

# OXYFUEL GAS WELDING AND CUTTING

Eighth Edition

**Kevin E. Bowditch**

Member of the American Welding Society  
Member of the Association for Career and  
Technical Education

**Mark A. Bowditch**

Member of the American Welding Society  
Member of the Association for Career and  
Technical Education



Publisher  
**The Goodheart-Willcox Company, Inc.**  
Tinley Park, IL  
[www.g-w.com](http://www.g-w.com)

Copyright © 2023  
by  
The Goodheart-Willcox Company, Inc.

Previous editions copyright 2012, 2004, 1999, 1991, 1985, 1980, 1976

All rights reserved. No part of this work may be reproduced, stored, or transmitted in any form or by any electronic or mechanical means, including information storage and retrieval systems, without the prior written permission of The Goodheart-Willcox Company, Inc.

Manufactured in the United States of America.

Library of Congress Control Number: 2021938137

ISBN 978-1-63776-068-0

1 2 3 4 5 6 7 8 9 – 23 – 26 25 24 23 22 21

**The Goodheart-Willcox Company, Inc. Brand Disclaimer:** Brand names, company names, and illustrations for products and services included in this text are provided for educational purposes only and do not represent or imply endorsement or recommendation by the author or the publisher.

**The Goodheart-Willcox Company, Inc. Safety Notice:** The reader is expressly advised to carefully read, understand, and apply all safety precautions and warnings described in this book or that might also be indicated in undertaking the activities and exercises described herein to minimize risk of personal injury or injury to others. Common sense and good judgment should also be exercised and applied to help avoid all potential hazards. The reader should always refer to the appropriate manufacturer's technical information, directions, and recommendations; then proceed with care to follow specific equipment operating instructions. The reader should understand these notices and cautions are not exhaustive.

The publisher makes no warranty or representation whatsoever, either expressed or implied, including but not limited to equipment, procedures, and applications described or referred to herein, their quality, performance, merchantability, or fitness for a particular purpose. The publisher assumes no responsibility for any changes, errors, or omissions in this book. The publisher specifically disclaims any liability whatsoever, including any direct, indirect, incidental, consequential, special, or exemplary damages resulting, in whole or in part, from the reader's use or reliance upon the information, instructions, procedures, warnings, cautions, applications, or other matter contained in this book. The publisher assumes no responsibility for the activities of the reader.

**The Goodheart-Willcox Company, Inc. Internet Disclaimer:** The Internet resources and listings in this Goodheart-Willcox Publisher product are provided solely as a convenience to you. These resources and listings were reviewed at the time of publication to provide you with accurate, safe, and appropriate information. Goodheart-Willcox Publisher has no control over the referenced websites and, due to the dynamic nature of the Internet, is not responsible or liable for the content, products, or performance of links to other websites or resources. Goodheart-Willcox Publisher makes no representation, either expressed or implied, regarding the content of these websites, and such references do not constitute an endorsement or recommendation of the information or content presented. It is your responsibility to take all protective measures to guard against inappropriate content, viruses, or other destructive elements.

**Image Credits.** Front cover: Penka Todorova Vitkova/Shutterstock.com

# Preface

*Oxyfuel Gas Welding and Cutting* presents the fundamentals of this skilled trade in an easy-to-understand manner. Each unit includes activities for you, the student welder, to complete.

Oxyfuel gas welding requires a great deal of practice to produce satisfactory weldments. To become a good welder, you will have to spend many hours running beads and making the joints presented in this write-in text. Read the text matter carefully, study and complete the questions, and perform the activities 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 career opportunities.

Each practice piece should be evaluated, and every effort should be made to correct any problem encountered. Where possible, test each weld for integrity, penetration, and 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 your name or initials on each practice piece.

The questions in the Check Your Progress section at the end of each unit will help you determine how well you understand the information provided. Additional up-to-date welding know-how can be acquired by carrying out the suggested activities.

