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SIXTH EDITION

Welding

PRINCIPLES AND PRACTICES

McGraw Hill

EDWARD R. BOHNART

Welding

Principles and Practices

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Sixth Edition

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Mc Graw Hill

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Contents

UNIT 3

Arc Cutting and Gas Tungsten Arc Welding 521

UNIT 4

Gas Metal Arc, Flux Cored Arc, and Submerged Arc Welding 655

UNIT 5

High Energy Beams, Automation, Robotics, and Weld Shop Management 815

Chapter 31 Welding and Bonding of Plastics 994

Chapter 32 Safety 1026

Appendices

Preface

Welding: Principles and Practices, 6e, is both a revision and an expansion of the *Theory and Practice of Arc Welding,* which was first published in 1943. The previous editions have enjoyed success during the years as a major text used in the training of welders by industry and the schools.

This book is designed to be used as the principal text for welding training in career schools, community technical college systems, technical junior colleges, engineering schools, and secondary technical schools. It is also suitable for on-the-job training and apprenticeship programs. It can serve as a supplementary text for classes in building construction, metalworking, and industrial technology programs.

Welding: Principles and Practices, 6e, provides a course of instruction in welding, other joining processes, and cutting that will enable students to begin with the most elementary work and progressively study and practice each process until they are skilled. Both principles and practice are presented so that the student can combine the "why" and the "how" for complete understanding.

The chapters have been arranged into sections to facilitate training programs with reduced contact time segments. Each section maintains the twofold approach of Welding Principles, in which students are introduced to fundamentals that will enable them to understand what is taking place in the application of the various processes, and Welding Practices, where they learn the necessary hands-on skills.

Welding: Principles and Practices, 6e, presents the fundamental theory of the practice in gas, arc, gas-shielded and self-shielded processes, welding, brazing, soldering, and plastic welding processes. The various applications of these processes are covered such as manual, semiautomatic, mechanized, automatic, and robotic methods. Current industrial practices are cited with use of various national welding codes and standards. The content is based on the American Welding Society along with other leading welding authorities.

Welding is an art, technology, and engineering science. It requires the skillful manipulation of the weld pool, a thorough knowledge of welding processes, and the characteristics of the type of material being used. Students can be assured of success if they are willing to spend the time required in actual practice work and the study of the principles presented in this text until they thoroughly understand their significance. Faithful adherence to this course of study will enable them to master the current industrial material joining and cutting processes thoroughly.

The Sixth Edition of *Welding: Principles and Practices Includes:*

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The sixth edition of *Welding* is now available online with Connect, McGraw Hill Education's integrated assignment and assessment platform. Connect also offers SmartBook for the new edition, which is the first adaptive reading experience proven to improve grades and help students study more effectively. All of the title's website and ancillary content is also available through Connect, including:

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Every chapter complies with the most current AWS Standards. The terminology is current so students know the most recent terms to use when they begin to practice. Additional information on many different topics including, safety, lead welding, arc wandering, gas metal arc braze welding, and more are also included in the text.

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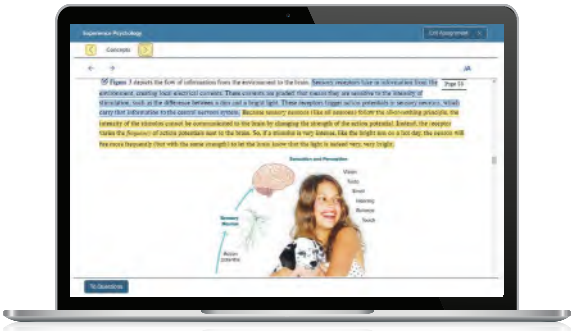

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I would also like to express thanks to the instructors who reviewed this textbook, thereby ensuring that it is clear, focused, accurate, and up-to-date.

