



Designation: F 1034 – 86 (Reapproved 1997)

Standard Guide for Classifying Industrial Robots¹

This standard is issued under the fixed designation F 1034; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide defines methods that may be used to classify the various types of industrial robots.

1.2 This guide is intended to facilitate communication regarding descriptions of industrial robots.

1.3 This guide does not cover automatic guided vehicles and systems, automatic storage and retrieval systems, automatic conveyor and shuttle systems, teleoperators (directly controlled by an operator), prostheses and other aids for the handicapped, mobile robots, numerical-controlled machine tools, personal robots, and undersea and space robots.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Document

2.1 ASTM Standard:

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods²

3. Terminology

3.1 Definitions of Terms Specific to This Standard:³

3.1.1 *accuracy*—the degree to which the average position of the tool point corresponds to the desired or commanded position.

3.1.2 *continuous path*—a control scheme whereby the inputs or commands specify every point along a desired path of motion.

3.1.3 *elbow*—the joint that connects the upper arm and the forearm.

3.1.4 *industrial robot*—an automated, controlled, reprogrammable, multi-function manipulative machine with or without locomotion for use in industrial automation systems' applications.⁴

3.1.5 *multifunction*—the capability to perform a variety of work assignments.

3.1.6 *non-servo controlled*—a robot that is generally driven by hydraulic or pneumatic cylinders or by electric stepping motors. The commanded point-to-point positions

may be either preset by mechanical stops or limit switches, generally two for each axis of motion; or determined by counting the electrical pulses to a stepping motor. The motions are accomplished without the benefit of feedback signals to define joint rotation or linear travel.

3.1.7 *point-to-point*—a control scheme whereby the inputs or commands specify only a limited number of points along a desired path of motion. The control system determines the intervening path segments.

3.1.8 *repeatability*—the closeness of repeated position movements under the same conditions, or the positional error of the tool point when it is automatically returned to a previously commanded or trained position.

3.1.9 *reprogrammable*—the capability to change programmed motions, or auxiliary functions, or both, without physically altering the system except possibly the end-of-arm tooling.

3.1.10 *servo controlled*—a robot driven by servo mechanisms whose driving signal is a function of the difference between commanded positions or rate, or both, and measured actual position or rate, or both. Such a robot is capable of stopping at or moving through a practically unlimited number of points in executing a programmed trajectory.²

3.1.11 *shoulder motion*—the joint or pair of joints that connect the arm to the base.

3.1.12 *variable programmed motion*—the capability to vary trajectories or stopping points, or both, of the tool point.

3.1.13 *waist motion*—a rotation of the robot about a center line that is perpendicular to the robot mounting base.

4. Significance and Use

4.1 The industrial robot has the ability to perform assignments in more than one specialized area with little or no basic design change in the unit. The industrial robot displays varying degrees of accuracy and repeatability and may be used for the following:

5. Application

5.1.1 Spray painting or the spray abrasion of surfaces;

5.1.2 Applying adhesives and sealants to surfaces;

5.1.3 Arc welding or the manipulation of an arc welding torch to deposit weld metal in a weld groove or on a surface;

5.1.4 *Spot Welding*—A process of joining metals by fusing them together by a series of weld nuggets;

5.1.5 *Assembly*—Robots place parts together in a preprogrammed sequence;

5.1.6 *Teaching*—Educational robots are generally small in size and weight and may be placed on desk or table tops for the purpose of teaching robot theory, application, and programming;

5.1.7 *Handling of Material*—General purpose robots may be used for material handling, including loading and un-

¹ This guide is under the jurisdiction of ASTM Committee E-49 on Computerization of Material and Chemical Property Data and is the direct responsibility of Subcommittee E 49.30 on System Development Methods.

Current edition approved Oct. 31, 1986. Published December 1986.

² Annual Book of ASTM Standards, Vol 14.02.

³ For further information refer to *Robotics Industries Association Glossary*, 1984 edition.

⁴ Proposed by the United States Technical Advisory Group (U.S. TAG) to the ISO/TC 184/SC2 of the International Standards Organization.

loading production equipment, packaging, palletizing, etc; and

5.1.8 *Tool Manipulation*—Including such processes as deburring, drilling, thermal cutting, and water jet cutting.

6. Classification of Industrial Robots

6.1 Industrial robots may be classified or categorized by their primary power sources, types of control, payload, programming method, mechanical configuration, degrees of freedom, and application.

6.2 While industrial robots are available in a wide range of capabilities and configurations, they are basically made up of a manipulator or mechanical unit that actually performs the manipulative function, the controller that stores data and directs the movement of the manipulator, and the energy system that provides the power to the manipulator.

7. Primary Power Sources

7.1 The primary power source of an industrial robot may be pneumatic, hydraulic, electric or any combination of these.

7.1.1 *Pneumatic*—Motive power units(s) may be air cylinders or servo motors operating with compressed gas(es) as the energy source.

7.1.2 *Hydraulic*—Motive power units(s) may be cylinders or servo motors operating with a hydraulic power pack as the energy source.