## About the Authors

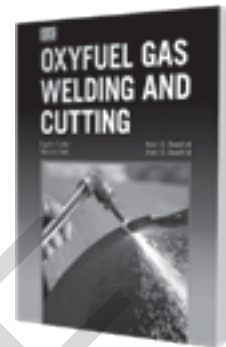
**Kevin E. Bowditch** is a retired welding engineer specialist for Subaru of Indiana Automotive Inc. His welding experience includes working for two automotive firms, two aerospace firms, a construction company (building nuclear plants), and a precision sheet metal firm. His initial welding training was at the Hobart Institute of Welding Technology. He earned his bachelor's degree in welding engineering from The Ohio State University, and has attended specialized conferences and courses sponsored by the American Welding Society, American Society of Mechanical Engineers, and American National Standards Institute. At Subaru, he helped develop and validate welding parameters to make over one billion spot and arc welds per year. Kevin Bowditch joined his father as a coauthor of *Modern Welding*, beginning with the 1984 edition, and has been a coauthor of *Welding Fundamentals* since its first edition was published in 1991.

**Mark A. Bowditch** joined the Bowditch team of welding authors in 1998, when he coauthored *Oxyfuel Gas Welding* with his brother Kevin Bowditch. Mark Bowditch has more than 10 years of experience as an educator, holds bachelor's, master's, and doctoral degrees, and has taken classes at the Hobart Institute of Welding Technology. In addition to employing his expertise and communication skills in preparing this edition of *Oxyfuel Gas Welding and Cutting*, he has also assumed responsibility as a coauthor with his brother and father for the 2005 and later revisions of *Welding Fundamentals* and *Modern Welding*. He is also an officer in the United States Air Force Reserves.

# TOOLS FOR STUDENT AND INSTRUCTOR SUCCESS

## Student Tools

*Oxyfuel Gas Welding and Cutting* provides students with a simple, unimposing, and clear text to use when learning oxyfuel gas welding, cutting, and allied processes (brazing, braze welding, and torch soldering). This write-in text is divided into 35 small, easy-to-understand units, with a series of review questions at the end of the unit to reinforce and evaluate student learning. The first section of the book, units 1–4, provides students with the general welding knowledge they need in order to successfully study and apply oxyfuel processes. This includes measurement, safety, and the interpretation of the welding symbols used in construction drawings. Subsequent units guide students through learning the various processes in small increments. This incremental approach ensures that students can thoroughly understand theory and master technique before proceeding to the next step.



## Instructor Tools

### LMS Integration

Integrate Goodheart-Willcox content within your Learning Management System for a seamless user experience for both you and your students. LMS-ready content in Common Cartridge® format facilitates single sign-on integration and gives you control of student enrollment and data. With a Common Cartridge integration, you can access the LMS features and tools you are accustomed to using and G-W course resources in one convenient location—your LMS.

G-W Common Cartridge provides a complete learning package for you and your students. The included digital resources help your students remain engaged and learn effectively.

When you incorporate G-W content into your courses via Common Cartridge, you have the flexibility to customize and structure the content to meet the educational needs of your students. You may also choose to add your own content to the course. For instructors, Common Cartridge includes the Online Instructor Resources.