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- Zephyr Manufacturing Company

Union Recognition

Recognition is due the United Association of Plumbers and Pipe Fitters National as well as the locals in Kaukauna, Wisconsin, St. Louis, Missouri, and Alton, Illinois; the International Association of Bridge, Structural, Ornamental, and Reinforcing Iron Workers; and the Sheet Metal Workers International Association. Their focus on skill training for the workforce in quality, productivity, and safety ensures that the practices presented in the text are current.

About the Author

Edward R. Bohnart is the principal of Welding Education and Consulting located in Wisconsin. He launched his consulting business after a successful career with Miller Electric Manufacturing Company, where he directed training operations. He is a graduate of the Nebraska Vocational Technical College in welding and metallurgy and has studied at both the University of Nebraska at Omaha and the University of Omaha. Previous certifications include AWS-SCWI, CWE, CWS, CWSR, CRAW-T, and AWS Certified Welder.

Bohnart was selected in the 2011 Class of Counselors of the American Welding Society, and he is also an AWS Distinguished Member and national past President. He remains active with the SkillsUSA organization and is past chair of the AWS Skills Competition Committee, which conducted the USOpen Weld Trials to select the TeamUSA welder for the WorldSkills Competition. He was the United States of America's Welding Technical Expert for the WorldSkills Competition from 1989 to 2009. Bohnart chaired the AWS C5 Committee on Arc Welding and Cutting Processes and remains on the committee as an advisor.

The American Welding Society has recognized Ed Bohnart with the National Meritorious Award, George E. Willis Award, and Plummer Memorial Educational Lecture Award. The Wisconsin State Superintendents Technology Education Advisory Committee has acknowledged him with the Technology Literacy Award. The state of Nebraska Community College System has appointed him Alumnus of the Year, and the Youth Development Foundation of SkillsUSA has honored Bohnart with the SkillsUSA Torch Carrier Award.

Ed has been active on the Edison Welding Institute Board of Trustees and on the American Institute of Steel Constructions Industry Round Table. He has served on the industrial advisory boards for Arizona State University, The University of Wisconsin–Stout, Fox Valley Technical Colleges, and the Haney Technical Center industrial advisory boards.

He has lectured at a number of major institutions, such as the Massachusetts Institute of Technology, Colorado School of Mines, Texas A&M, Arizona State University, and the Paton Institute of Welding, Kiev, Ukraine.

UNIT 1

Introduction to Welding and Oxyfuel

1

History of Welding

Overview

You are about to begin the learning process of preparing yourself for a position in one of the fastest growing industries in the world of work—the *welding industry.*

Welding is the joining together of two pieces of metal by heating to a temperature high enough to cause softening or melting, with or without the application of pressure, and with or without the use of filler metal. Any filler metal used has either a melting point approximately the same as the metals being joined or a melting point that is below these metals but above 800 degrees Fahrenheit (°F).

New methods, new applications, and new systems have continued to develop over the last few decades. Continuing research makes welding a dynamic leader in industrial processes. The industry has made tremendous progress in a short period of time. Furthermore, it has made a major contribution toward raising the standard of living of the American people. By simplifying and speeding up industrial processes and making it possible to develop environmentally sound industries like wind and solar power, hybrid power vehicles, plants to produce organic fuels, and continued development in nuclear, fossil fuels along with continued space exploration and utilization, it has increased the world's supply of goods, Fig. 1.1.

Chapter Objectives

After completing this chapter, you will be able to:

1-1 Explain the history of metalworking and welding.

1-2 Explain the development of modern welding.

1-3 Give details of the mission of welding in the industrial process.

1-4 Describe the diverse welding processes.

1-5 List the various welding occupations.

1-6 Define welder qualifications and characteristics.

1-7 Express the duties and responsibilities of a welder.

1-8 Recognize welder safety and working conditions.

1-9 Identify trade associations and what responsibility they have in the welding industry.

1-10 Establish goals to keep you up-to-date in the field.

