Preface

Shielded Metal Arc Welding presents the fundamentals of this skilled trade in an easy-to-understand manner. The skills-focused and clearly illustrated text covers the study of basic welding concepts, such as welding safety and basic weld joints, as well as more challenging welding techniques, including welding sheet metal, aluminum, and pipe. In addition to providing instruction for SMAW in all welding positions on ferrous and nonferrous metals, this text also covers surfacing and padding, strategies for controlling distortion, weld inspection and quality control, and tips for building a successful welding career.

SMAW requires setting the correct welding parameters, remaining comfortable while welding, watching the weld pool, and devoting a great deal of practice to produce satisfactory welds and weldments. To become a good welder, you will have to spend many hours running beads and making the joints presented in this text. Read the text carefully, study and complete the questions, and perform the practice procedures and activities under the supervision of an instructor or trainer, as required. This will aid you in developing skills and techniques that will enable you to enter the welding industry and to prepare yourself for many exciting career opportunities.

Each practice piece should be evaluated, and every effort should be made to correct any problem that is encountered. Where possible, test each weld for integrity, check the penetration, and evaluate the appearance. Your instructor will help you do this. To conserve material, it is recommended that both sides of the practice piece be used whenever practical. Identify your work by stamping or using soapstone to write your name or initials on each practice piece. At the end of each chapter, review questions will help you determine how well you understand the skills and information presented in the chapter. Additional up-to-date welding know-how can be acquired by completing the Hands-On Activities. Be sure to practice *safety* at all times.

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About the Author

Dr. W. Richard Polanin is a retired professor at Illinois Central College, as well as the former program chair of the Manufacturing Engineering Technology and Welding Technology programs. Although retired from full-time teaching at Illinois Central College, he continues to teach locally and nationally. In addition to more than 40 years as an educator, Dr. Polanin remains active as a consultant in welding and manufacturing. He has published numerous technical papers and has made many technical presentations in the areas of welding, manufacturing, robotics, and manufacturing education.

Dr. Polanin has bachelor's and master's degrees from Illinois State University, as well as a doctorate from the University of Illinois. He is a graduate of the Illinois Scholars program sponsored by the Illinois State Board of Education and Illinois Community College. Dr. Polanin is an AWS-certified welding inspector, an AWS-certified welding educator, and a SME-certified manufacturing engineer. He was president of the American Welding Society (AWS) in 2022 and has served as chair of the AWS Education and Training Committee. Dr. Polanin currently serves as the co-principal investigator for Weld-Ed, the National Center for Welding Education and Training, and he is the chair of the International Institute of Welding Commission XIV, Education and Training.

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Reviewers

The author and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of *Shielded Metal Arc Welding*.

Jerry Comeaux
San Jacinto College – North
Houston, Texas

Todd Crossley
St. Stephen Secondary
Bowmanville, Ontario, Canada

Matthew Farchmin
Lake Superior College
Duluth, Minnesota

Logan Loftus
Iowa Valley Jr-Sr High School
Marengo, Iowa

John Paul Massey
Johnson County Community College
Overland Park, Kansas

William Masterson
Bluegrass Community and Technical College
Lexington, Kentucky

John Maxwell
Orange Coast College
Costa Mesa, California

Brian Moelker
Sydenham High School
Sydenham, Ontario, Canada

Jake Segars
Franklin County High School
Carnesville, Georgia

Greg Siepert
Hutchinson Community College
Hutchinson, Kansas

Leonard Walsh
Goodwin University
East Hartford, Connecticut

Aaron Wulk
South Piedmont Community College
Monroe, North Carolina

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Acknowledgments

The author and publisher would like to thank the following companies, organizations, and individuals for their contribution of resource material, images, or other support in the development of *Shielded Metal Arc Welding*.

American Welding Society (AWS)
Arcair Co.
Harris Products Group
Hobart Brothers Co.
Hypertherm, Inc.
J. Jones (Harris)
Lincoln Electric Co.
McNDT Pipeline, Ltd.
Miller Electric Mfg. LLC

New to This Edition

The 11th edition of *Shielded Metal Arc Welding* has been thoroughly revised by the author and carefully vetted by experts in the field of welding to make sure the material is technically accurate, up to date, and presented in the most logical and effective manner. Content has been updated throughout the text to feature the latest technology, techniques, tools, and equipment. Significant updates include the following:

- Content has been updated to align with the latest applicable AWS SENSE Level I—Entry Welder standards.
- The chapter sequence has been revised, and chapters were combined where relevant.
- Content includes expanded coverage of workplace skills, math and measurement, machine maintenance and repair, pipe welding, hardness testing, and nondestructive and destructive testing methods.
- A new chapter, Chapter 8, *Thermal Cutting*, replaces *Cutting with the Arc* and expands on oxyfuel gas cutting (OFC) and plasma arc cutting (PAC). The chapter includes new step-by-step practice procedures.
- The exciting new interior design makes it easy to navigate and engage with content.
- Safety has been further emphasized with prominent and more frequent Warning and Caution boxes.
- Tech Tips have been added for helpful guidance in the shop.
- Full-color artwork has been incorporated throughout the text. Artwork has been updated to show the latest tools, equipment, and techniques. Illustrations have been updated or enhanced for clarity and an improved learning experience.
- Content has been updated to align learning outcomes with sections and end-of-chapter review and assessment.
- End-of-chapter questions have been enhanced to include Know and Understand, Apply and Analyze, and Hands-On Activities.

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Features of the Textbook

The instructional design of this textbook includes student-focused learning tools to help you succeed. This visual guide highlights these features.

Chapter Opening Materials

Each chapter opener contains a list of learning outcomes, a list of key terms, and an introduction.

Learning Outcomes clearly identify the knowledge and skills to be gained when the chapter is completed. These outcomes are labeled and correlated to related assessment elements to facilitate reporting and remediation.

Key Terms list the key words to be learned in the chapter.

Introductions provide an overview and preview of the chapter content.


CHAPTER 6

Arc Welding Equipment

LEARNING OUTCOMES

After studying this chapter, you will be able to:

6.1 Describe how welding machines provide electrical power.
6.2 Identify the pieces of equipment that complete the welding circuit.
6.3 Explain the types of current used in welding and how they affect the welding process.
6.4 Describe how to maintain and repair welding machines.
6.5 List the basic weld cleaning and hot metal handling tools.

KEY TERMS

alternating current (AC)
ampere
arc blow
chipping hammer
current
direct current (DC)
direct current electrode negative (DCEN)
direct current electrode positive (DCEP)
duty cycle
electrode holder
inverter
lead
lug
polarity
quick connect
rated current
rectifier
slag
transformer
welding machine
wire brush
workpiece connector

Introduction

The equipment used for SMAW includes the welding machine (power source), cables (leads), electrode holders, cleaning accessories, tools for handling hot metals, and protective clothing and devices. Different types of welding machines are used depending on the welding application, location of the required welding (if the welding is away from power company electrical supply), and the efficiency of the welding machine.

Additional Features

Additional features are used throughout the body of each chapter to further learning and knowledge.

Warnings alert you to potentially dangerous materials and practices.

Cautions alert you to practices that could potentially damage equipment or instruments.

Tech Tips provide advice and guidance that is especially applicable for on-the-job situations.

Procedures provide clear, step-by-step instructions for hands-on learning.


Chapter 10 Preparing to Weld

10.1 Setting Up Equipment

CAUTION

When attaching the electrode, keep the holder and electrode clear of the work area. When the holder is not in use, hang it in the place provided. Do not lay the holder on the bench or table while the machine is on.

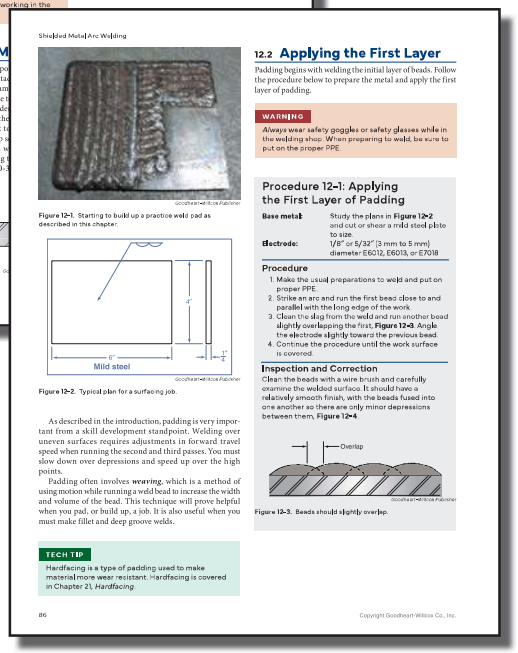
WARNING

Always put on your personal protective equipment (PPE) before welding. Replace any items that are not up to standards. Remove all flammable materials and solvents from the welding area and put shields in place if others will be working in the immediate area.

