

Risk Assessment Guide for Robotic Arc Welding



American Welding Society



**AWS D16.3M/D16.3:2009
An American National Standard**

**Approved by the
American National Standards Institute
November 13, 2008**

Risk Assessment Guide for Robotic Arc Welding

2nd Edition

Supersedes AWS D16.3M/D16.3:2001

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/D16.3:2009, *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.



American Welding Society

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International Standard Book Number: 978-0-87171-669-9

American Welding Society

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Foreword

This foreword is not part of AWS D16.3M/D16.3:2009, *Risk Assessment Guide for Robotic Arc Welding*, 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. This second edition has been updated with the latest terms and guidelines and has been reformatted to meet the latest AWS specifications for standards.

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, 550 N.W. LeJeune Road, Miami, FL 33126.

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Risk Assessment Guide for Robotic Arc Welding

1. Scope

The purpose of D16.3M/D16.3:2009, *Risk Assessment Guide for Robotic Arc Welding*, is to identify and evaluate potential safety hazards associated with robotic arc welding. It is not intended to be a guideline for other 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.

It 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.

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.

The inclusion of all safety, health issues, and concerns are beyond the scope of any one document and therefore are not fully addressed herein. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

2. Normative References

The following standards contain provisions, which through reference in this text, constitute provisions of

this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS Documents¹

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

AWS A3.0, *Standard Welding Terms and Definitions*

Other Documents

RIA R15.06, *American National Standard for Industrial Robot and Robot Systems—Safety Requirements*.²

3. Definitions

Terms used in this document are in accordance with AWS 3.0, *Standard Welding Terms and Definitions*. In addition, for the purposes of this document, the following terms and definitions apply:

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

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

automatic mode. The robot state in which automatic operation can occur.

automatic operation. The state in which the robot is executing its programmed task as intended.

barrier. A physical means of isolating a hazard or defining a space.

¹ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

² RIA standards are published by the Robotic Industries Association, 900 Victors Way, P.O. Box 3724, Ann Arbor, MI 48106.

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 define the capabilities, actions, and responses of the robot system. This program is usually not intended for modification by the user.

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

discrete input. An on-off signal from peripheral equipment to the robot controller.

discrete output. An on-off signal to peripheral equipment from the robot controller.

emergency stop. The operation of a circuit using hardware-based components that overrides all other controls, reduces all mechanisms to a zero energy state, causes the cessation of all mechanical movement, and terminates the electrical welding output of the welding power source.

enabling device. A manually operated device that, when continuously activated, permits motion. Deactivating 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.)

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

envelope (space), restricted. 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.

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

hazard. Something with the potential to cause harm.

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

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

infrared sensor. An electric device that 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.

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

interlocked barrier. A physical barrier which separates persons from the hazard by means of an interlock.

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

light curtain. A noncontact perimeter barrier device that 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 envelope (space) by stopping or causing to stop all robot motion and which 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.

maintenance support personnel. Skilled craftsmen and technicians who install the equipment and troubleshoot/repair the systems while in production.

mobile robot. A self-propelled and self-contained robot that is capable of moving over an unconstrained course.

motion detector. A sensor that monitors for movement of an object.

noise hazard. Sound levels exceeding the prevailing code regulations for noise exposure.

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

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.

output enable. Discrete output signal for activating all automatically controlled discrete output signals.

part handling. The function performed by a robot to manipulate a component, tool, or workpiece through a motion routine.

pendant. Any manually repositionable control device, including a 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.

physical barrier. A rigid boundary to prevent or deter access to a robotic work cell area. Cages, gates, walls and fences are all examples of physical barriers.

pinch points. Objects against which a human can be trapped and injured. Items include safeguarding devices, robot arm, tooling, building structure, and ancillary equipment.

program. (noun)—Sequence of instructions to be executed by the computer or robot controller to control a robot/robot system; (verb)—furnish (a computer) with a code of instructions; (verb)—teach a robot system a specific set of movements and instructions to accomplish a task.

programmers. The system development engineers and technicians doing the initial work and the weld technicians who maintain the programs that are in production.

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

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

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. Flat, pressure sensitive device that 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 work cell 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.

signage. Environmental 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 is possible through only one source of control that cannot be overridden by another control source.

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.

tool center point (TCP). The point defined for a given application relative to the mechanical interface coordinate system.

ultrasonic sensor. An electrostatic transceiver that sends a signal to the robotic controller if an object reaches a predetermined distance from the transceiver. This signal can activate an alarm or terminate robotic motion.