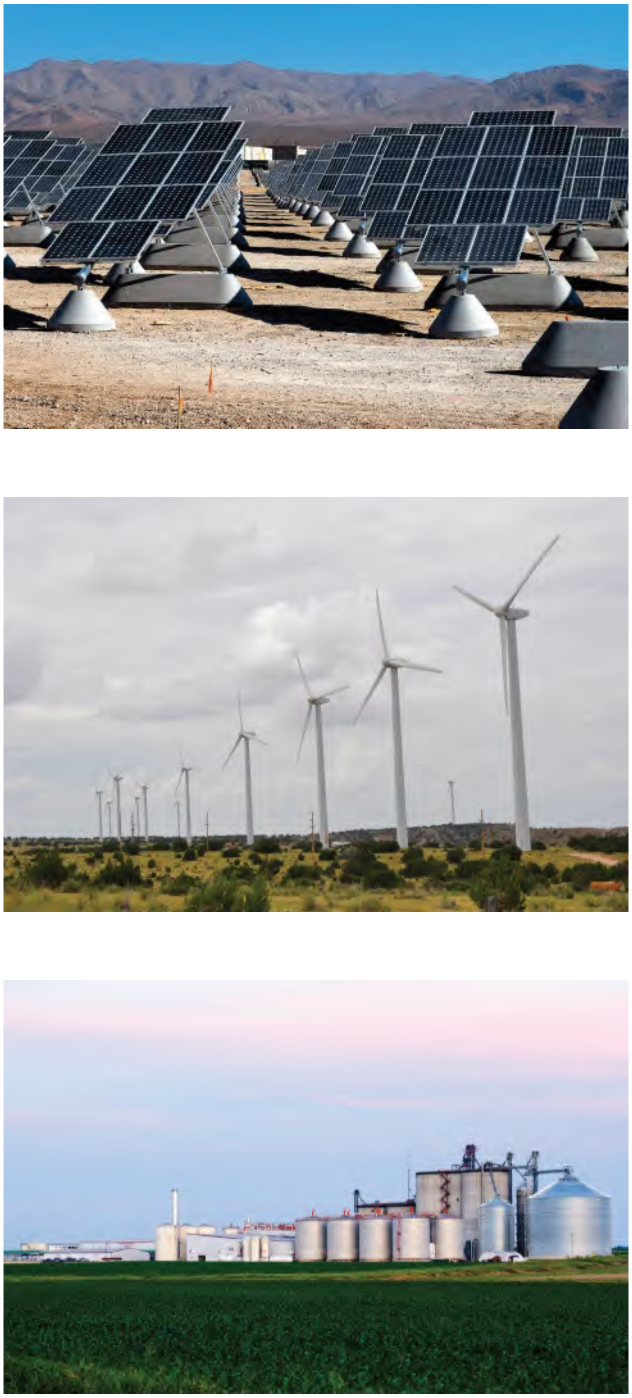

Fig. 1-1 Use of natural energy sources (green energy) such as solar, wind turbines, and bio-fuels like ethanol are getting a tremendous amount of interest in the way of research, development, and real applications. As they continue to develop, other issues will need to be dealt with, such as ROI. Welding plays a very important role in the manufacture of these green energy sources. (top) Stocktrek Images/Getty Images; (middle) Bear Dancer Studios/Mark Dierker; (bottom) Mark A. Dierker/McGraw Hill

Welding is usually the best method to use when fastening metal. If you want to build something made of metal, you can fasten the parts by using screws or rivets, bending the parts, or even gluing the parts. However, a quality, long-lasting, attractive, safe product is best fabricated by using one of the many types of prevailing welding processes.

The History of Metalworking

Metalworking began when early people found that they could shape rocks by chipping them with other rocks. The first metal to be worked was probably pure copper because it is a soft, ductile metal that was widely available. **Ductile** means easily hammered, bent, or drawn into a new shape or form. Excavations in Egypt and in what is now the United States indicate the use of copper as early as 4000 B.C. and before 2000 B.C., respectively. More than 4,000 years ago, copper mines on the peninsula of Sinai and the island of Cyprus were worked. Welding began more than 3,000 years ago when hot or cold metals were hammered to obtain a forge weld. Forged metals, bronze and iron, are mentioned in the Old Testament.

