

Certification Program Emphasizes Safe Use of Robots

BY VERN MANGOLD

The AWS Certified Robotic Arc Welding program stresses technical competency and safety



Welding personnel who achieve CRAW status demonstrate they possess the technical knowledge to perform robotic arc welding tasks in a safe, efficient, and economical manner.

The use of industrial robots to perform arc welding processes is relatively new in the world of manufacturing technology. Industrial robots turn 50 years old this year, and the process of robotic arc welding has existed in rudimentary form since 1972. A slightly more mature process is robotic resistance welding, casually known as spot welding. Spot welding is typically used to join sheet metal structures, and robots have successfully welded automobile bodies together since 1965. Robotic arc welding only became a reality when improvements in the servo and computer technologies robots use and the ability of robots to move in a continuous, variable, and controlled fashion were perfected. Computer-enabled servo control technologies allowed machines, for the first

time, to duplicate the dexterity and precision of human hand motion.

Due to the natural evolution of manufacturing science, the development of the robotic arc welding process was created first, and the practical application of the technology to manufacturing tasks followed. Of course, the promise of robotic arc welding would never be realized fully if the technology could not be used in a safe manner. By trial and error, the robotic arc welding process gradually developed until today when it is considered a mature and prime manufacturing process technology.

In 1985, the American Welding Society (AWS) Technical Activities Committee added a new technical machinery committee to the family of technical commit-

tees under its purview. The leadership of John Hinrichs, a past AWS director-at-large and former executive at A. O. Smith Automotive Products Co. (later Tower Automotive), was instrumental in bringing robotic arc welding to AWS's attention. Hinrichs leveraged both his extensive experience with arc welding robots and his contacts within industry to convince the AWS to become actively involved in the safe and efficient application of the new robot arc welding technology. At Tower Automotive, Hinrichs's engineers developed techniques and manufacturing protocols for arc welding robots, which became the foundational information and benchmark for the new committee. Since its inception, the committee has published four successful AWS/ANSI

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For more information concerning the AWS Certified Robotic Arc Welding program, contact the AWS Certification Dept. at (305) 443-9353, ext. 273, or visit www.aws.org. You can also contact any of the Approved Testing Centers identified in this article.

robot standards as well as technical reports and other tools that continue to enhance and augment the safe application of arc welding robots.

The new group was designated D16, Committee on Robotic and Automatic Welding. The first task it addressed was development of an arc welding robot system safety standard. D16.1, *Specification for Robotic Arc Welding Safety*, became an ANSI-approved standard in 2001.

The Industrial Robot

From the earliest introduction of continuous-path articulated robots, the process of continuous-path arc welding has been considered a natural extension of the use of robots in the manufacture of automotive and other transportation-related products. Resistance welding of car bodies provided the predecessor technology that was fundamental for the introduction and eventual acceptance of equipment supplied by companies seeking better methods of arc welding steel and aluminum structures. Although the technological developments ushered in a new opportunity to create robotic arc welding applications, additional developments were required to make the applications commercially viable and acceptable to the general industrial manufacturing community. The missing element in this process was standardization and harmonization of the language and specifications used by industrial robot integrators, suppliers, and end users.

Today, industrial arc welding robots are clearly valuable tools in the welding engineer's tool box. In certain industries, almost without exception, product designers who create metal products consider the design of new products and revisions to existing product designs to incorporate robotic arc welding processes. The use of hand arc welding processes in the production of automotive and transportation products is virtually nonexistent in factories both small and large and foreign or domestic. In addition to the manufacture of automotive and transportation products, arc welding robots are considered critical to the production of a wide variety of commercial and industrial products ranging from submarines to small appliances — Fig. 1. Arc welding robot technology has nearly become a commodity process for some applications, and the range of applications continues to grow and expand. Recent developments have added welding of exotic, high-strength, and dissimilar metals to the ever-increasing list of applications for robot technology.