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

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

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

4. General Considerations

4.1 Risk Assessment Description. 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) Description of the application,
- (2) Itemization of the equipment,
- (3) A listing of potential hazards, and
- (4) Analysis of the safety risks associated with the identified hazards.

4.2 Performance. A risk assessment should be performed by personnel who possess the knowledge of the robot application. A single person should be given the clear-cut assignment to lead the team risk-assessment effort. Some possible candidates include the company safety director, welding engineer, or project leader. A separate risk assessment should be performed for each independent arc welding robot installation.

4.2.1 Design Risk Assessment. The design risk assessment is prepared during or after the selection of capital equipment that will be utilized in a robot arc welding system. The design risk assessment is a process of hazard analysis that occurs during system design.

4.2.2 Field Risk Assessment. The field risk assessment is a type of hazard analysis that occurs after the system is complete, at time of installation, and at inspection periods thereafter as deemed appropriate.

5. Elements of the Risk Assessment

5.1 Application Description. The robot arc welding cell description should include information about the robot(s), tooling, fixturing, material or part handling equipment, workpiece positioning equipment, operator interface, and safety devices. The description should detail the type of product being welded and the procedure used.

The documentation that records the description can consist of technical drawings and other engineering information pertaining to the application.

5.2 Robot Operating Characteristics. Operating characteristics are utilized to establish robot and robot system classification. Robots for arc welding applications can be identified by the following operating characteristics:

- (1) working payload
- (2) working reach
- (3) working maximum velocity

5.3 Robot Classification. The robot classification is based upon operating characteristics of the robot and robot system. The robot classification establishes the minimum safeguarding protocol procedures required.

5.4 Categories of Hazards

5.4.1 Hazards to Personnel. Hazards to personnel are summarized as follows:

- (1) fumes and gases
- (2) radiation
- (3) noise

- (4) chromium and nickel in welding fumes
- (5) electrical hazards
- (6) fire and explosion
- (7) burns
- (8) mechanical hazards
- (9) tripping and falling
- (10) falling objects
- (11) confined spaces
- (12) contact lens wear
- (13) ergonomic aspects

This list is not exhaustive and represents the minimum number of identified potential hazards to personnel.

5.4.2 Electromagnetic Hazards. Before installing welding equipment, the user should make an assessment of potential electromagnetic problems in the surrounding area. The following items should be taken into account:

- (1) supply cables, control cables, signaling and telephone cables above, below, and adjacent to the welding equipment;
- (2) radio and television transmitters and receivers;
- (3) computer and other control equipment;
- (4) safety critical equipment, e.g., guarding of industrial equipment;
- (5) personnel health, e.g., the use of pacemakers and hearing aids;
- (6) equipment used for calibration or measurement;
- (7) the immunity of other equipment in the environment; the user should ensure that other equipment being used is compatible, which may require additional protective measures;
- (8) the time of day that welding or other activities will be carried out; and
- (9) the size of the surrounding area (will depend on the structure of the building and other activities that are taking place); the surrounding area may extend beyond the boundaries of the premises.

5.5 Risk Analysis. The risk of injury to personnel should be analyzed using the process described in 5.5.1 and 5.5.2.

5.5.1 Risk Determination/Severity for Robotic Arc Welding Applications. The type of risk and the potential level of personnel injury are determined by identifying the application as follows:

(1) robot operating subclassification (see Table 1)

(2) application classifications (see Table 2)

5.5.2 Minimum Safeguards. The minimum safeguards for robotic arc welding applications are identified in 5.5.2.1 through 5.5.2.3.

5.5.2.1 Classification Summary. See Table 3.

5.5.2.2 Minimum Safeguarding Protocols. See Table 4.

5.5.2.3 Safeguarding and Warning Devices. The following is a list of commonly used safeguarding and warning devices:

(1) audible alarm

(2) barrier

Table 1
Robot Operating Subclassification

A. HIGH ENERGY ROBOT

Any of the following minimum performance characteristics would qualify a robot as a high-energy machine:

- Over 15 kg [33 lb] payload capacity at TCP of the robot.
- Over 14 N-m [10 ft-lbf] of rotational torque of any auxiliary equipment.
- Over 1.3 m/s [50 in/s] velocity of robot or any other moving equipment in the system.