Archaeologists have determined that bronze was developed sometime between 3000 and 2000 B.C. Iron became known to Europe about 1000 B.C., several thousand years after the use of copper. About 1300 B.C. the Philistines had four iron furnaces and a factory for producing swords, chisels, daggers, and spearheads. The Egyptians began to make iron tools and weapons during the period of 900 to 850 B.C. After 800 B.C. iron replaced bronze as the metal used in the manufacture of utensils, armor, and other practical applications. A welded iron headrest for Tutankhamen (King Tut) was crafted around 1350 B.C.

The famous Damascus swords and daggers were made in Syria about 1300 B.C. These were sought after because of their strength and toughness. Their keen edge was likely capable of severing heavy iron spears or cutting the most delicate fabric floating in the air. The swords were made by forge-welding iron bars of different degrees of hardness, drawing them down, and repeating the process many times.

The working of metals—copper, bronze, silver, gold, and iron—followed one another in the great ancient civilizations. By the time of the Roman Empire, the use of iron was common in Europe, the Near East, and the Far East. The Chinese developed the ability to make steel from wrought iron in A.D. 589. The Belgians were responsible for most of the progress made in Europe, due to the high degree of metalworking skill developed by their workers. By the eighth century, the Japanese manufactured steel by repeated welding and forging and controlled the amount of carbon in steel by the use of fluxes. They produced the famous Samurai sword with a blade of excellent quality and superior handiwork.

The blast furnace was developed for melting iron about the years A.D. 1000 to 1200. One such furnace was in the Province of Catalonia in Spain. The fourteenth and fifteenth centuries saw great improvements in the design of blast furnaces. The first cast iron cannon was produced in the early 1600s.

About the middle of the eighteenth century, a series of inventions in England revolutionized the methods of industry and brought on what later came to be known as the Industrial Revolution. Our present factory system of mass production was introduced. An American, Eli Whitney, developed the idea of interchanging parts in the manufacture of arms. By the beginning of the nineteenth century, the working of iron with the use of dies and molds became commonplace. Early in the twentieth century, Henry Ford was involved in developing the assembly line method for manufacturing automobiles.

Early Developments in Welding

At the beginning of the nineteenth century, Edmund Davy discovered **acetylene**, a gas that was later used in oxyacetylene welding, heating, and cutting. The electric arc was first discovered by Sir Humphry Davy in 1801 while he was conducting experiments in electricity. He was concerned primarily with the possibilities of the use of the arc for illumination. By 1809, he had demonstrated that it was possible to maintain a high voltage arc for varying periods of time. By the middle of the nineteenth century, workable electrical-generating devices were invented and developed on a practical basis. These inventions were the forerunner of the present arc welding process.

The first documented instance of fusion welding was done by Auguste de Meritens in 1881. He welded lead battery plates together with a carbon electrode. Two of his pupils, N. Benardos and S. Olszewski, saw the possibilities of this discovery and experimented with the arc powered by batteries that were charged from high voltage dynamos. After four years of work, they were issued a British patent for a welding process using carbon electrodes and an electric power source. Applications of the process included the fusion welding of metals, the cutting of metals, and the punching of holes in metal. Although they experimented with solid and hollow carbon rods filled with powdered metals, the solid electrodes proved more successful. Repair welding was the primary goal of the inventors.

Bare metal electrode welding was introduced in 1888 by N. G. Slavianoff, a Russian. His discovery was first recognized in Western Europe in 1892. C. L. Coffin was one of the pioneers of the welding industry in the United States. In 1889, he received a patent on the equipment and process for flash-butt welding. In 1890, he received additional patents for spot-welding equipment. In 1892, working without knowledge of Slavianoff's work, he received a patent for the bare metal electrode *arc welding* process. By the turn of the century, welding was a common method of repair. At this time, welding was given added impetus by the development of the first commercial *oxyacetylene welding* torch by two Frenchmen, Foresche and Picard. Bare electrode welding became the prevailing electric arc welding method used in the United States until about 1920.