7.1.3 *Electric*—Motive power units(s) are ac or dc servo motors or stepping motors.

8. Motion Controls

8.1 Motion controls may be servo or non-servo; they are either point-to-point or continuous path.

8.2 It is recognized that other forms of control may exist within the bounds of the two defined in 3.1.2, 3.1.6, 3.1.7, and 3.1.10.

9. Programming Methods

9.1 A programming method may consist of set points, memory devices, teaching by the use of a keyboard or an on-line terminal, off-line, down loading from a host computer or a computer/aided design system.

9.1.1 *Set Points*—Simple robots are programmed by setting hard stops at the ends of the desired travel path. Intermediate stops may be set in and controlled by a sequencing device such as memory drums or step sequencers where the sequence of motions is preset by inserting pegs or stops into positions on the periphery of a rotating drum. The pegs or stops trip electric or pneumatic switches as the drum rotates. The sequence of motions may also be preset electronically by use of a programmable controller.

9.1.2 *Manual Teach Programming*—Manual teach programming may be accomplished by: manually leading the robot arm through the desired path including intermediate stops, manually leading or walking a slave unit or a mechanical simulating device through the desired path including intermediate stops, and using a manually controlled programming unit (teach pendant) to drive the robot arm to points in the desired path in a sequence of steps.

9.1.3 The off-line program may be produced on remote device and loaded into robot memory and may be explicit or

goal directed and can encompass just the logic, or just the data, or both. Off-line programming requires a high-level computer programming language and increased computer power. Computer-aided design (CAD)/computer-aided manufacturing (CAM) data base programs may be computer generated by utilizing the data base resident in a CAD system. These programs may be down loaded from the CAD system directly or via a host computer or distributed numerical control (DNC) system to the robot controller. These programs are of the continuous path type.

9.1.4 Programs may be altered by an editing function in the robot's controller or by signals from external sensing devices.

10. Axis Identification Convention

10.1 An industrial robot, as a body occupying space, has six degrees of freedom, three in translation and three in rotation. However, the robotic system may have more than six axes of motion by the addition of powered translation devices or additional links and powered joints, or both, between the arm and the end effector.

10.2 *Translation Axes*—The translation axes are the two coordinate axes at right angles to each other parallel to the earth's surface or robot base. These axes are often identified as X and Y. One coordinate axis perpendicular to the robot base and generally in the direction of gravity is often identified as Z.

10.3 The rotation axes are between the last of the interconnected set of robot arm links and the mechanical interface or end-effector mounting surface. These axes support, move, and orientate the end effector. The term often used for these axes are roll, pitch, and yaw.

10.4 The numerous robotic configurations do not always permit axes identifications to be the simple X, Y, Z, roll, pitch, and yaw. In these cases the following convention shall be used:

10.4.1 *Axis 1*—The axis of motion nearest the earth or foundation mounting surface is Axis 1. This is the origin of the first member of the robot structure.

10.4.2 *Axis 2*—The next axis of motion in the direction toward the mechanical interface (end-of-arm tooling mounting surface) is Axis 2.

10.4.3 Successive axes of motion will be sequentially numbered to the very last axis of motion.

10.5 All figures in this guide will have the axes of motion identified in numerical sequence as in 10.4. The translation and rotational motions are enclosed in parentheses as applicable.

11. Mechanical Configuration

11.1 *Geometric Description*—The mechanical configurations of the robots arm may be geometrically described as cylindrical, rectilinear, spherical, or articulated. The base of an industrial robot is generally floor mounted, although some may be wall, ceiling, or rail mounted.

11.2 *Work Envelope Description*:

11.2.1 The work envelope of a cylindrical industrial robot is defined by cylindrical coordinates. The robot has three major axes of motion, two are linear and the third angular. Linear motions consist of the arm moving up and down (Z Axis) and in and out (Y Axis). Angular rotations are around

the vertical axis and are often referred to as a waist motion. (See Fig. 1.) An added motion may be achieved by mounting the robot on a mobile transporter or movable platform that travels on a track. (See Fig. 2.)

11.2.2 The work envelope of a rectilinear (often referred to as rectangular or cartesian) robot, is a six-sided parallel-piped. The major axes of motion are X, Y, and Z. There are several variants to this configuration including, but not limited to, the following:

11.2.2.1 *Gantry Robot*—A bridge crane where the X motion is the bridge traveling on elevated rails. The Y motion is the carriage traversing the bridge, and the Z motion being an arm attached to the carriage, able to move up and down. One or more bridges may traverse in the X axis, (see Fig. 3).

11.2.2.2 *Cantilevered Arm*—Mounted to a column and the column mounted on a base or transporter that has motion on a track (see Fig. 4). The motions are Y (arm in and out), Z (arm up and down on the column), and X (column or arm traverses on the track).

11.2.2.3 *Modular Units*—A variant that may be assembled together as required. The number of axes of motion with modular units is almost limitless (see Fig. 5). The motions are primarily linear but do not exclude rotation as in a robot's wrist.

