AWS D16.3M/D16.3:2026
An American National Standard

Risk Assessment Guide for Robotic Arc Welding



American Welding Society®



AWS D16.3M/D16.3:2026

An American National Standard

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Risk Assessment Guide for Robotic Arc Welding

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Prepared by the
American Welding Society (AWS) D16 Committee on Robotic and Automatic Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

AWS D16.3M/D16.3:2025, *Risk Assessment Guide for Robotic Arc Welding*, provides recommendations and guidelines for the safe implementation of robotic arc welding. Emphasis is placed on conformance of this process with prevailing industry standards for hazard analysis and proper safeguarding.



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Foreword

This foreword is not part of this standard but is included for informational purposes only.

The AWS D16 Committee on Robotic and Automatic Welding was organized in 1985 to provide a centralized source for the exchange of technical information between manufacturers, installers, and operators of robotic and automated arc welding equipment.

AWS D16.3 was initially published in 2001. The fourth edition provides updated recommendations and guidelines for the safe implementation of robotic arc welding.

A vertical line in the margin or underlined text in clauses, tables, or figures indicates an editorial or technical change from the previous edition.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D16 Committee on Robotic and Automatic Welding, American Welding Society, 8669 NW 36 St, # 130, Miami FL 33166.

Table of Contents

Page No.

Personnel v
Foreword vii
List of Tables x
List of Figures x

1. General Requirements 1
1.1 Scope 1
1.2 Units of Measurement 1
1.3 Safety 1

2. Normative References 2

3. Terms and Definitions 2

4. General Considerations 7
4.1 Risk Assessment Process 7
4.2 Performance 7
4.3 System Modifications 7

5. Elements of the Risk Assessment Process 7
5.1 Application Description 8
5.2 Robot Operating Characteristics 8
5.3 Robot Classification 8
5.4 Categories of Hazards 8
5.5 Risk Analysis 9

6. Documentation 12
6.1 Classification Summary 12
6.2 Work Cell (Workspace) Description 12
6.3 Summary of Potential Hazards 12
6.4 Method of Safeguarding 12

Annex A (Informative)—Informative References 15
Annex B (Informative)—Sample Risk Assessment Form 17
Annex C (Informative)—Requesting an Official Interpretation on an AWS Standard 23

List of AWS Documents on Robotics and Automatic Welding 25

List of Tables

Table		Page No.
1	Robot Operating Subclassification	10
2	Application Classifications	10
3	Classification Summary	10
4	Recommended Safeguarding Protocols	11

List of Figures

Figure		Page No.
1	Plan View Example of a Protocol 1 Robotic Arc Welding Work Cell (Not All-Inclusive)	13

Risk Assessment Guide for Robotic Arc Welding

1. General Requirements

1.1 Scope. The purpose of D16.3M/D16.3:2026, *Risk Assessment Guide for Robotic Arc Welding*, is to identify hazards associated with robotic arc welding. This will help protect personnel. It is not intended to be a guideline for other industrial robotic applications. This guide is intended for persons performing risk assessment and applies to arc welding robots and robot arc welding systems performing the gas metal arc welding (GMAW) or flux cored arc welding (FCAW) process. Applicable ANSI B11 standards include B11.0, B11.19, B11.20, et al.

Exclusions:

This standard is not intended to be a guideline for other robotic applications, such as:

(1) Automatic guided vehicle systems,

(2) Undersea and space robots,

(3) Automatic conveyor and shuttle systems,

(4) Teleoperators,

(5) Mobile robots, and

(6) Multiple robots.

Although this guide is not written with mandatory requirements, mandatory language, such as the use of "shall", will be found in those portions of the document where failure to follow the instructions or procedures could produce inferior, misleading or unsafe results.

1.2 Units of Measurement. This standard makes use of both the International System of Units (SI) and U.S. Customary Units. The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

1.3 Safety. Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments or revisions of the publications may not apply since the relevant requirements may have changed.