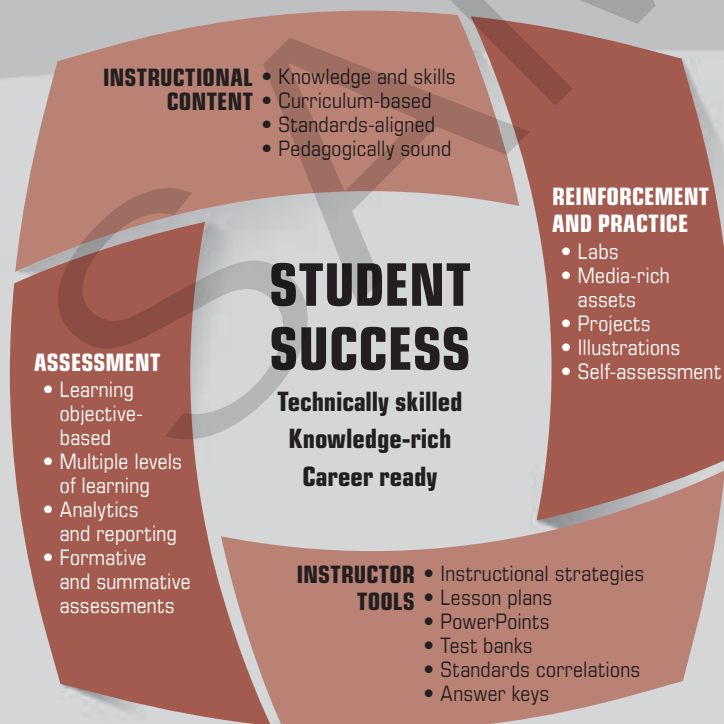


## Online Instructor Resources (OIR)

Online Instructor Resources provide all the support needed to make preparation and classroom instruction easier than ever. The OIR includes Instructor Resources in one accessible location. These resources provide instructors with time-saving preparation tools such as answer keys, editable lesson plans, and other teaching aids. The OIR is available as a subscription and can be accessed at school, at home, or on the go.



## G-W Integrated Learning Solution



**The G-W Integrated Learning Solution offers easy-to-use resources that help students and instructors achieve success.**

- ▶ **EXPERT AUTHORS**
- ▶ **TRUSTED REVIEWERS**
- ▶ **100 YEARS OF EXPERIENCE**

**EMPLOYABILITY SKILLS · TECHNICAL SKILLS · ACADEMIC KNOWLEDGE · INDUSTRY RECOGNIZED STANDARDS**

# 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.

## Features

**Safety Information** is presented in a second color to alert you to potentially dangerous materials and practices. **Procedures** are provided throughout the textbook to provide clear instructions for hands-on service activities.

## 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-Unit Content

End-of-unit material provides an opportunity for review and application of concepts. **Check Your Progress** questions enable you to demonstrate knowledge, identification, and comprehension of chapter material. **Things to Do** extend your learning and help you apply knowledge.

**UNIT 12**

### Backhand and Forehand Welding

**Manipulating the Torch**

Two techniques are used in manipulating (handling) the torch and welding filler metal in oxyfuel gas welding. They are known as backhand and forehand welding. Forehand welding is the easier and more commonly used method. However, each has certain advantages for different metal thicknesses.

**Forehand Method**

In the *forehand method*, welding moves from right to left (for a right-handed person). The welding filler metal is moved ahead of the torch tip and away from the completed portion of the weld, **Figure 12-1**. The welding flame is pointed in the direction of travel and at a downward angle. The flame melts the edges of the joint and preheats the welding filler metal. **Welding rod** (also called filler metal or filler rod) comes in long, straight lengths for use in oxyfuel gas welding.

The torch tip is moved in a circular, semicircular, or weaving path to evenly distribute the

**Figure 12-2.** Motion of the torch tip in forehand welding. A—Circular pattern; B—Semicircular pattern; C—Weaving pattern.

74

### Oxyfuel Gas Welding and Cutting

**Figure 14-3.** Use a soapstone or chalk marker to draw lines on material for running beads.

**Procedures for Running a Bead with Welding Rod**

Follow these procedures for running a bead with welding rod:

- Set the oxygen and acetylene regulators for 6 psig (40 kPa) of pressure. Light the torch and adjust the flame to neutral.
- Bring the flame down to the metal surface to form a molten pool near the right-hand edge. Use a circular motion to begin the pool. Hold the torch at a 0° work angle and a 35° to 45° travel angle. This is the same torch position used to create a continuous weld pool.
- After the pool is formed, move the torch in a circular or semicircular pattern. Begin dipping the end of the welding rod into the molten pool. The welding rod should be held at a 0° work angle and 45° travel angle opposite the torch along the weld axis, **Figure 14-4**.
- Slowly move the molten pool along the chalk line using a continuously circular motion while adding filler metal to the weld pool. Allow the flame to move around the rod to melt both the rod and base metal. A gentle up-and-down motion of the rod along the weld axis at a 45° travel angle will produce a rounded bead with an even ripple and good fusion.