Bare metal electrode welding was handicapped because the welds produced by these electrodes were not as strong as the metal being welded and the welding arc was very unstable. In 1907, Kjellberg, a Swedish engineer, received a patent covering the electrode-coating process. The coating was thin and acted only as a stabilizer of the arc rather than as a purifier of the weld metal. It produced welds that were little better than those made with bare electrodes. In 1912, Kjellberg received another patent for an electrode with a heavier coating made of asbestos with a binder of sodium silicate. See Fig. 1-2. Benardos patented a process in 1908 that has come into popular use in the past few decades. This is the **electroslag** process of welding thick plates in one pass.

Welding technology and its industrial application progressed rather slowly until World War I. Prior to that time, it was used chiefly as a means of maintenance and repair. The demands of the war for an increased flow of goods called for improved methods of fabrication.

ABOUT WELDING

Shipbuilding

Through 1945, some 5,171 vessels of all types were constructed to American Bureau of Shipping standards during the Maritime Commission wartime shipbuilding program. At this time in shipbuilding history, welding was replacing riveting as the main method of assembly.

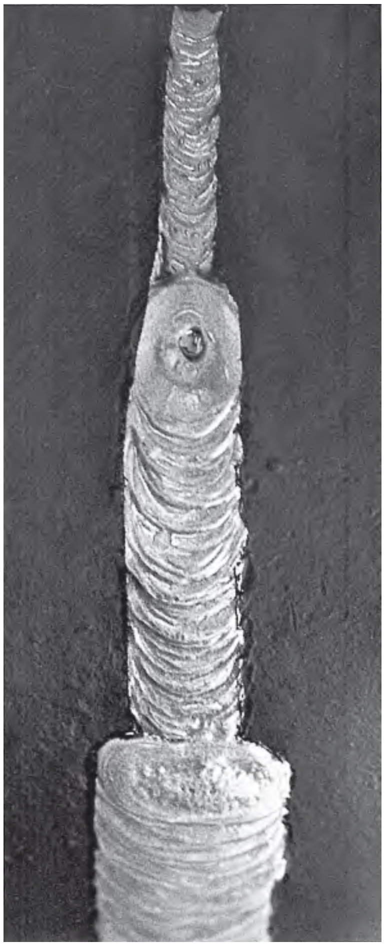

Fig. 1-2 The ability to make multipass welds such as this one, on plate and pipe, led to the growth of the industry. Welds are sound and have uniform appearance. Edward R. Bohnart

At the end of World War I, welding was widely accepted. Research on coated electrodes through the 1920s resulted in electrode coatings and improved core wire. This significant development was the main reason for the rapid advancement of the stick welding process. This term has now been superseded by the term *shielded metal arc welding* (SMAW). The development of X-raying goods made it possible to examine the internal soundness of welded joints which indicated a need for improved methods of fabrication.

The Development of Modern Welding

During the postwar period, the design of welding machines changed very little. Since welding was first done with direct current (d.c.) from battery banks, it was only natural that as welding machines were developed, they would be d.c. machines. In the late 1920s and during the 1930s, considerable research was carried on with alternating current (a.c.) for welding. The use of a.c. welding machines increased through the early 1930s. One of the first high frequency, stabilized a.c. industrial welding machines was introduced in 1936 by the Miller Electric Manufacturing Company. The a.c. welding machines have since become popular because of the high rate of metal deposition and the absence of arc blow.

World War II spurred the development of inert gas welding, thus making it possible to produce welds of high purity and critical application. A patent was issued in 1930 to Hobart and Devers for the use of the electric arc within an inert gas atmosphere. The process was not well received by industry because of the high cost of argon and helium and the lack of suitable torch equipment.