As with any other tool, industrial robots must be properly selected. Robots should be applied to manufacturing tasks designed to be safe in nature and compat-

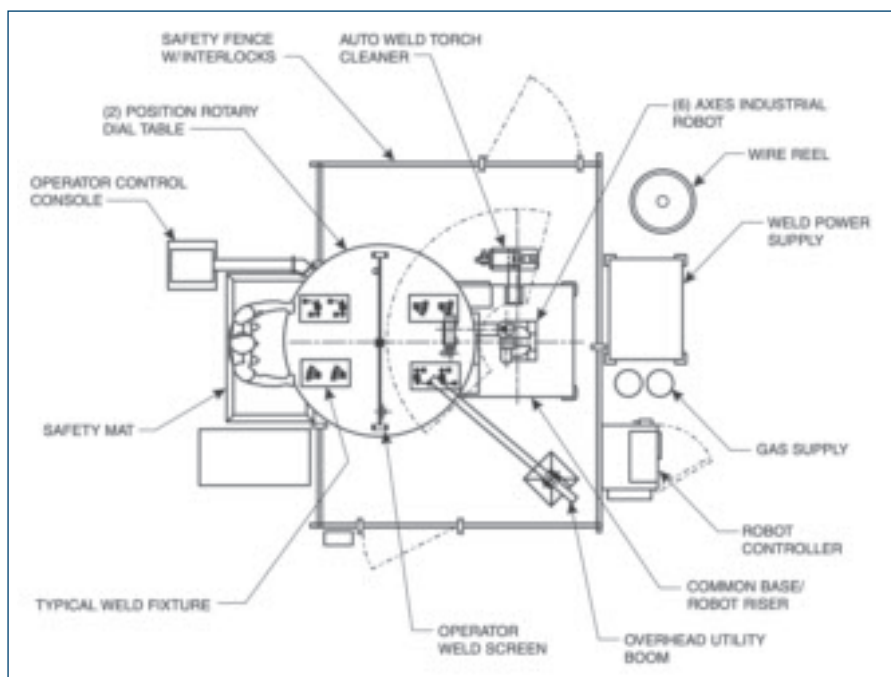


Fig. 1 — Typical small parts robotic arc welding work cell from AWS D16.3, Risk Assessment Guide for Robotic Arc Welding.

ible with prevailing regulations, rules, and standards. The technology is only effective if it can be used safely and efficiently.

Safety First

It is significant that the D16 Committee has produced standards that address the technical needs of the welding industry in the logical areas of business productivity and efficiency. The committee first produced D16.2, *Guide for Components of Robotic and Automatic Arc Welding Installations*, in 1998, and the Do's and Don'ts technical report and pocket robotic arc welding guide in 1999. But D16.1, *Specification for Robotic Arc Welding Safety*, remains the most important publication the D16 Committee has produced. The D16.1 standard provides comprehensive directions and information necessary for the safe use of robotic arc welding technology.

Safety Considerations for Arc Welding Robot System Integrators

Unlike other welding process tools, an industrial robot does not operate in a stand-alone or nonintegrated environment. Robots are only useful if they are integrated with a computer-controlled manufacturing process. The term "system" is very broad and inclusive. Systems are not simply elaborate manufacturing production cells consisting of numerous robots and all manner of ancillary and pe-

ripheral equipment. An arc welding robot system can be as basic as a robot positioned along an indexing conveyor awaiting a signal to advance forward to produce a specific welding operation. Even simple systems must be integrated electronically with other process equipment, thereby changing the safety paradigm.

In reality, if a robot is not integrated into a manufacturing system, no arc welding robot system safety standard is required. Practical applications of industrial robots that do not require integration are reduced to noncontact inspection processes that rely on the robot machine equipped with embedded machine vision and other sophisticated sensory systems. Arc welding with robots is not an example of those types of applications.

To understand the unique safety requirements of arc welding robot systems, we need to study the industry-accepted definitions of robots and robot systems. The key definitions and nomenclature associated with arc welding robots have been harmonized by the Robotic Industry Association and the AWS. The following definitions are from AWS D16.1:

Industrial Robot (Robot): An automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes.

Industrial Robot System (Robot System): An industrial robot combined with ancillary and peripheral equipment necessary to perform a production arc welding process. The robot is electrically interfaced to the ancillary and peripheral equipment.