**Figure 14-4.** The method for adding filler metal when running a weld bead. The torch motion is the same as for creating a weld pool.

- Run a continuous bead the full length of the metal. The travel speed should be slow enough to produce a uniform 3/8" (9.6 mm) wide convex bead. If the rod becomes too short or the flame goes out, start again by forming another molten pool at the last ripple. Continue welding. **Note:** Do not throw away short pieces of welding rod. Place them end to end on the firebrick and fuse them together with the torch. Allow them to cool before using.
- End the bead by fusing enough rod into the weld pool to keep the same bead height. Maintain a constant travel speed and rod motion to obtain uniform bead width and good fusion. The weld should penetrate approximately 25% of the metal thickness.
- Continue running practice beads until you can consistently make them to acceptable standards. See **Figure 14-5**.

**Running a Bead with Filler Metal on Thick Steel**

63

Unit 4 Welding Symbols

21

Name \_\_\_\_\_ Date \_\_\_\_\_ Class \_\_\_\_\_

### Check Your Progress

Follow the directions given for each problem.

1. Add information to the reference lines and arrows to completely describe the joints indicated.

2. Each item has a set of two drawings. Read the symbol on the left-hand drawing. Then, draw the weld on the right-hand drawing.

Copyright Goodheart-Willcox Co., Inc.

# 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 *Oxyfuel Gas Welding and Cutting*:

American Torch Tip Co.

American Welding Society

Linde BmbH, Munich

Miller Electric Mfg. LLC

Uniweld Products, Inc.

The ESAB Group, Inc.

## New to This Edition

For this edition of *Oxyfuel Gas Welding and Cutting*, numerous photos have been replaced to show updated equipment and to reflect changes among equipment manufacturers. The text was reviewed to ensure it is accurate and up-to-date.

Notable changes for this edition include the following:

- Title changed to reflect the cutting content included in the book.
- In chapter 4, Figures 4-1 and 4-4 were updated to reflect changes in AWS A2.4 standards.
- Added a Procedures table of contents to help students quickly locate hands-on activities to practice in the welding lab.

# Brief Contents

## Basic Welding Knowledge

- 1 Introduction to Oxyacetylene Welding..... 1
- 2 Welding Safety..... 5
- 3 Measurement for Welding ..... 11
- 4 Welding Symbols..... 17

## Preparation for Welding

- 5 Preparing the Joint ..... 23
- 6 Oxyfuel Gases and Cylinders..... 27
- 7 Welding Torches and Tips..... 33
- 8 Assembly of Welding Equipment... 41
- 9 Metal Identification..... 47
- 10 Welding Rods and Fluxes ..... 51

## Starting to Weld

- 11 The Welding Flame ..... 57
- 12 Backhand and Forehand Welding..... 63
- 13 Creating a Continuous Weld Pool..... 67
- 14 Running a Bead with Welding Rod ..... 73

## Basic Welding Techniques

- 15 Lap Joint Welding..... 79
- 16 Outside Corner Joint Welding..... 83
- 17 T-Joint Welding..... 87
- 18 Butt Joint Welding..... 91
- 19 Out-of-Position Welding ..... 95
- 20 Inspection of Welds..... 101

## Cutting Techniques

- 21 Cutting Equipment ..... 107
- 22 Cutting Processes ..... 113

## Welding Techniques for Thick Metal

- 23 Lap Joint Welding Thick Steel ..... 119
- 24 T-Joint Welding Thick Steel ..... 123
- 25 Butt Joint Welding Thick Steel..... 127

## Aluminum Welding

- 26 Welding Aluminum ..... 133

## Brazing Techniques

- 27 Brazing Processes ..... 137
- 28 Brazing Lap Joints..... 143
- 29 Running a Bead with Brazing Filler Metal ..... 147
- 30 Braze Welding Lap and T-Joints... 151
- 31 Braze Welding Butt Joints ..... 157
- 32 Braze Welding Cast Iron..... 161

## Soldering Techniques

- 33 Soldering ..... 165

## Technical Information

- 34 Additional Welding Techniques.... 169
- 35 Professional Welding Advancement..... 175