SHOP TALK

Beams

Beams used in bridges must be welded on both sides. In automated systems, a second station can handle the reverse side, or a turnover station is used to get the beam back to be sent through a second time.

Russell Merideth, an engineer for the Northrop Aircraft Company, was faced with the task of finding an improved means of welding aluminum and magnesium in the inert atmosphere. Because of a high burnoff rate, the magnesium procedure was replaced by a tungsten electrode, and a patent was issued in 1942. Later in 1942, the Linde Company obtained a license to develop the *gas tungsten arc welding* (*GTAW*) [or *tungsten inert gas* (*TIG*)] *process*, also known as HELIARC, used today, Fig. 1-3. The company perfected a water-cooled torch capable of high amperage.

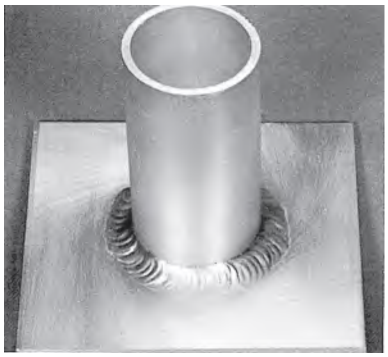

Fig. 1-3 An aluminum weld made using the TIG process. The welding of aluminum is no longer a problem and can be done with the same ease as that of steel. Edward R. Bohnart

GTAW welding was first done with rotating d.c. welding machines. Later, a.c. units with built-in high frequency were developed. In about 1950, selenium rectifier type d.c. welding machines came into use, and a.c.-d.c. rectifier welding machines with built-in frequency for GTAW welding became available in the 1950s. Since that time, the Miller Electric Manufacturing Company has developed the Miller controlled-wave a.c. welder for critical welds on aircraft and missiles. Now, many manufacturers of welding machines produce square-wave a.c. machines.

The use of aluminum and magnesium increased at a rapid rate as a result of (1) the development of GTAW welding, and (2) the desirable characteristics of reduced weight and resistance to corrosion. As the size of weldments increased, thicker materials were employed in their construction. It was found that for aluminum thicknesses above 1/4 inch, GTAW welding required preheating. Since this was costly and highly impractical for large weldments, a number of welding equipment manufacturers engaged in the search for another welding process.

In 1948, the U.S. patent office issued a patent for the **gas metal arc welding (GMAW)** process. The GMAW term superseded the earlier terms of *metal inert gas* (*MIG*) and *metal active gas* (MAG).

The GMAW process concentrates high heat at a focal point, producing deep penetration, a narrow bead width, a small heat-affected zone, and faster welding speeds resulting in less warpage and distortion of the welded joint and minimum postweld cleaning. The use of GMAW has increased very rapidly; it is now used in virtually all industries. A GMAW or similar process is responsible for over 70 percent of welds being performed today. In the early 1950s, the gas shielded flux cored arc welding (FCAW) process was developed, Fig. 1-4. It was referred to as "dual shield" as it had a flux but also required external gas shielding. Late in the 1950s, self-shielded flux cored wires were introduced. And in the early 1970s, all position flux cored wires became available. Metal cored wires came along shortly after this. The solid wire, metal cored wire, and flux cored wire use nearly the same equipment; however, since flux cored wires produce a slag that covers the entire weld, it is considered a separate process.

During the 1980s and continuing today, rapid changes are evolving in the welding industry as engineers devise more advanced filler metal formulas to improve arc performance and weld quality on even the most exotic of materials. Even though our history is vague in the areas of welding and filler metal development, it has shown that advancements are inevitable and will continue, such as exotic multiple gas mixes, state-of-the-art electrodes, onboard computers, hybrid processes, and robotic welding. Some processes were developed for limited applications

Fig. 1-4 Two different sized production fillet welds on steel made with the flux cored arc welding process. Edward R. Bohnart

and are used to fill a particular need. Other methods are evolving that may significantly change the way welds will be made in the future.