Robots differ from other manufactur-

ing process capital equipment due to their unique capability to react to the manufacturing environment. The robots are integrated directly with other equipment and devices. The ability of the robot to change processes, operations, and functions autonomously without any manner of human involvement or direct control is a control feature welcomed by the end user.

Why is the difference between arc welding robot systems and teleo-operated machines important? A robotic arc welding system will create a schedule of safety hazards that change as the application changes and the sensory input system dictates. The arc welding industry reports very few serious lost-time injuries that involve the collision or direct interaction of robots and humans. The overwhelming number of serious injury accidents and fatalities can be directly attributed to the interaction of personnel to hazards that involve the robot system's ancillary and peripheral equipment. Robots typically do not strike humans but robot-controlled systems that are not properly designed or deployed can potentially cause all manner of nonrobot collision-related accidents.

The Certified Robotic Arc Welding Program

In keeping with the longstanding AWS tradition of emphasizing safety, the D16 Committee developed the *Specification for the Qualification of Robotic Arc Welding Personnel* (D16.4). Subsequently, the QC19 Certification Project Team Task Force developed the QC19, *Specification for AWS Certification of Robotic Arc Welding Personnel*. The program has many similarities to the AWS Certified Welding Inspector (CWI) program. For example, to earn Certified Robotic Arc Welding (CRAW) credentials, the candidate must pass both a closed-book written examination and a hands-on welding performance examination.

So how does the CRAW program benefit employers and workers? Employers benefit through knowing that welding personnel who have earned the certification will demonstrate the requisite level of technical knowledge required to perform robotic arc welding tasks in a safe, efficient, and economical manner. It also signifies that the CRAW Operator or Technician has demonstrated the capability of working with various codes, standards, and specifications. Since proof of active practice or reexamination is required every three years, certification also signifies that the CRAW Operator or Technician is current with the welding industry. In addition, candidates who are successful in achieving the certification earn the right to carry the CRAW credential with pride and to advertise their achievement

on their professional résumés.

Robot system safety involves the combination of two different manufacturing sciences and processes: gas metal arc welding and robot system design. The combined safety considerations must be addressed to effectively use arc welding robots safely and productively. The CRAW program validates the safe application of arc welding robots by testing individuals on the physics of the welding process and the programming and operation of sophisticated industrial robots.

There are two levels of AWS-sanctioned CRAW certification: Certified Technician (CRAW-T) and Certified Operator (CRAW-O).

Requirements

AWS D16.4:2005, *Specification for the Qualification of Robotic Arc Welding Personnel*, sets the education and experience requirements for taking the CRAW examination as follows:

To become CRAW-T certified, candidates must have a minimum of 3000 hours or three year's arc welding experience with all relevant processes, have a two-year associates degree in welding/robotics/electrical or equivalent, and hold current CWI (Certified Welding Inspector) certification.

CRAW-O candidates must have a minimum of 2000 hours or two years of arc welding experience, and a combination of training and work experience that equals three years.

In addition, candidates must comply with all the other requirements set forth in AWS D16.4, as well as those in AWS QC19, *Specification for AWS Certification of Robotic Arc Welding Personnel*. QC19 can be downloaded for free from the site www.aws.org/certification/CRAW.

The distinctions between manual welding environments and the environment created by the presence of an automatic, self-starting, and adaptive robot arc welding system are addressed in both D16.1 and D16.2. Robot systems have all of the potential hazards encountered in manual arc welding, along with some that are unique to robot systems. Successful CRAW candidates must first understand the fundamentals of the arc welding system, then demonstrate their knowledge of the unique robot system hazards and the accepted methodologies for their mitigation. These hazards are as follows:

Arc-Welding-Specific Hazards

- Ultraviolet radiation
- Sparks and spatter
- Hot surfaces
- Electrical shock
- Effluent.

Robot-Specific Hazards:

- Automatic self start
- Singularity
- Collision
- Variable pinch points
- Single point of control issues
- Training and observation personnel protection
- Robot program verification
- Forced outputs and system testing.

