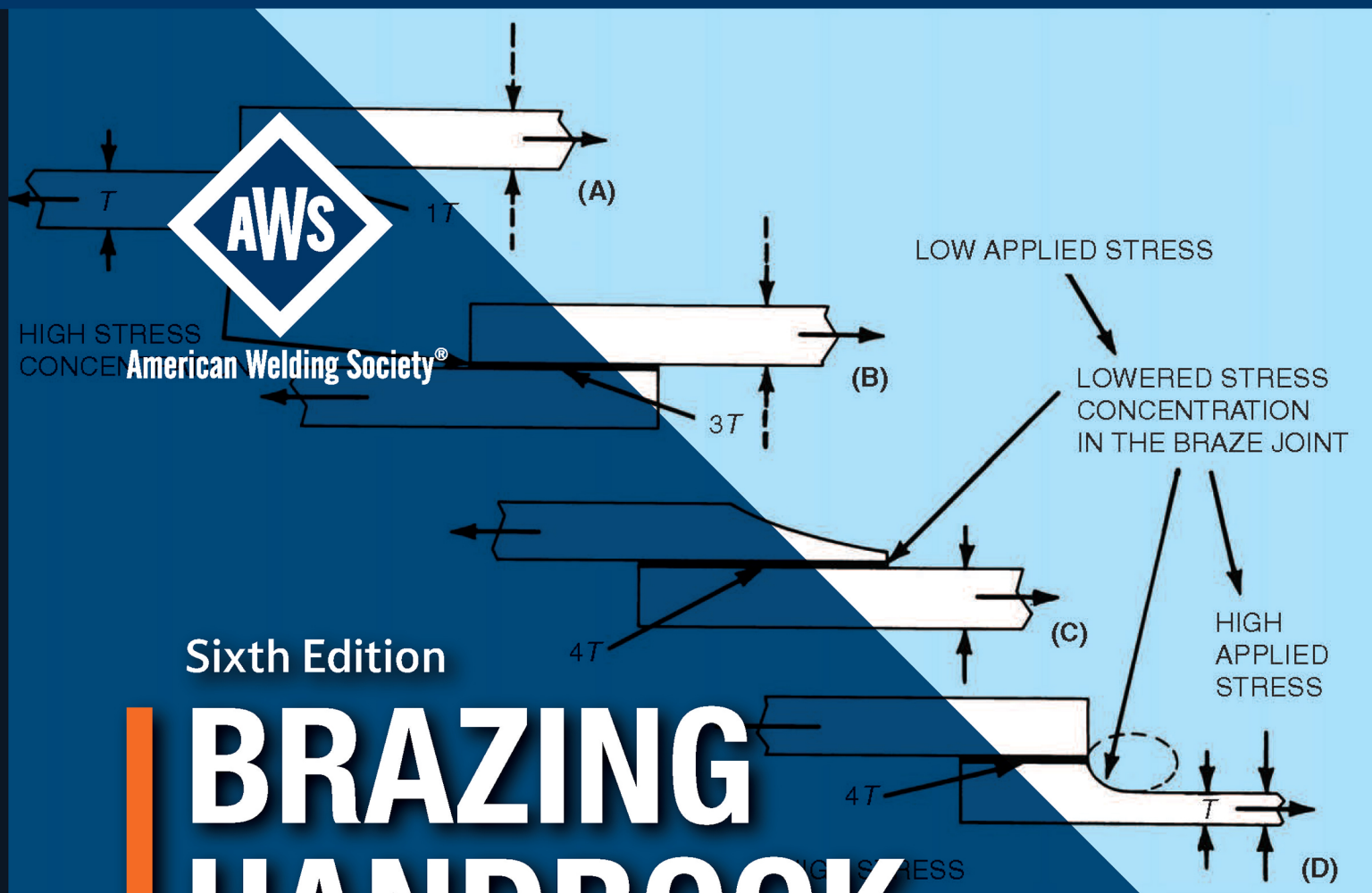


Sixth Edition

# BRAZING HANDBOOK

## Volume 1: Fundamentals

# Brazing Handbook

## VOLUME 1, FUNDAMENTALS

## Sixth Edition

**Revises Brazing Handbook, 5th Edition, 2007**

Prepared by the
American Welding Society (AWS) C3 Committee on Brazing and Soldering