# Contents

## Basic Welding Knowledge

### Unit 1

- Introduction to Oxyacetylene Welding . . . 1**  
Welding, Cutting, and Joining Processes /  
Process Definitions

### Unit 2

- Welding Safety . . . . . 5**  
Safety First / Personal Protection / Welding  
Equipment / Ventilation / Fire Watch /  
Fire Extinguisher and Fire Classifications  
/ Burn Hazards / Safe Practices

### Unit 3

- Measurement for Welding. . . . . 11**  
Systems of Measurement / Using a Rule /  
Units of Metric Measurement

### Unit 4

- Welding Symbols . . . . . 17**  
Welding Symbols on Drawings / How to  
Read Welding Symbols

## Preparation for Welding

### Unit 5

- Preparing the Joint . . . . . 23**  
Types of Joints / Selecting and Preparing  
Joints / Cleaning the Metal

### Unit 6

- Oxyfuel Gases and Cylinders. . . . . 27**  
Oxygen and Acetylene / Oxygen /  
Acetylene / Storing Oxygen and Fuel  
Gases

### Unit 7

- Welding Torches and Tips. . . . . 33**  
Functions of Torches / Torch Types / Torch  
Valves / Check Valves and Flashback  
Arrestors / Welding Tips

### Unit 8

- Assembly of Welding Equipment . . . . 41**  
Oxyfuel Gas Welding Equipment / Pressure  
Regulators / Setup Procedures

### Unit 9

- Metal Identification . . . . . 47**  
Importance of Identification / Ferrous or  
Nonferrous / Identification Procedure

### Unit 10

- Welding Rods and Fluxes . . . . . 51**  
Filler Metal / Classification and Size / Rod  
Selection / Welding Fluxes

## Starting to Weld

### Unit 11

- The Welding Flame. . . . . 57**  
Producing a Flame / Types of Flames /  
Lighting the Torch / Shutting Off the  
Torch

### Unit 12

- Backhand and Forehand Welding . . . . 63**  
Manipulating the Torch / Forehand Method  
/ Backhand Method / Holding the Torch

### Unit 13

- Creating a Continuous Weld Pool . . . . 67**  
Basic Operations / Preparing the Equipment  
and Material / Procedures for Running  
a Continuous Weld Pool / Finishing the  
Task

### Unit 14

- Running a Bead with Welding Rod. . . . 73**  
Purpose of Welding Rod / Preparing the  
Equipment and Material / Procedures  
for Running a Bead with Welding Rod  
/ Running a Bead with Welding Rod on  
Thick Steel / Procedures for Running a  
Bead on Thick Material

## Basic Welding Techniques

### Unit 15

- Lap Joint Welding . . . . . 79**  
Forming a Lap Joint / Preparing the  
Equipment and Material / Procedures for  
Welding Lap Joints

## Unit 16

### Outside Corner Joint Welding . . . . . 83

Forming a Corner Joint / Preparing the Equipment and Material / Procedures for Welding Outside Corner Joints

## Unit 17

### T-Joint Welding . . . . . 87

Forming T-Joints / Preparing the Equipment and Material / Procedures for Making Fillet Welds

## Unit 18

### Butt Joint Welding . . . . . 91

Forming a Butt Joint / Preparing the Equipment and Material / Procedures for Welding Butt Joints

## Unit 19

### Out-of-Position Welding . . . . . 95

Basic Positions / Preparing the Equipment and Material / Welding in the Horizontal Position / Welding in the Vertical Position / Welding in the Overhead Position

## Unit 20

### Inspection of Welds . . . . . 101

Flaws and Defects / Nondestructive Evaluation / Destructive Evaluation

## Cutting Techniques

### Unit 21

#### Cutting Equipment . . . . . 107

Cutting Equipment versus Welding Equipment / Essential Elements for Burning / The Cutting Torch / The Cutting Tip / Safety Precautions

### Unit 22

#### Cutting Processes . . . . . 113

Cutting Skills / Preparing the Equipment and Material / Procedures for Cutting Steel / Shutting Down the Cutting Outfit