B. MEDIUM ENERGY ROBOT

The following provides a range of performance characteristics that define a medium-energy machine:

- 3 kg to 15 kg [7 lb to 33 lb] payload capacity at TCP of the robot.
- Less than 14 N-m [10 ft-lbf] of rotational torque of any auxiliary equipment.
- Less than 1.3 m/s [50 in/s] velocity of robot or any other moving equipment in the system.

C. LOW ENERGY ROBOT

All of the following are required to qualify a robot as a low energy machine:

- Less than 3 kg [7 lb] payload capacity at TCP of the robot.
- Less than 14 N-m [10 ft-lbf] of rotational torque of any auxiliary equipment.
- Less than 1.3 m/s [50 in/s] velocity of robot or any other moving equipment in the system.

Table 2
Application Classifications

A. CLASS 1

- Pinch points exist that can cause trapping of personnel between robot and auxiliary equipment within a space of 460 mm [18 in] or less.
- Auxiliary equipment velocity in the excess of 1.3m/s [50 in/s] and/or total minimum transfer mass of 30 kg [66 lb].
- The robot control does not have a single point of control for all auxiliary equipment.

B. CLASS 2

- Pinch points exist that can cause trapping of personnel between robot and auxiliary equipment within a space of 460 mm to 760 mm [18 in to 30 in].
- Auxiliary equipment velocity is in the range from 0.25 m/s to 1.3 m/s [10 in/s to 50 in/s] and/or total transfer mass of 2 kg to 30 kg [5 lb to 66 lb].
- The robot control has a single point of control for all auxiliary equipment.

C. CLASS 3

- Pinch points are nonexistent or involve equipment spacing that exceeds 760 mm [30 in].
- No hazards are created by the action of auxiliary equipment.
- The robot control has a single point of control for all auxiliary equipment.

Table 3
Classification Summary

APPLICATION CLASSIFICATION	ROBOT SYSTEM TYPE		
	HIGH ENERGY	MEDIUM ENERGY	LOW ENERGY
CLASS 1	PROTOCOL 1	PROTOCOL 1	PROTOCOL 1
CLASS 2	PROTOCOL 1	PROTOCOL 2	PROTOCOL 3
CLASS 3	PROTOCOL 2	PROTOCOL 3	PROTOCOL 4

Table 4
Minimum Safeguarding Protocols^a

A. PROTOCOL #1

- Physical barriers are required throughout;
- Lockout/tag out procedures required for maintenance;
- Alternate procedures for regular servicing;
- Single teach pendant/single programmer;
- Hard mechanical stops to restrict unintended envelope movement;
- Protection from all environmental hazards; and
- All safety circuits are required to be control-reliable in accordance with ANSI/RIA R15.06, *American National Standard for Industrial Robot and Robot Systems—Safety Requirements*.

B. PROTOCOL #2

- Physical barriers are required throughout;
- Lockout/tagout procedures required for maintenance;
- Alternate procedures for regular servicing;
- Second person equipped with suitable enable device;
- Hard mechanical stops to restrict unintended movement;
- Protection from all environmental hazards; and
- All safety circuits are required to be control-reliable in accordance with ANSI/RIA R15.06, *American National Standard for Industrial Robot and Robot Systems—Safety Requirements*.

C. PROTOCOL #3

- Physical barriers are preferred;
- Lockout/tag out procedures required for maintenance;
- Alternate procedures for regular servicing;
- Single teach/multiple programmer observer equipped with suitable enable device;
- All persons equipped with suitable enabling device;
- Protection from all environmental hazards; and
- All safety circuits are required to be control-reliable in accordance with ANSI/RIA R15.06, *American National Standard for Industrial Robot and Robot Systems—Safety Requirements*.

D. PROTOCOL #4

- Passive safeguards allowed;
- Lockout/tag out procedures required for maintenance;
- Single teach/multiple observers;
- Multiple maintenance workers;
- Protection from all environmental hazards; and
- All safety circuits are required to be control-reliable in accordance with ANSI/RIA R15.06, *American National Standard for Industrial Robot and Robot Systems—Safety Requirements*.

^a For additional information, see appropriate references in Annex B.