American Welding Society (AWS) documents:

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Additive Manufacturing, Adhesive Bonding, Brazing, Soldering, Thermal Cutting, Thermal Spraying, and Nondestructive Examination*

AWS D16.1, *Specification for Robotic Arc Welding Safety*

AWS D16.2, *Guide for Components of Robotic and Automatic Arc Welding Installations*

AWS D16.4, *Specification for the Qualification of Robotic Arc Welding Personnel*

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

International Organization for Standardization (ISO) standards:

ISO 10218-1, *Safety Requirements — Part 1: Industrial Robots*

ISO 10218-2, *Safety Requirements — Part 2: Industrial Robot Applications and Robot Cells*

Occupational Safety and Health Administration (OSHA) documents:

OSHA 1904, *General requirement for recording and reporting occupational injuries and illnesses*

OSHA 1910.147, *Control of hazardous energy* (Lockout/Tagout)

OSHA 1910.212, *General requirements for all machines* (Machine guarding)

OSHA 1910.219, *Mechanical power transmission apparatus*

Robotic Industries Association (RIA) document:

ANSI/RIA R15.06, *American National Standard for Industrial Robot and Robot Systems*

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

actuator. A mechanism used to affect motion.

(1) A power mechanism which converts electrical, hydraulic, or pneumatic energy to effect motion.

(2) A mechanical mechanism within a control device (e.g., a rod which opens contacts).

(3) A device (e.g., specialized key) which initiates a (un)locking sequence.

ancillary equipment. A component added to an industrial robotic welding system to provide an extra function to support the welding process or its application. (e.g., laser scanners, video cameras, nozzle cleaners, wire cutters, anti-spatter spray, wire straighteners).

application. The type of welding application will influence the risk assessment. A description of the components that are to be welded, the weld process to be used, the sequence of operation of the welding robot(s), and any other information that is needed to understand the operation of the system should be compiled by the user.

approved. To accept as satisfactory to agreed standards or specifications.

audible alarm. An electrical or mechanical signal, clearly discernible above environmental noise, indicating a condition requiring the operator's attention.

automatic mode. Operating mode in which the robot control system operates autonomously in accordance with the task program.

auxiliary equipment. A component integrated into an industrial robot system to provide a function additive to that of the primary robot. (e.g., integrated servo positioner under teach pendant control).

barrier. A physical means of separating people from the hazard.

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 which define the capabilities, actions and responses of the robot system. This program is usually not intended to be modified by the user.

control station. Part of the robot system which contains one or more control devices intended to activate or deactivate functions of the system or parts of the system. The control station can be fixed in place (e.g. control panel), or movable (e.g. pendant).

design risk assessment. A hazard analysis that is conducted during the design phase and occurs prior to system installation.

drive power. The energy source or sources for the robot actuators.

emergency stop. The operation of a circuit that overrides all other robot controls, removes drive power, causes all moving parts to stop, and removes energy sources, including stored energy, from other hazardous functions present in the safeguarded space but does not cause additional hazards.

enabling device. A manually operated device which when continuously activated, permits motion.

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, potential, kinetic, or other sources of power/movement.

envelope. The three-dimensional space encompassing the movements of all robot parts (see space).

field risk assessment. A type of hazard analysis that occurs after the system is complete, at time of installation, and at inspection periods thereafter as deemed appropriate, includes but is not limited to relocation, working changeover, and process change. The field risk assessment typically references the Design Risk Assessment.

guard. A physical barrier which protects personnel from exposure to a hazardous area.

hard stop. Rigid mechanical interface device which will prevent movement of a robotic system past the point of contact.

hazard. A potential source of harm.

hazardous motion. Any motion that is likely to cause personal physical harm.

industrial arc welding robot system (robot system).

(1) An industrial robot combined with ancillary and auxiliary equipment necessary to perform a production arc welding process. Typically, the robot is electrically interfaced to ancillary and auxiliary equipment.

(2) Any equipment, devices, or sensors required for the robot to perform its task

(3) Any communication interface that is operating and monitoring the robot, equipment, or sensors, as far as these ancillary devices are supervised by the robot control system.

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

industrial robot. An automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes which may be either fixed in place or mobile for use in industrial automation applications.

industrial robot cell. One or more robot system(s) including associated machinery and equipment and the associated safeguarded space and protective measures.

industrial robot system. Equipment that includes the robot(s) (hardware and software) consisting of the manipulator power supply and control system, the end-effector(s), and any other associated machinery and equipment within the safeguarded space.

infrared sensor. An electric device which monitors the light spectrum for infrared emissions. The sensor will send a signal to the controller when the infrared light is detected at or above a preset level.

inspection. Examination or measurement to verify whether an item or activity conforms to specified requirements.

integrator. Entity that designs, provides, manufactures or assembles robot systems or integrated manufacturing systems and is in charge of the safety strategy, including the protective measures, control interfaces and interconnections of the control system. The integrator can be a manufacturer, assembler, engineering company, or the user.