While the CRAW program addresses every aspect of arc welding robot safety, it is not limited only to arc welding safety. It is designed to assist arc welding robot integrators in complying with prevailing regulations and voluntary industry standards. The CRAW certification includes a performance test that demonstrates the candidate's understanding of robot programming and control of welding process parameters.

CRAW certification requires that the candidate provide specific personal information that includes, but is not limited to, documentation of work and academic ex-

Table 1 — Written Test Categories

Topic	Minimum Number	Approximate Percentage
Weld Equipment Setup	10	8
Welding Processes	20	15
Weld Examination	10	8
Definitions and Terminology	10	8
Symbols – Welding and Robotics	5	4
Safety	14	12
Destructive Testing	10	8
Conversion and Calculations	5	4
Robot Programming and Logic	25	20
Welding Procedures	10	8
Kinematic Concepts	5	4
Robot Arc Weld Cell Components-ID	5	4
TOTAL	136	100%

perience, satisfactory completion of a written, closed-book examination combined with a practical hands-on performance test. The examination tests the candidate's knowledge of welding processes, welding procedures, destructive and nondestructive tests, welding terms, definitions, symbols, inspection procedures, safety, quality assurance and responsibilities, weld procedure development, and welding application performance validation.

Selected AWS welding standards serve as the principal reference documents for candidates who are pursuing CRAW certification. The documents are also used by AWS and the D16 Committee to formulate written examination questions and to subsequently validate the answers provided by the candidate. In addition to ANSI/AWS standards, other ANSI standards must also be considered as documents to be studied by the candidates.

Table 1 lists the topics to be included in the written examination and how the questions are weighted.

The performance test requires the candidate demonstrate robotic arc welding programming skills. The actual weld production and posttest inspection will determine the skill and knowledge level of the candidate. The written performance examination tests the candidate's knowledge of general robot and arc welding technology. The objective performance test is described in AWS QC 19. The GMAW process is used to produce the welded coupon (Fig. 2) and the candidate must demonstrate knowledge of the process during the system inspection and, subsequently, through the actual performance examination. While it is preferred the performance examination be completed and passed on the same day that the written examination is proctored, it can be completed and passed three months prior to or after the written exam. The welding coupon is a standard performance examination device that is supplied to the candidate in a tack welded condition by the CRAW examination proctor.

Following are the five performance examination topics.

- Identification of components and demonstration of use,
- Procedure and welding process setup,
- Robot programming of test piece,
- Welding of test piece,
- Weld quality assessment.

Candidates for the CRAW certification program do not need an employer or other commercial organization to sponsor them. Individuals with the requisite qualifications can apply to any authorized AWS Approved Testing Center (ATC) and, if accepted, can sit for the written and performance examinations. The candidate is responsible for all fees and costs associated with the CRAW program.

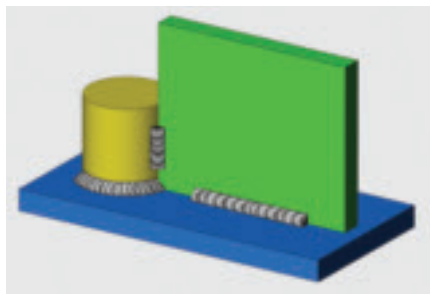


Fig. 2 — A welding coupon, similar to the artist rendering shown above, must be produced by the successful CRAW candidate as a part of the performance test. The coupon is composed of mild steel shapes that are pretacked and prepped for continuous welding by the CRAW robot.

Potential candidates who seek to pursue CRAW certification are responsible for studying and reviewing the referenced CRAW materials and the relevant ANSI standards and other documents that govern both the written examination and the procedures and requirements of the performance test. The list of reference documents is available in AWS QC19, which can be downloaded at www.aws.org/certification/docs/QC19.pdf.

Code of Professional Conduct

CRAW-O and CRAW-T certified pro-

fessionals, regardless of any other AWS certification level achieved, agree, by affixing their signature to the application for certification, to be bound by a code of professional conduct contained in the AWS Code of Ethics. Compliance with the code includes the requirement that the CRAW-certified professional will perform his or her required welding tasks at all times with a concern for public safety.