- (3) hard stop
- (4) infrared sensor
- (5) interlock switch
- (6) laser scanner
- (7) light curtain
- (8) motion detector
- (9) physical barrier
- (10) safety fence
- (11) safety mat
- (12) safety mirror
- (13) signage
- (14) ultrasonic sensor
- (15) video monitoring devices
- (16) visual alarm
- (17) operator weld screen

6. Documentation

6.1 Classification Summary. The risk assessment should be documented to ensure that the procedures and requirements that are established by the risk assessment are properly followed by all personnel associated with the arc welding robot application. A sample form is shown in Annex C.

6.2 Work Cell (Workspace) Description. For each robot work cell that is applied to a welding task, a work cell or workspace description should be produced. See Figure 1 for an example. This description should include,

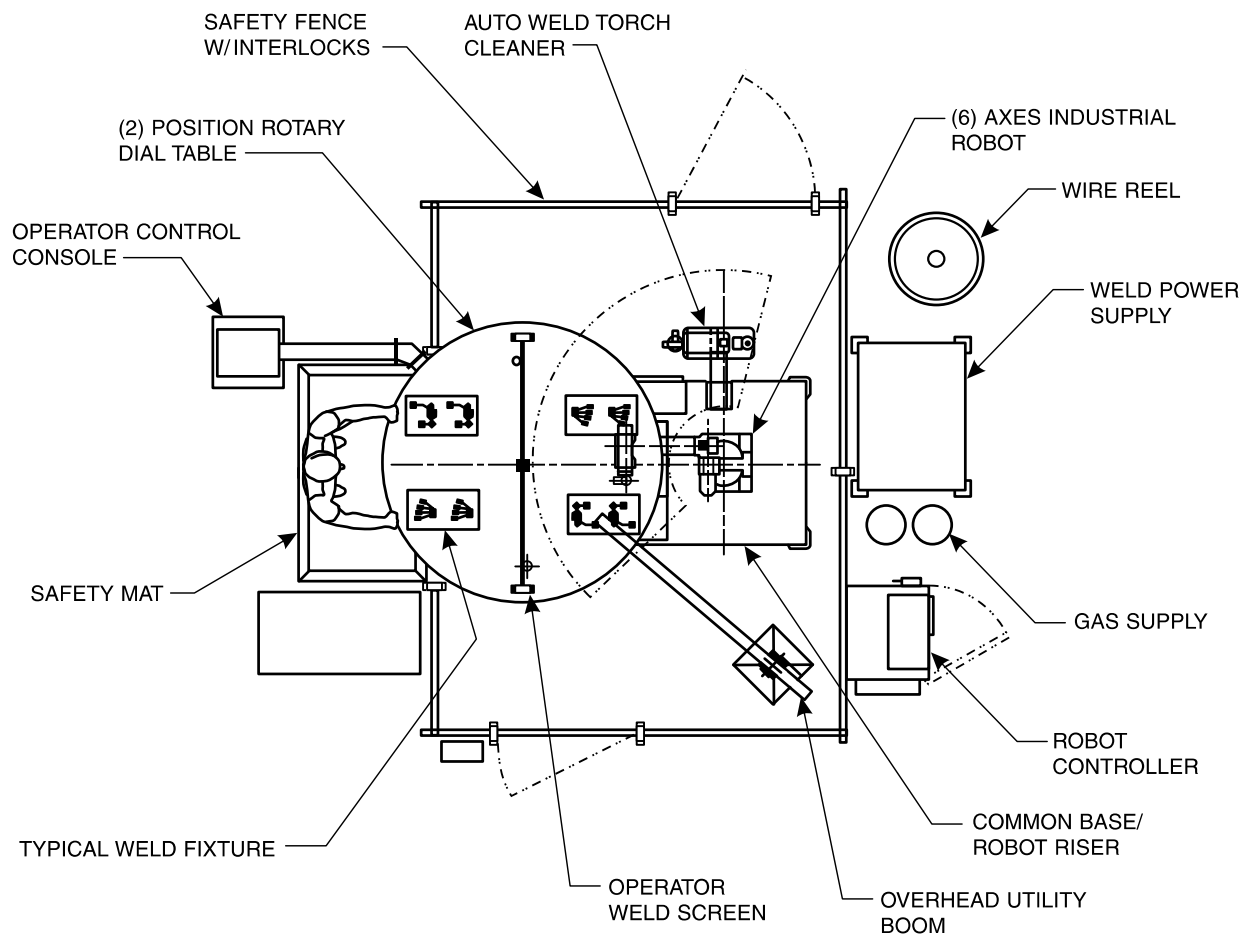


Figure 1—Example of a Robot Arc Welding Work Cell (Not All-Inclusive)

at a minimum, plan and side elevation drawings that depict the general arrangement of the equipment that is incorporated in the work cell. The work cell description should include a summary of the welding robot and peripheral equipment functions. A definitive sequence of operations should be included with the work cell description. Discrete interconnection of equipment utilized within the work cell should be incorporated with the sequence of operations.