interlock. An arrangement whereby the operation of one control or mechanism allows or prevents the operation of another.

interlock switch. An electrical or mechanical means by which operation of a component is prevented or maintained unless required conditions are met.

joint. An axis of motion. For a six (6) axis, articulated servo-controlled welding robot, the joints are typically defined as follows:

Joint 1—Rotary or waist rotation

Joint 2—Shoulder rotation

Joint 3—Elbow rotation

Joint 4—Outer link or upper arm rotation

Joint 5—Wrist bend or yaw

Joint 6—Wrist roll or swivel

light curtain. A noncontact perimeter barrier device which will send a signal to the system controller if an object penetrates or interrupts the plane of the perimeter.

limiting device. A device that restricts the maximum space by stopping or causing a stop to all robot motion and is independent of the control program and the task programs.

lockout/tagout. A means to render equipment incapable of inadvertent release of energy from sources such as electrical, mechanical, pneumatic, and hydraulic, including stored energy, during periods of maintenance or servicing. Refer to the OSHA standard for The Control of Hazardous Energy (Lockout/Tagout).

manipulator. The mechanism of a machine that usually consists of a series of segments jointed or sliding relative to one another used for grasping and/or moving objects usually in several degrees of freedom.

manufacturer. Any person or organization who manufactures, converts, modifies, or otherwise alters robotic arc welding systems.

maximum space. Space which can be swept by the moving parts of the robot as defined by the manufacturer plus the space which can be swept by the end-effector and the workpiece.

mobile robot. A self-propelled and self-contained autonomous device that is capable of moving over a mechanically unconstrained course.

monitoring device. A device, which may be used to verify the function of another device.

motion detector. A sensor which monitors motion of an object. This is often accomplished with several infrared sensors in close proximity, or with rotary or linear encoding devices coupled to actuators.

network. The user's internal communications broadband network(s), either hardwired or wireless, and related host servers and computers connected to the arc welding robot(s) and related control systems.

noise. Hazards producing sound vibrations exceeding the prevailing code regulations for noise exposure.

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

operator control. Point of operation performed solely by a single individual who is responsible for the safe use of the robot.

part handling. A robot that utilizes a grasping device to manipulate a component, tool, or weldment through a motion routine.

pendant. A hand-held device linked to the control station with which a robot or auxiliary equipment can be programmed or moved. Also called teach pendant.

perimeter barrier. A rigid, fence-like structure that surrounds the restricted envelope (space) of a system of one or more robots and may have entry openings for process equipment, material, and/or personnel authorized to operate or maintain the robot system.

periodic safety checks. A required procedure documented by the equipment manufacturers, integrators, and end-users to validate proper and reliable functionality of all safety, motion braking/stop, or energy source devices and related software.

physical barrier. A rigid boundary to safeguard personnel access. Cages, gates, walls, shields, and fences are all examples of physical barriers.

pinch point. Any location where it is possible to be caught between moving parts or between a moving and stationary part.

point of operation. The location(s) within the safeguarded space where work is performed on the material or workpiece. ANSI/RIA R15.06-1999.

preventative maintenance. Documented procedures from the equipment manufacturers and integrators to confirm, preserve, or extend the operational performance and useful life of the integrated system, including safety equipment functionality.

program.

(1) The instruction set of commands and locations within the robot control that determines robot arm path, trajectory, speed, and interface.

(2) The act of teaching the robot commands and path information.

protective stop. Type of interruption of operation that allows a cessation of motion for safeguarding purposes and which retains the program logic to facilitate a restart.

qualification. Verification by testing the knowledge or abilities gained through training, experience, or both that enables individuals to perform certain function.

qualified. Having complied with specific requirements defined within a standard.

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

restricted space. The portion of the maximum space restricted by limiting devices that establish limits which will not be exceeded.

risk. A combination of the probability and the degree of the possible injury or damage to health in a hazardous situation.

risk assessment. A comprehensive, documented evaluation of the possible injury or damage severity to health in a hazardous situation in order to select appropriate prevention or remediation safeguards. Risk assessments should be conducted and documented in phases and in advance of equipment purchase, design and build, after integration, and upon final integration, installation, and commissioning at the end-user site.

robot. See **industrial robot**.

robot actuator. Powered mechanism that converts electrical, hydraulic, or pneumatic energy to effect motion and controlled by the robot controller.

robot system. See **industrial robot system**.

robotic arc welding gun. An apparatus fixed to the end of the robot that directs the placement of an electrode, plasma column or filler metal supplied as a continuous electrode and provides the means for supplying welding current and shielding gas as necessary.

safeguarding device. A means that detects or prevents access to a hazard.