Figure 10–2. The electrode should be positioned at a 90° angle in the electrode holder when running a flat weld.

10.2 Positioning the M

Figure 10–1. Weld characteristics.


Shielded Metal Arc Welding

12.2 Applying the First Layer

Padding begins with welding the initial layer of beads. Follow the procedure below to prepare the metal and apply the first layer of padding.

WARNING

Always wear safety goggles or safety glasses while in the welding shop. When preparing to weld, be sure to put on the proper PPE.

Procedure 12–1: Applying the First Layer of Padding

Base metal: Study the plans in Figure 12–2 and cut or shear a mild steel plate to size.
Electrode: 1/8" or 5/32" (3 mm to 5 mm) diameter E6012, E6013, or E7018

Procedure

1. Make the usual preparations to weld and put on proper PPE.
2. Strike an arc and run the first bead close to and parallel with the long edge of the work.
3. Clean the slag from the weld and run another bead slightly overlapping the first, Figure 12–3. Angle the electrode slightly toward the previous bead.
4. Continue the procedure until the work surface is covered.

Inspection and Correction

Clean the beads with a wire brush and carefully examine the welded surface. It should have a relatively smooth finish, with the beads fused into one another so there are only minor depressions between them, Figure 12–4.

Figure 12–2. Typical plan for a surfacing job.

Figure 12–3. Beads should slightly overlap.

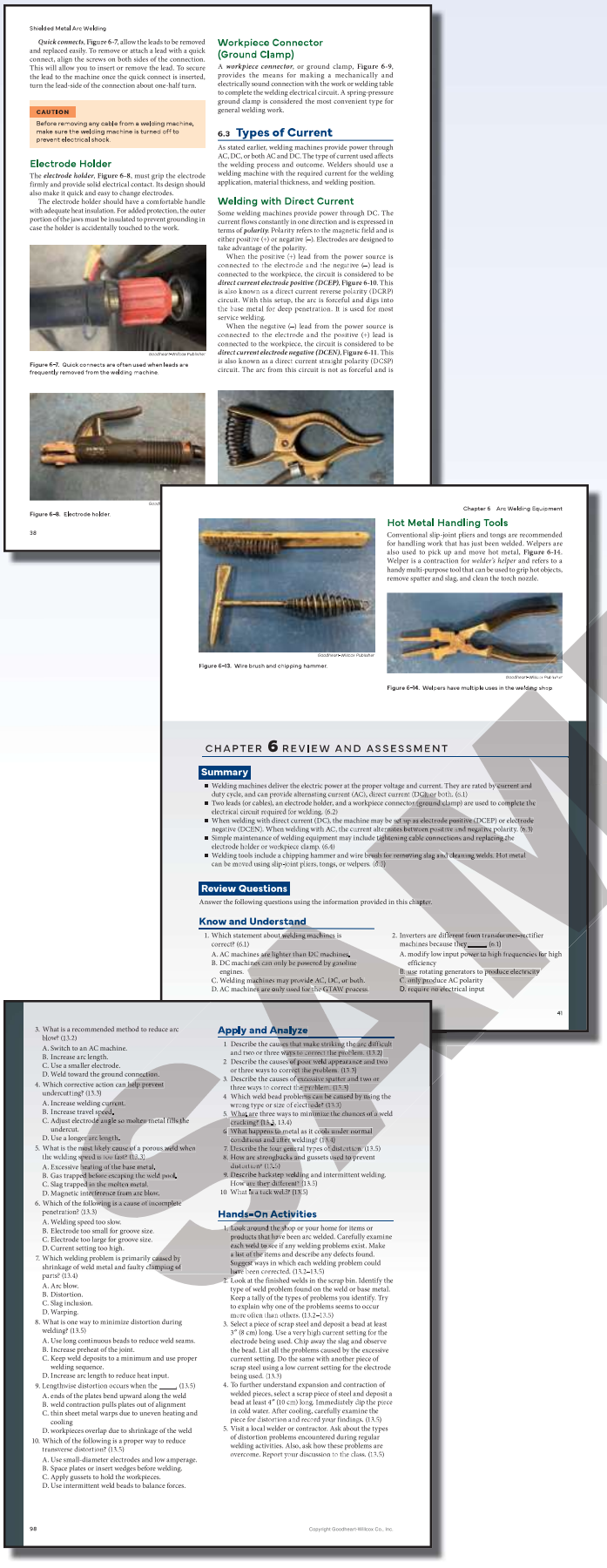
As described in the introduction, padding is very important from a skill development standpoint. Welding over uneven surfaces requires adjustments in forward travel speed when running the second and third passes. You must slow down over depressions and speed up over the high points.