6.2.1 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.

6.2.2 Process. The process description needs to be a detailed explanation of what work is performed and in what sequence. A timing chart is required to understand the operation sequence. Operations that occur simultaneously or in sequence need to be identified. Man-machine interfacing requirements need to be defined. The process description should include standard AWS weld process procedural information and a flow chart of the arc welding robot operation.

6.3 Summary of Potential Hazards. A summary sheet should be utilized to list all potential hazards identified as a result of the risk analysis.

6.4 Method of Safeguarding. Safeguarding methods should be provided for each potential hazard identified.

7. Training

7.1 Risk Assessment Training Program. The risk assessment process should be performed and maintained by qualified individuals who have successfully completed training described in this clause. Personnel who are responsible for assessing the safety risks associated with robot arc welding systems should be trained in the application and use of this standard. The training program should include the following subject material:

- (1) understanding of robot arc welding application design,
- (2) methodology of classifying arc welding robots,
- (3) methodology of identifying operating characteristics, and
- (4) information concerning the proper use of minimum safeguarding protocols.

7.2 Other Safety Training Program. All personnel associated with the use of arc welding robots should be trained appropriate to their responsibility and exposure. Additional training could include, but is not limited to, instruction provided by the users in-house safety department, the manufacturer of the arc welding robot, or by the system integrator who supplies the arc welding robot.

Annex A (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS D16.3M/D16.3:2009, *Risk Assessment Guide for Robotic Arc Welding*, but is included for informational purposes only.

A1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

A2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

A2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry

along with the edition of the standard that contains the provision(s) the inquirer is addressing.

A2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

A2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

A2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

A3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official

interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

A4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

A5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The AWS Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be

obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

A6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

Annex B (Informative)

Informative References

This annex is not part of AWS D16.3M/D16.3:2009, *Risk Assessment Guide for Robotic Arc Welding*, but is included for informational purposes only.

American National Standards Institute (ANSI)³

ANSI B11.19, *Performance Criteria for Safeguarding*

ANSI B11.20, *Machine Tools—Safety Requirements For Integrated Manufacturing Systems*

ANSI Z136.1, *Safe Use of Lasers*

American Society of Mechanical Engineers (ASME)⁴

ASME B15.1, *Safety Standard for Mechanical Power Transmission Apparatus*

American Welding Society (AWS)⁵

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

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

AWS F2.3M: 2001, *Specification for Use and Performance of Transparent Welding Curtains and Screens*

AWS AWR, *Arc Welding With Robots: Do's and Don'ts*

AWS *Safety and Health Facts Sheets*

National Fire Protection Association (NFPA)⁶

NFPA 79, *Electrical Standard for Industrial Machinery*

Underwriters Laboratory (UL)⁷

UL 1740, *Standard for Safety for Robots and Robotic Equipment*

³ ANSI standards are published by the American National Standards Institute Publication and Operations Office, 25 West 43rd Street, 4th Floor, New York, NY 10036.

⁴ ASME standards are published by the American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

⁵ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

⁶ NFPA standards are published by the National Fire Protection Association, One Batterymarch Park, Quincy, MA, 02269-9101.

⁷ UL standards are published by the Underwriters Laboratory, 333 Pfingsten Road, Northbrook, IL 60062-2096.

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Annex C (Informative)

Sample Risk Assessment Form

This annex is not part of AWS D16.3M/D16.3:2009, *Risk Assessment Guide for Robotic Arc Welding*, but is included for informational purposes only.

The sample form below contains examples of items that could be found on a robot-system risk-assessment form. The form is not all-inclusive and may be customized as needed.