The following processes involve the use of the electric arc:

- Arc spot welding
- Atomic-hydrogen welding
- Electrogas
- Plasma arc welding
- Stud welding
- Submerged arc welding
- Underwater arc welding

Other specialized processes include:

- Cold welding
- Electron beam welding
- Explosive welding
- Forge welding
- Friction welding
- Friction stir welding
- Laser welding
- Oxyhydrogen welding
- Thermit welding
- Ultrasonic welding
- Welding of plastics

Today, there are over 90 welding processes in use. The demands of industry in the future will force new and improved developments in machines, gases, torches, electrodes, procedures, and technology. The shipbuilding, space, and nuclear industries conduct constant research for new metals, which in turn spurs research in welding. For example, the ability to join metals with nonmetallic materials is the subject of much effort. As industry expands and improves its technology, new welding processes will play an indispensable part in progress.

Currently, five welding associations provide guidance and standards related to the welding industry.

- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- American Society of Mechanical Engineers (ASME)
- American Welding Society (AWS)
- American Bureau of Shipping (ABS)

Welding as an Occupation

A student needs to learn all phases of the trade. Welding, reading drawings, math, and computer knowledge will secure a successful career. Many qualified welders are certified by the AWS, ASME, and API. The tests are difficult and require many hours of practice.

Because welders hold key positions in the major industries, they are important to the economic welfare of our country. Without welding, the metal industry would be seriously restricted; many of the scientific feats of the past and the future would be impossible. As long as there are metal products, welders will be needed to fabricate and repair them.

JOB TIP

Job Hunting

Looking for a job is a job! When you begin, make a list of what you plan to do in the next week. Assess what kind of job you want. As you complete items on your list, you not only will be closer to your goal, but you also will be in control of the job-hunting process and will be less stressed.

Welding is gender friendly, Fig. 1-5. Thousands of women are employed throughout the industry. Many women find the work highly satisfying and are paid well at a rate equivalent to that of men.

Welding is done in nearly every country in the world. You may wish to work in the oil fields of the Near East or in our own country. You may wish to work in some jungle area of South America or Africa, constructing buildings, power plants, pipelines, or bridges. Our many military installations throughout the world offer jobs for civilian workers. Employment opportunities for welders are plentiful in all parts of the United States.

Fig. 1-5 Welding is generally considered a nontraditional occupation for women. However, it can be a very lucrative and in-demand skill for those women choosing this career path. A procedure is being used setting up a plasma arc gouging operation. Andersen Ross/The Image Bank/Getty Images

Keep in mind that the field of welding can offer you prestige and security. It can offer you a future of continuous employment with steady advancement at wages that are equal to other skilled trades and are better than average. It can offer you employment in practically any industry you choose and travel to all parts of the world. It is an expanding industry, and your chances for advancement are excellent. Welders have the opportunity to participate in many phases of industrial processes, thus giving them the broad knowledge of the field necessary for advancement to supervisory or technical positions.

Industrial Welding Applications

Welding is not a simple operation. The more than 90 different welding processes are divided into three major types: arc, gas, and resistance welding. A number of other types, such as induction, forge, thermit, flow welding, and brazing are used to a somewhat lesser extent.

Resistance welding includes spot welding, seam welding, flash welding, projection welding, and other similar processes that are performed on machines. These welding areas are not the subject of this text. Because of the specialized nature of the machines, operators are usually taught on the job. They are semiskilled workers who do not need

Fig. 1-6 Welding in the vertical position. Miller Electric Mfg. Co.

Fig. 1-7 Instructor observing students practicing for a 5G position pipe weld test. The welder is working out of the overhead position on the pipe and getting into the vertical position. The progression of the weld is uphill. The flux cored arc welding process is being used and is being applied in a semiautomatic fashion. Miller Electric Mfg. Co.

specific hands-on welding skills. The arc and gas welding processes will be extensively covered later in this text.