Padding often involves **weaving**, which is a method of using motion while running a weld bead to increase the width and volume of the bead. This technique will prove helpful when you pad, or build up, a job. It is also useful when you must make fillet and deep groove welds.

TECH TIP

Hardfacing is a type of padding used to make material more wear resistant. Hardfacing is covered in Chapter 21, *Hardfacing*.

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Shielded Metal Arc Welding

Quick connects, Figure 6-7, allow the leads to be removed and replaced easily. To remove or attach a lead with a quick connect, align the screws on both sides of the connection. This will allow you to insert or remove the lead. To secure the lead to the machine once the quick connect is inserted, turn the lead-side of the connection about one-half turn.

CAUTION

Before removing any cable from a welding machine, make sure the welding machine is turned off to prevent electrical shock.

Electrode Holder

The *electrode holder*, Figure 6-8, must grip the electrode firmly and provide solid electrical contact. Its design should also make it quick and easy to change electrodes.

The electrode holder should have a comfortable handle with adequate heat insulation. For added protection, the outer portion of the jaws must be insulated to prevent grounding in case the holder is accidentally touched to the work.

Figure 6-7. Quick connects are often used when leads are frequently removed from the welding machine.

Figure 6-8. Electrode holder.

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Workpiece Connector (Ground Clamp)

A *workpiece connector*, or ground clamp, Figure 6-9, provides the means for making a mechanically and electrically sound connection with the work or welding table to complete the welding electrical circuit. A spring-pressure ground clamp is considered the most convenient type for general welding work.

6.3 Types of Current

As stated earlier, welding machines provide power through AC, DC, or both AC and DC. The type of current used affects the welding process and outcome. Welders should use a welding machine with the required current for the welding application, material thickness, and welding position.

Welding with Direct Current

Some welding machines provide power through DC. The current flows constantly in one direction and is expressed in terms of *polarity*. Polarity refers to the magnetic field and is either positive (+) or negative (–). Electrodes are designed to take advantage of the polarity.

When the positive (+) lead from the power source is connected to the electrode and the negative (–) lead is connected to the workpiece, the circuit is considered to be *direct current electrode positive (DCEP)*, Figure 6-10. This is also known as a direct current reverse polarity (DCRP) circuit. With this setup, the arc is forceful and digs into the base metal for deep penetration. It is used for most service welding.

When the negative (–) lead from the power source is connected to the electrode and the positive (+) lead is connected to the workpiece, the circuit is considered to be *direct current electrode negative (DCEN)*, Figure 6-11. This is also known as a direct current straight polarity (DCSP) circuit. The arc from this circuit is not as forceful and is

Chapter 6 Arc Welding Equipment

Figure 6-13. Wire brush and chipping hammer.

Hot Metal Handling Tools

Conventional slip-joint pliers and tongs are recommended for handling work that has just been welded. Welpers are also used to pick up and move hot metal, Figure 6-14. Welper is a contraction for *welder's helper* and refers to a handy multi-purpose tool that can be used to grip hot objects, remove spatter and slag, and clean the torch nozzle.

Figure 6-14. Welpers have multiple uses in the welding shop.

CHAPTER 6 REVIEW AND ASSESSMENT

Summary

- Welding machines deliver the electric power at the proper voltage and current. They are rated by current and duty cycle, and can provide alternating current (AC), direct current (DC), or both. (6.1)
- Two leads (or cables), an electrode holder, and a workpiece connector (ground clamp) are used to complete the electrical circuit required for welding. (6.2)
- When welding with direct current (DC), the machine may be set up as electrode positive (DCEP) or electrode negative (DCEN). When welding with AC, the current alternates between positive and negative polarity. (6.3)
- Simple maintenance of welding equipment may include tightening cable connections and replacing the electrode holder or workpiece clamp. (6.4)
- Welding tools include a chipping hammer and wire brush for removing slag and cleaning welds. Hot metal can be moved using slip-joint pliers, tongs, or welpers. (6.5)

Review Questions

Answer the following questions using the information provided in this chapter.