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

American Welding Society®

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# Dedication

**This book is dedicated to the memory of the Chairman of C3A Committee Carmen A. Paponetti, President/ Founder of Expert Brazing & Heat Treating, Inc., who passed away during the handbook completion. It was his idea to prepare and publish a 3-volume brazing handbook, instead of one volume as in all previous editions. He also compiled the first version of the contents of all three volumes in 2007 and assembled the first team of authors of the relevant chapters. With his energy and enthusiasm, Carmen convinced the other members of the C3 Committee on Brazing and Soldering to take up what seemed like an incredible challenge at the time. And now engineers, scientists, and students of the brazing community can read the most comprehensive brazing handbook in the world, including all the main and necessary information on our technology.**

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# FOREWORD

This foreword is not part of the *Brazing Handbook*, but is included for informational purposes only.

The new edition has taken several years to complete, requiring the collaboration and support of many individuals and companies; their contribution has been invaluable! The AWS Handbook Committee members have risen to this challenge and responded with an outstanding technical reference for the brazing industry.

The brazing technology has been continuously evolving, owing to advances in relevant materials science and engineering disciplines and the critical role brazing plays in various industry sectors. Many new developments in brazing processes and materials have been included in this 6th edition handbook. The in-depth understanding of the fundamental principles involved in brazing technology is essential for researchers, engineers, and professionals in the field to select and develop suitable brazing processes and to design and build products that meet the demanding standards. The objective of Volume 1—*Fundamentals* is to provide general references to basic principles and data sources related to various aspects of brazing. This volume covers the following topics in its chapters: F-1, *Basics of Brazing*, F-2, *Phase Change Phenomena and Joint Metallurgy in Brazing*, F-3, *Wetting and Capillarity in Brazing*, F-4, *Brazement Design*, F-5, *Mechanical Properties of Brazed Joints*, F-6, *Brazing Filler Metals*, F-7, *Corrosion of Brazed Joints*, F-8, *Fluxes and Atmospheres*, F-9, *Precleaning and Surface Preparation*, F-10, *Assembly and Fixturing*, and F-11, *Inspection of Brazed Joints*.

You will notice that each chapter was assigned to a reviewer who was responsible for its final technical criteria. Many reviewers had assistance from others at their respective company or within the industry. Without their collaboration, the book would not have been possible.

Special thanks go to all the authors and reviewers to the members of the AWS C3 Committee on Brazing and Soldering and AWS C3A Subcommittee for the Brazing Handbook who addressed the many challenges that accompany such an undertaking.

The Brazing Handbook Committee expresses its appreciation to AWS staff members who assisted with this volume for tremendous technical and editorial support. Without their dedication, this volume would not have been completed.

Ray Xu
Chair, C3A Subcommittee for the Brazing Handbook

Hui Zhao
C3A Subcommittee on Brazing Handbook, *Fundamentals* Volume Chair

# PREFACE

This preface is not part of the *Brazing Handbook*, but is included for informational purposes only.

Knowledge of the ancient art of brazing is continuously being supplemented by an ever-increasing amount of technical information about metals and their behavior, so that today brazing must be considered both an art and a science. This sixth Edition of the *Brazing Handbook* addresses the fundamental concepts of brazing and incorporates the many advances made since the *Brazing Manual* was first published in 1955.

The American Welding Society defines brazing as "a group of joining processes in which the workpiece(s) and brazing filler metal are heated to the brazing temperature to form a brazed joint. The brazing filler metal is distributed and retained between the closely fitted faying surfaces of the joint by capillary action."