What's Next

Future CRAW activities include the prospect for a new program that addresses the application of gas tungsten arc welding (GTAW). The GTAW application presents unique safety hazards for the welding process engineer to evaluate and consider. A CRAW program designed with this application in mind can be a valuable tool for improving both the safety and acceptance of robotic GTAW applications.

CRAW certification represents one of the many ways that AWS reaches out to industry to train and encourage manufacturing professionals to apply advanced safety standards, procedures, and practices in the design of arc welding robot systems. The U.S. robotic arc welding industry is very safe and will continue to become safer as the CRAW program propagates into more manufacturing operations. ♦

Where You Can Go to Become Certified

Currently, six organizations have achieved AWS Approved Testing Center (ATC) status — Fig. A. All six entities are deeply involved in both the science and the business of applying robots to arc welding applications.

Each CRAW-authorized ATC is free to customize its CRAW training program. Each of the current ATCs offers a variety of training and orientation packages that are designed to assist all candidates regardless of their background and experience. Following is a brief description of the ATCs and their offerings.

1. **OTC Daihen, Inc., Tipp City, Ohio** (www.daihen-otc.com). The company, a division of the Daihen Corp., Osaka, Japan, is the most recent ATC — Fig. B. It has been active in the arc welding market in the United States for more than 30 years. OTC DAIHEN, initially known as OTC America (Osaka Transformer Co.) set up its first office in Charlotte, N.C., in 1979. Originally, the company only supplied welding equipment for other Japanese transplant companies, but soon entered the U.S.-based Japan-

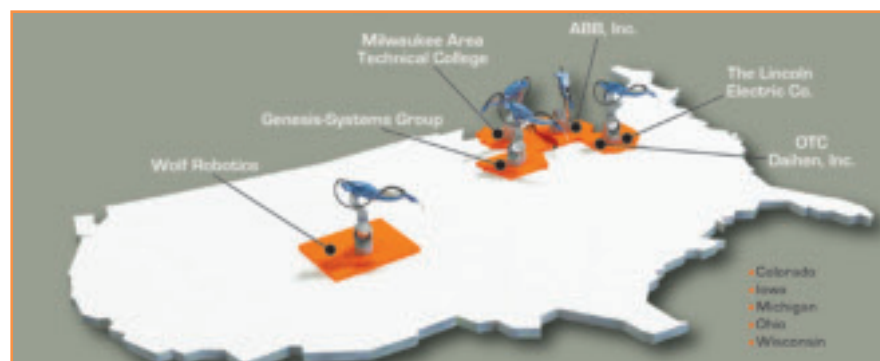


Fig. A — The locations of the six current AWS Approved Testing Centers.

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Fig. B — Larry Barley, the OTC-designated CRAW-T examination proctor, stands in front of the new OTC CRAW work cell. Barley recently earned CRAW-T status; he became an AWS CWI more than 20 years ago. This robot system is an integral component of the OTC-designated CRAW cell.

ese automotive market as a provider of gas metal arc welding equipment and systems.

In the late 1970s, OTC Japan developed its first generation of dedicated arc

welding robots, and the company entered the robot business in America in 1983. In recent years, the company launched its Dynamic Robotics Div. and moved the U.S. headquarters to Tipp City, Ohio.



Fig. C — ABB's state-of-the-art weld lab includes several robotic weld cells. The center offers more than 45 courses that combine classroom instruction with hands-on learning.

2. ABB, Inc., Auburn Hills, Mich. (www.abb.com/robotics). ABB became the first AWS Approved Testing Center specifically established for Certification of Robotic Arc Welding (CRAW) personnel. ABB offers a prep course to prepare for the certification exam, in addition to providing the personnel, facilities, and procedures to administer the certification testing for AWS. The CRAW and all of ABB's robotic welding courses are led by Keith Lloyd, CWI, CWE, CRAW-T, and ABB senior training instructor.

ABB offers a state-of-the-art training laboratory — Fig. C. “We can support the training needs of customers who have older ABB welding technology, in addition to those who have our most current welding solutions, which makes ABB a prime location for the CRAW,” Lloyd said. The welding lab is equipped with a two-station manual weld booth, two IRB140 compact weld cells, one FlexArc 250R, and three FlexArc USCs with IRB 1410 robots.