In a sense, welders are both artists and scientists. Arc and gas welders have almost complete control of the process. Much of their work demands manipulative skill and independent judgment that can be gained only through training and a wide variety of job experience. They must know the properties of the metals they weld; which weld process to use; and how to plan, measure, and fabricate their work. They must use visualization skills and be precise, logical, and able to use their heads as well as their hands. Most welders are expected to be able to weld in the vertical and overhead positions, Figs. 1-6 and 1-7, as well as in the flat and horizontal positions.

Gas welders may specialize in oxyacetylene or GTAW processes. Some welders are skilled in all the processes. You should acquire competence in shielded metal arc SMAW, GTAW, and GMAW processes for both plates and pipes.

Qualifications and Personal Characteristics

The standards are high in welding. In doing work in which lives may depend on the quality of the welding—high-rise buildings, bridges, tanks and pressure vessels of all kinds, aircraft, spacecraft, and pipelines—welders must be certified for their ability to do the work, and their work is inspected, Figs. 1-8 and 1-9. Welders are required to pass periodic qualification tests established by various code authorities, insurance companies, the military, and other governmental inspection agencies. Certifications are issued according to the kind and gauge of metal and the specific welding process, technique, or procedure used. Some welders hold several different certifications simultaneously.

Fig. 1-8 Using a method of weld inspection known as magnetic-particle testing in pipe fabrication. This non-destructive method followed by radiograph and/or ultrasonic testing assures weld soundness for critical pipe welds. Mark A. Dierker/McGraw Hill

Fig. 1-9 Workers using a crane to lift a cask filled with highly radioactive fuel bundles at a Hanford, Washington, nuclear facility. The construction of this type of vessel relies heavily upon welding. U.S. Department of Energy, The Monroe Evening News/AP Images

Fig. 1-10 A large amount of art metalwork is done with welding processes. Leon Werdinger/Alamy Stock Photo

The welder must perform certain basic tasks and possess certain technical information in order to perform the welding operation. In making a gas weld, the welder attaches the proper tip to the torch and adjusts the welding regulators for the proper volume and pressure of the gases. The welder must also regulate the flame according to the needs of the job.

For electric arc welding, the welder must be able to regulate the welding machine for the proper welding current and select the proper electrode size and type, as well as the right shielding gas.

Welding requires a steady hand. The welder must hold the torch or electrode at the proper angle, a uniform distance from the work, and move it along the line of weld at a uniform speed.

During the welding process, the welder should use visualization skills to form a mental picture of how the weld will be created. Although much of the work is single pass, welds made on heavy material often require a number of passes side by side and in layers according to the specified weld procedure.

Welders must also be able to cut metals with the oxyacetylene cutting torch and with the various cutting procedures involving the plasma arc cutting machine. Flame cutting is often the only practical method for cutting parts or repairing steel plate and pipe. **Plasma arc cutting** is used to cut all types of metals. Proper use of an electric or pneumatic grinder will save many hours in the welding process.

The master welder is a master craftsperson, Fig. 1-10. Such a person is able to weld all the steels and their alloys, as well as nickel, aluminum, tantalum, titanium, zirconium, and their alloys and claddings. From heavy pressure vessels requiring 4-inch plate to the delicate welding of silver and gold, the welds are of the highest quality and can be depended upon to meet the requirements of the job.

SHOP TALK

Medical Alert

The technology of medical heart pacemakers continues to change. Some pacemakers are less likely to be prone to interference by electromagnetic fields. People who weld and have pacemakers are safer if there are other people nearby to help if they have problems. Waiting 10 seconds between each weld may be a good strategy for those with pacemakers.

The following welding occupations require a high school education:

- Welding operator
- Welder fitter
- Combination welder
- Master welder
- Welding supervisor
- Welding analyst
- Inspector
- Welding supervisor
- Welding superintendent
- Equipment sales
- Sales demonstrator
- Sales troubleshooter
- Welding instructor
- Robotics welder operator
- Job or fabrication shop owner