11.2.2.4 An additional variant has two (or more) cantilevered arms mounted on a common horizontal rail that, in turn, is mounted on a column. (See Fig. 6.) The cantilevered arms have independent X axis motion and a common Y and Z axis motion.

11.2.3 *Spherical Work Envelope*—The work envelope of a spherical (sometimes referred to as polar) industrial robot is a portion of a sphere (see Fig. 7). The major motions are angular and linear. The angular motions are a waist turn in a horizontal plane and a shoulder turn in a vertical plane. The linear motion is radial and is the extension and retraction of the arm. This robot configuration may also be mounted on a transporter that travels on a track to achieve another major axis of motion (X axis) (see Fig. 8).

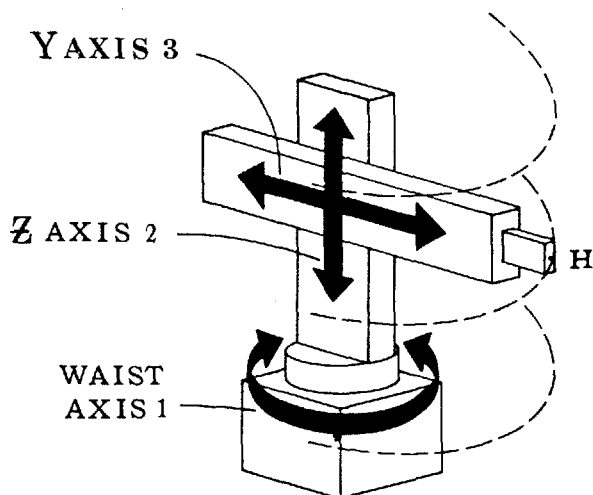


FIG. 1 Cylindrical Coordinate Robot

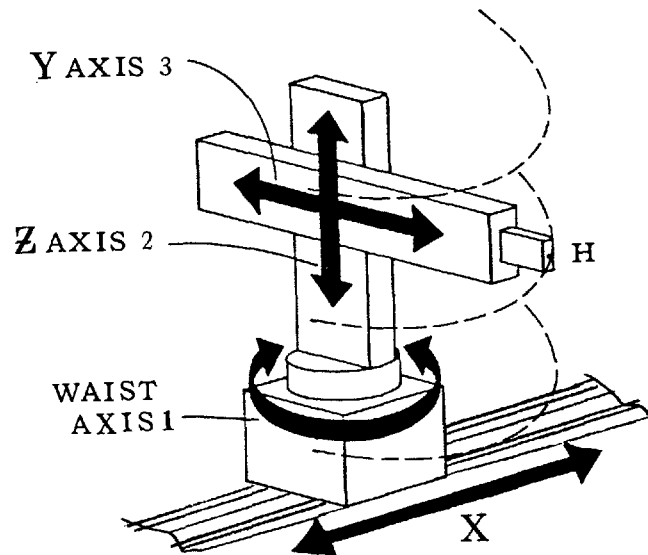


FIG. 2 Cylindrical Coordinate Robot on a Transporter

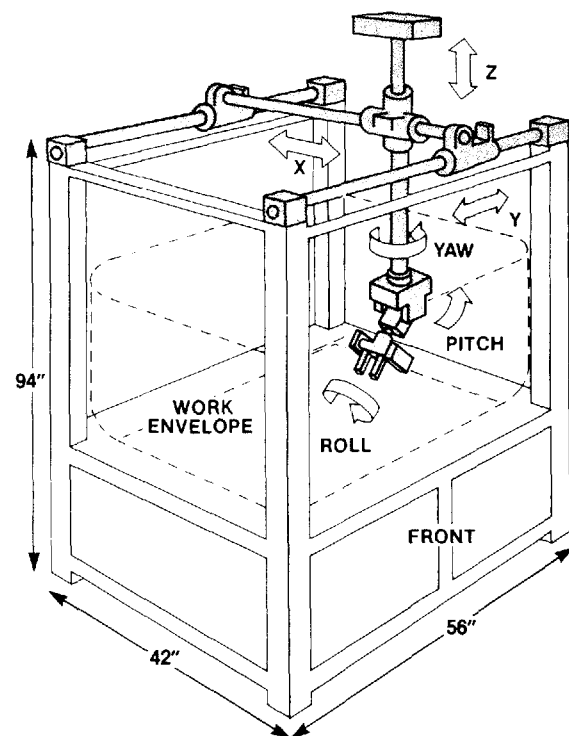


FIG. 3 Gantry Robot Rectangular Coordinate Robot

11.2.3.1 *Pendulum Configuration*—A variant of the spherical work envelope where the vertical arm is supported on a gimbal (see Fig. 9).

11.2.4 The irregular work volume is generated by a jointed-arm industrial robot that has often been referred to as revolute, articulated, or anthropomorphic. The major axes of motion are generated by the coordinated angular movements of the major joints. All have a waist turn. Two of the three major motions may be either in the vertical or horizontal plane.