equipment.

Robot System Integrator
A company or business who either directly or through a subcontractor will assume responsibility for the design, fabrication, and integration of the required robot, robotic peripheral equipment, and other required ancillary equipment for a particular robotic application.

Safeguard
A barrier guard, device, or safety procedure designed for the protection of personnel.

Safety Procedure
An instruction designed for the protection of personnel.

Sensor
A device that responds to physical stimuli (such as heat, light, sound, pressure, magnetism, motion, etc.) and transmits the resulting signal or data for providing a measurement, operating a control, or both.

Service
To adjust, repair, maintain, and make fit for use.

Single Point of Control
The ability to operate the robot such that initiation or robot motion from one source of control is possible only from that source and cannot be overridden from another source.

Slow Speed Control
A mode of robot motion control where the velocity of the robot is limited to allow persons sufficient time either to withdraw the hazardous motion or stop the robot.

Start-up
Routine application of drive power to the robot or robot system.

Start-up, Initial
Initial drive power application to the robot or robot system after one of the following events:

- Manufacture or modification;
- Installation or reinstallation;
- Programming or program editing; and
- Maintenance or repair.

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

Teach Mode
The control state that allows the generation and storage of positional data points effected by moving the robot arm through a path of intended motions.

Teacher
A person who provides the robot with a specific set of instructions to perform a task.

Tool Center Point (TCP)
The origin of the tool coordinate system.

User
A company, business, or person who uses robots and who contracts, hires, or is responsible for the personnel associated with robot operation.

Appendix IV: 4-2. Other Robotic Systems not Covered by this Chapter

Service robots are machines that extend human capabilities.

Automatic guided-vehicle systems are advanced material-handling or conveying systems that involve a driverless vehicle which follows a guide-path.

Undersea and space robots include in addition to the manipulator or tool that actually accomplishes a task, the vehicles or platforms that transport the tools to the site. These vehicles are called remotely operated vehicles (ROV's) or autonomous undersea vehicles (AUV's); the feature that distinguishes them is, respectively, the presence or absence of an electronics tether that connects the vehicle and surface control station.

Automatic storage and retrieval systems are storage racks linked through automatically controlled conveyors and an automatic storage and retrieval machine or machines that ride on floor-mounted guide rails and power-driven wheels.

Automatic conveyor and shuttle systems are comprised of various types of conveying systems linked together with various shuttle mechanisms for the prime purpose of conveying materials or parts to prepositioned and predetermined locations automatically.

Teleoperators are robotic devices comprised of sensors and actuators for mobility and/or manipulation and are controlled remotely by a human operator.

Mobile robots are freely moving automatic programmable industrial robots.

Prosthetic robots are programmable manipulators or devices for missing human limbs.

Numerically controlled machine tools are operated by a series of coded instructions comprised of numbers, letters of the alphabet, and other symbols. These are translated into pulses of electrical current or other output signals that activate motors and other devices to run the machine.