A. SYSTEM INFORMATION

1. Robot Brand and Model _____ Payload _____
2. System Name or Description _____
3. Type of System _____
4. Type of Tooling _____
5. Safety Devices _____
6. Welding Equipment _____
7. Welding Torch _____
8. Peripheral Equipment _____
9. Other Equipment _____

B. HAZARDS TO PERSONNEL (list all potential hazards and safeguarding methods that apply; see 5.4.1)

Check if used
on the system

- | | |
|--|--------------------------|
| 1. Fumes and Gases | |
| a. Potential Hazards _____ | ☐ |
| b. Description of Safeguarding Method(s) _____ | ☐ |
| 2. Radiation | |
| a. Potential Hazards _____ | ☐ |
| b. Description of Safeguarding Method(s) _____ | ☐ |
| 3. Noise | |
| a. Potential Hazards _____ | ☐ |
| b. Description of Safeguarding Method(s) _____ | ☐ |
| 4. Chromium and Nickel in Welding Fumes | |
| a. Potential Hazards _____ | ☐ |
| b. Description of Safeguarding Method(s) _____ | ☐ |

5. Electrical Hazards	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
6. Fire and Explosion	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
7. Burns	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
8. Mechanical Hazards	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
9. Tripping and Falling	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
10. Falling Objects	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
11. Confined Spaces	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
12. Contact Lens Wear	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
13. Ergonomic Aspects	
a. Potential Hazards _____	☐
b. Description of Safeguarding Method(s) _____	☐
C. ELECTROMAGNETIC PROBLEMS (check those that apply; see 5.4.2)	
1. Cables near the welding equipment	☐
a. Types of cables _____	
2. Radio and Television transmitters and receivers _____	☐
3. Computer and other control equipment _____	☐
4. Guards for other equipment _____	☐
5. Health of the people in the area (pacemakers, hearing aids, etc.) _____	☐
6. Equipment used for calibration or measurement _____	☐
7. Immunity of other equipment in the area _____	☐

8. The time of day that welding or other activities will be carried out _____ ☐
9. The size of the surrounding area _____ ☐

D. SAFEGUARDING AND WARNING DEVICES (check those that apply; see 5.5.2.3)

1. Audible alarm ☐
2. Hard Stops on the robot system ☐
- a. Description of Types _____
- b. Locations _____
3. Interlock Switches ☐
- a. Description of Types _____
- b. Description of Locations _____
4. Light Curtains ☐
- c. Description of Types and Brands _____
- d. Description of Locations _____
5. Physical Barrier Types ☐
6. Safety Fences ☐
- a. Types and Location _____
- b. Height _____
7. Safety Mat Brands and Locations ☐
8. Safety Mirrors ☐
- a. Locations _____
9. Signage ☐
- a. List of Warnings _____
- b. Visibility _____
10. Video Monitoring Devices ☐
- a. Types and Brands _____
11. Visual Alarms ☐
12. Operator Weld Screen ☐
13. Zone Monitoring ☐
- a. Infrared Sensors and Locations _____
- b. Laser Scanner _____
- c. Motion Detectors _____
- d. Ultrasonic Sensor _____
14. Other Safeguarding Devices ☐

E. CLASSIFICATION SUMMARY (see 6.1)

1. ROBOT OPERATING SUBCLASSIFICATION (5.5.1) _____
2. ROBOT APPLICATION CLASSIFICATIONS (5.5.1) _____
3. CLASSIFICATION SUMMARY (5.5.2) _____
4. MINIMUM SAFEGUARDING PROTOCOLS (5.5.2) _____

F. WORK CELL (WORKSPACE) DESCRIPTION (see 6.2)—Layout of general arrangement of the system

G. APPLICATION (see 6.2.1)

1. Components to be welded _____
2. Welding Processes to be used _____
3. Welding Robot Sequence of Operation _____
4. Other System Operation Information _____

H. PROCESS DESCRIPTION (see 6.2.2)

1. Sequence of Operations _____

2. Man-Machine Interfacing Requirements _____

3. AWS Welding Procedure (WPS) number _____

I. SUMMARY OF POTENTIAL HAZARDS (see 6.3)

J. METHODS OF SAFEGUARDING (see 6.4)

Risk Assessment Performed by _____ Date _____

Approved By _____ Date _____

List of AWS Documents on Robotics and Automatic Welding

Designation	Title
D16.1M/D16.1	<i>Specification for Robotic Arc Welding Safety</i>
D16.2M/D16.2	<i>Guide for Components of Robotic and Automatic Arc Welding Installations</i>
D16.3M/D16.3	<i>Risk Assessment Guide for Robotic Arc Welding</i>
D16.4M/D16.4	<i>Specification for the Qualification of Robotic Arc Welding Personnel</i>
AWR	<i>Arc Welding With Robots: Do's and Don'ts</i>

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