At the main training center in Auburn Hills, more than 45 courses in programming, electric service (troubleshooting), mechanical/preventive maintenance, software, processes, and customized courses on a variety of ABB robots are offered. All courses provide classroom instruction combined with hands-on learning.

ABB Robotics is a supplier of industrial robots, robot software, peripheral equipment, modular manufacturing cells, and service for tasks such as welding, handling, assembly, painting and finishing, picking, packing, palletizing, and machine tending.

3. Milwaukee Area Technical College (MATC), Milwaukee, Wis. (www.matc.edu). The college, within its two-year associate degree program for welding technology, offers an in-depth curriculum addressing the topics of the CRAW written exam. Two semesters of robotic study provide students with the necessary skills and knowledge to succeed in industry as CRAW-credentialed manufacturing professionals. MATC is exploring an Advanced Technical Certificate aimed at specific training targeting those already in industry who wish to become AWS certified to CRAW-O or CRAW-T. Contact Larry Gross at gross1@matc.edu for more information.

4. Genesis Systems Group, Davenport, Iowa (www.genesis-systems.com). In business since 1983, the company's expertise is in the design, manufacture, and implementation of robotic welding systems. With more than 3000 robotic welding system installations, Genesis has work cells located in more than 40 states and 12 different countries. The company has the CWI and CRAW personnel on hand to help candidates achieve their CRAW-O and CRAW-T certification goals.

As one of the first AWS ATCs, the company's training department has developed a four-day intensive class designed to help students master the skills needed to obtain this elite national certification. Major topics include welding processes, metallurgy, discontinuities and defects, visual inspection, welding symbols, destructive and nondestructive testing, and safety. The state-of-the-art training facility has five complete welding cells with FANUC robots, which allow students to utilize hands-on practice for the practical part of the test and to enhance their robot skills. The practical test is processed on site. The class is four days, Monday through Thursday, with the CRAW test held on Friday.

Genesis is offering an additional CRAW class October 10. In addition, the company offers multiple robotic training classes, including basic, advanced, maintenance, and FANUC WeldPro at its Davenport, Iowa, facility.

5. The Lincoln Electric Co., Cleveland, Ohio (www.lincolnelectric.com). The Automation Center at Lincoln Electric's world headquarters in Cleveland is an AWS ATC for training and certification testing for the CRAW program, which al-

lows welding personnel employed in various industry segments including education, to measure themselves against an industry standard. It also signifies the individual has demonstrated the capability of working with various codes, standards, and specifications.

Each program (CRAW-O and CRAW-T) has several levels and is based on knowledge of robotics, welding experience, and education. The student is required to take a comprehensive written examination, two-hour practical examination, and demonstrate the ability to perform a proper robotic weld from a schematic drawing. AWS sets the requirements, and certification must be renewed every three years.

Prerequisites for the Lincoln Electric CRAW program include submitting an application to AWS along with the appropriate fees. For any questions relating to the CRAW certification process or schedule of classes, contact Lincoln Electric Automation at (888) 935-3878 or e-mail automation@lincolnelectric.com.

6. Wolf Robotics, LLC, Ft. Collins, Colo. (www.wolfrobotics.com). As an ATC, Wolf Robotics conducts periodic training

and testing of individuals for the CRAW-T program. Certification testing for CRAW-T and CRAW-O is conducted at its facility on scheduled dates. Students have to pass a two-hour closed-book written exam with about 130 questions on welding fundamentals and robotic arc welding systems that includes welding processes and procedures, robot programming, safety, and other welding-related subjects. An additional two-hour welding performance test is also required to test the student on robotic arc welding cell operation. A weld test piece is presented to the student along with an engineering weld drawing. The student is required to read and decipher weld symbols then program the robot to weld the part according to instructions.

The welding performance test is conducted and evaluated by a CRAW-T instructor. The written test is administered by authorized AWS personnel and results are returned in 1–2 weeks. In preparation, Wolf Robotics offers an optional three-day training seminar that includes two days of review for the written portion and one day of hands-on practical training using Wolf lab robots. ♦