## Welding Techniques for Thick Materials

### Unit 23

#### Lap Joint Welding Thick Steel . . . . . 119

Thick Steel Modifications / Preparing the Equipment and Material / Procedures for Welding Lap Joints on Thick Steel

### Unit 24

#### T-Joint Welding Thick Steel . . . . . 123

Thick Steel Modifications / Preparing the Equipment and Material / Procedures for Welding T-Joints on Thick Steel

### Unit 25

#### Butt Joint Welding Thick Steel. . . . . 127

Joint Preparation / Preparing the Equipment and Material / Procedures for Welding Butt Joints on Thick Steel

## Aluminum Welding

### Unit 26

#### Welding Aluminum . . . . . 133

Aluminum Alloys / Characteristics of Aluminum / Preparing the Equipment and Material / Procedures for Welding Aluminum

## Brazing Techniques

### Unit 27

#### Brazing Processes . . . . . 137

Two Metal-Joining Processes / Advantages of Brazing Processes / Filler Metals for Brazing / Fluxes for Brazing / Basic Brazing Procedures / Brazing Safety

### Unit 28

#### Brazing Lap Joints. . . . . 143

Basic Brazing Steps / Preparing the Equipment and Material / Procedures for Lap Joint Brazing

## Unit 29

### Running a Bead with Brazing Filler

<b>Metal .....</b>	<b>147</b>
Braze Welding versus Welding / Preparing the Equipment and Material / Procedures for Braze Welding	

## Unit 30

### Braze Welding Lap and T-Joints..... 151

Creating Strong Joints / Preparing the Equipment and Material for Lap Joints / Procedures for Braze Welding Lap Joints / Preparing the Equipment and Material for T-Joints / Procedures for Braze Welding T-Joints	
--	--

## Unit 31

### Braze Welding Butt Joints..... 157

Butt Joints and Edge Preparation / Preparing the Equipment and Material / Procedures for Braze Welding Butt Joints	
--	--

## Unit 32

### Braze Welding Cast Iron ..... 161

Purposes and Advantages of Brazing / Preparing the Equipment and Material / Procedures for Braze Welding Cast Iron / Testing the Braze Weld	
---	--

## Soldering Techniques

### Unit 33

#### Soldering..... 165

Soldered Joint Use / Advantages of Soldering / Filler Metals for Soldering / Fluxes for Soldering / Basic Procedures and Safety / Preparing the Material and Equipment / Procedures for Soldering	
---	--

## Technical Information

### Unit 34

#### Additional Welding Techniques ..... 169

Common Welding Processes / Arc Welding / Resistance Welding / Other Welding Processes	
---	--

### Unit 35

#### Professional Welding Advancement ... 175

Growing Demand / Position Descriptions / Educational Opportunities	
--	--

#### Appendix..... 180

#### Glossary of Technical Terms ..... 182

#### Index ..... 187

# Procedures Contents

Setup Procedures (Oxyfuel Gas Welding Outfit) .....	42
Lighting the Torch.....	58
Shutting Off the Torch .....	59
Running a Continuous Weld Pool .....	67
Finishing the Task .....	69
Running a Bead with Welding Rod.....	74
Running a Bead on Thick Material.....	75
Welding Lap Joints.....	80
Welding Outside Corner Joints .....	83
Making Fillet Welds (on T-Joints) .....	88
Welding Butt Joints .....	91
Cutting Steel.....	113
Shutting Down the Cutting Outfit.....	116
Welding Lap Joints on Thick Steel.....	119
Welding T-Joints on Thick Steel .....	123
Welding Butt Joints on Thick Steel .....	127
Welding Aluminum (V-Groove Butt Joint).....	134
Brazing a Lap Joint.....	144
Running a Braze Weld Bead .....	147
Braze Welding Lap Joints.....	152
Braze Welding T-Joints .....	153
Braze Welding Butt Joints .....	157
Braze Welding Cast Iron.....	161
Soldering (Copper Tubes and Fittings).....	167