Know and Understand

1. Which statement about welding machines is correct? (6.1)
   A. AC machines are lighter than DC machines.
   B. DC machines can only be powered by gasoline engines.
   C. Welding machines may provide AC, DC, or both.
   D. AC machines are only used for the GTAW process.
2. Inverters are different from transformer-rectifier machines because they _____. (6.1)
   A. modify low input power to high frequencies for high efficiency
   B. use rotating generators to produce electricity
   C. only produce AC polarity
   D. require no electrical input

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3. What is a recommended method to reduce arc blow? (13.2)
   A. Switch to an AC machine.
   B. Increase arc length.
   C. Use a smaller electrode.
   D. Weld toward the ground connection.
4. Which corrective action can help prevent undercutting? (13.5)
   A. Increase welding current.
   B. Increase travel speed.
   C. Adjust electrode angle so molten metal fills the undercut.
   D. Use a longer arc length.
5. What is the most likely cause of a porous weld when the welding speed is too fast? (13.3)
   A. Excessive heating of the base metal.
   B. Gas trapped before escaping the weld pool.
   C. Slag trapped in the molten metal.
   D. Magnetic interference from arc blow.
6. Which of the following is a cause of incomplete penetration? (13.3)
   A. Welding speed too slow.
   B. Electrode too small for groove size.
   C. Electrode too large for groove size.
   D. Current setting too high.
7. Which welding problem is primarily caused by shrinkage of weld metal and faulty clamping of parts? (13.4)
   A. Arc blow.
   B. Distortion.
   C. Slag inclusion.
   D. Warping.
8. What is one way to minimize distortion during welding? (13.5)
   A. Use long continuous beads to reduce weld seams.
   B. Increase preheat of the joint.
   C. Keep weld deposits to a minimum and use proper welding sequence.
   D. Increase arc length to reduce heat input.
9. Lengthwise distortion occurs when the _____. (13.5)
   A. ends of the plates bend upward along the weld
   B. weld contraction pulls plates out of alignment
   C. thin sheet metal warps due to uneven heating and cooling
   D. workpieces overlap due to shrinkage of the weld
10. Which of the following is a proper way to reduce transverse distortion? (13.5)
    A. Use small-diameter electrodes and low amperage.
    B. Space plates or insert wedges before welding.
    C. Apply gussets to hold the workpieces.
    D. Use intermittent weld beads to balance forces.

Apply and Analyze

1. Describe the causes that make striking the arc difficult and two or three ways to correct the problem. (13.2)
2. Describe the causes of poor weld appearance and two or three ways to correct the problem. (13.3)
3. Describe the causes of excessive spatter and two or three ways to correct the problem. (13.3)
4. Which weld bead problems can be caused by using the wrong type or size of electrode? (13.3)
5. What are three ways to minimize the chances of a weld cracking? (13.2, 13.4)
6. What happens to metal as it cools under normal conditions and after welding? (13.4)
7. Describe the four general types of distortion. (13.5)
8. How are strongbacks and gussets used to prevent distortion? (13.5)
9. Describe backstep welding and intermittent welding. How are they different? (13.5)
10. What is a tack weld? (13.5)

Hands-On Activities

1. Look around the shop or your home for items or products that have been arc welded. Carefully examine each weld to see if any welding problems exist. Make a list of the items and describe any defects found. Suggest ways in which each welding problem could have been corrected. (13.2–13.5)
2. Look at the finished welds in the scrap bin. Identify the type of weld problem found on the weld or base metal. Keep a tally of the types of problems you identify. Try to explain why one of the problems seems to occur more often than others. (13.2–13.5)
3. Select a piece of scrap steel and deposit a bead at least 3" (8 cm) long. Use a very high current setting for the electrode being used. Chip away the slag and observe the bead. List all the problems caused by the excessive current setting. Do the same with another piece of scrap steel using a low current setting for the electrode being used. (13.3)
4. To further understand expansion and contraction of welded pieces, select a scrap piece of steel and deposit a bead at least 4" (10 cm) long. Immediately dip the piece in cold water. After cooling, carefully examine the piece for distortion and record your findings. (13.5)
5. Visit a local welder or contractor. Ask about the types of distortion problems encountered during regular welding activities. Also, ask how these problems are overcome. Report your discussion to the class. (13.5)

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Illustrations

Illustrations have been designed to clearly and simply communicate the specific topic. Photographic images have been updated to show the latest equipment.

End-of-Chapter Content

End-of-chapter material provides an opportunity for review and application of concepts.

A concise **Summary** provides an additional review tool and reinforces key learning outcomes. This helps you focus on important concepts presented in the text.

Know and Understand questions enable you to demonstrate knowledge, identification, and comprehension of chapter material.

Apply and Analyze questions extend learning and develop your abilities to use learned material in new situations and to break down material into its component parts.

Hands-On Activities extend your learning and help you apply knowledge.

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SAMPLE