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

safeguarded space. The space defined by the perimeter safeguarding.

safeguarding. The act of providing personnel with protection from a hazard.

safety fence. A type of physical barrier used to deter accidental entry into a robotic work cell area. Signs should be placed on the fence warning of the hazards within its boundaries.

safety mat. A flat pressure-sensitive mat which sends a signal to the robotic controller if activated.

safety mirror. Large mirrors, often wide angle, placed in strategic locations to allow the operator visual access to areas of the robotic workcell that would otherwise be obstructed.

safety procedure. A set of instructions designed for the protection of personnel.

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

shall. A term used to designate a mandatory requirement.

shield. A barrier that protects against the hazards of arc flash, weld spatter, and/or flying sparks. The barrier may move with the fixture, positioner, or be integrated into other safety barriers.

should. A term used to designate recommended (non-mandatory) safe practices.

signage. Graphic communication whose functions include direction, identification, information, regulation, warning, or restriction.

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

slow speed control. A mode of robot motion control where the speed is limited to 250 mm/s [10 in/s] to allow persons sufficient time to either withdraw from hazardous motion or stop the robot.

space. The three-dimensional volume encompassing the movements of all robot parts through their axes (previously called envelope).

specification. A group of attributes, conditions, or tolerances that are desired or required.

standard. A generic term incorporating codes, specifications, recommended practices, classifications, methods, and guides that have been prepared by a sponsoring body, and approved and adopted in accordance with established procedures.

task program. Set of instructions for motion and auxiliary and ancillary functions that define the specific intended task of the robot system.

teach. Programming the robot through the use of a handheld pendant, control-augmented end effector, or arc welding gun that is specifically designed for the task.

teach mode. The control state that allows the generation, storage, and playback of positional data points and peripheral equipment functions while under slow speed control. This is not functional or performance verification.

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

tool center point (TCP). The point defined for a given application with regard to the mechanical interface coordinate system. For robot arc welding systems, typically the termination of the work end of the electrode extension.

user. Entity that uses robots and is responsible for the personnel associated with the robot operation.

verification. Confirmation by examination and provision of objective evidence that the documented and agreed upon requirements have been fulfilled.

video monitoring devices. Video camera equipment, mounted remotely from the operator, allowing the operator clear viewing of an otherwise obstructed or an improved view of a normally visible area.

visual alarm. A mechanical or electronic signal, clearly discernible above environmental distractions (e.g., lights, moving equipment) informing the operator of a situation requiring his attention. Steady lights, flashing light, and flags are all examples of visual alarms.

welding terminals. The connectors of an arc welding power source which furnish welding power and, when provided, high-frequency energy for the welding arc.

4. General Considerations

4.1 Risk Assessment Process. The risk assessment process is influenced by the specific application, type of robot(s), and the interaction of the robot(s) with other equipment. A risk assessment includes the following:

(1) Application description,

(2) Itemization of the equipment,

(3) A listing of potential personnel safety hazards,

(4) Analysis of the safety risks associated with the identified hazards,

(5) Mitigation selection,

(6) Verification of mitigation, and

(7) Documentation.

4.2 Performance. A risk assessment should be performed by personnel who possess the knowledge of the risk assessment process and the robot application. A single person should be given the clear-cut assignment and authorization to lead the team risk-assessment effort. Some possible candidates to perform the user's risk assessment include the company safety director, welding engineer, project leader or operational representatives. A separate risk assessment should be performed for each independent arc welding robot installation. Risk assessment falls under two major categories:

(1) Design Risk Assessment

(2) Field Risk Assessment

4.3 System Modifications. Any modification to the application, safeguarding or physical/electrical changes made to the industrial robot cell shall require a new field risk assessment to be performed by the user.

5. Elements of the Risk Assessment Process

The purpose of the risk assessment is to identify potential hazards to personnel associated with robot cells so that appropriate safeguarding and other risk reduction measures can be proposed and implemented. This section identifies the robot application and operating characteristics as a means to analyze risk and determine minimum requirements for safeguards.

For the purposes of this risk assessment methodology, potential hazards to personnel can be classified as taking place during either production or non-production activities. In order for risks to be effectively mitigated, the risk assessment shall evaluate potential risks and identify effective risk reduction methods during both production and non-production activities.