Brazing must meet each of three criteria:

1. The parts must be joined without melting the base metals.
2. The filler metal must have a liquidus temperature above 840 °F (450 °C).
3. The filler metal must wet the base metal surfaces and be drawn into or held in the joint by capillary action.

To achieve a good joint using any of the various brazing processes described in this *Brazing Handbook*, the parts must be properly cleaned and must be protected, either by fluxing or protective atmosphere during the heating process, to prevent excessive oxidation. The parts must be designed to afford a capillary for the filler metal when properly aligned, and a heating process must be selected that will provide the proper brazing temperature and heat distribution.

No analysis of a subject that is continuously being improved can hope to be complete, nor can the subject be covered with a thoroughness that would satisfy the specialist. For this reason, most chapters provide a list of references that give additional and more detailed information on the subject. Yet even after the additional research, trial and error may be required to successfully complete unusual applications. It is hoped, however, that the trials and errors will be fewer for having this *Brazing Handbook* as a guide.

Comments, inquiries, and suggestions for future revisions of the *Brazing Handbook* are welcome. They should be sent to the Secretary, AWS C3 Committee on Brazing and Soldering, American Welding Society, 8669 NW 36 Street, # 130, Miami, FL 33166.

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# BASICS OF BRAZING

Photograph courtesy of *The Gold Bulletin*

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# CHAPTER F-1

# BASICS OF BRAZING

## INTRODUCTION

The process of brazing that we know today began as an ancient art. Through our increased understanding of the nature and behavior of materials, this art evolved into technology and science. In a very general sense, brazing is a joining process that relies on the melting, flow, and solidification of a brazing filler metal to form a leak-tight seal, a strong structural bond, or both between materials. The process is unique in that this metallurgical bond is formed by melting the brazing filler metal only; the components being joined undergo no melting.

Brazing is a well-established commercial process capable of producing strong joints. It is widely used in industry because, in large part, it is capable of joining most metallic and ceramic materials. It is a versatile process that can be performed using manual techniques as well as automated production modes. Brazing lends itself to the production of large assemblies and assemblies composed of dissimilar metals. Brazing produces a tiny, clean fillet in contrast to the irregular bead made by welding, an advantage when appearance is critical. One of the main advantages of brazing is usually associated with cost savings. High production processes adapt well to today's improved processes. Brazing especially adapts to large production quantities as well as single individual parts.

The term *brazing* refers, in fact, to a group of processes. The American Welding Society (AWS) defines *brazing* (B) as a group of joining processes in which the workpiece(s) and brazing filler metal are heated to the brazing temperature to form a brazed joint. The brazing filler metal is distributed and retained between the closely fitted faying surfaces of the joint by capillary action.[1,2] The term *brazing temperature* refers to the base material temperature(s) at which a braze can be accomplished.[3]

This definition serves to distinguish brazing from the other joining processes of soldering and welding. Brazing and soldering share many important features, but the term *brazing* is used to refer to the joining processes using the filler metals with a liquidus temperature above 842 °F (450 °C), while *soldering* refers to the joining processes using the filler metal that has a liquidus equal to or below this temperature. Brazing differs from welding in that in brazing the intention is to melt the brazing filler metal, not the base materials. In welding, the filler metals and base metals typically are melted to affect the coalescence of materials.

Several factors influence the quality of the brazed joint. To achieve a good joint using any of the brazing processes, the components to be joined must be properly cleaned and protected from excessive oxidation by fluxing or the use of a controlled atmosphere. The assembly should be designed so that the components are properly aligned, and the capillary effect may be formed in gaps between parts, permitting the molten brazing filler metal to flow. It is

1. American Welding Society (AWS) Committee on Definitions. 2020. *Standard Welding Terms and Definitions*, *Including Terms for Adhesive Bonding, Brazing, Soldering, and Thermal Spraying*, AWS A3.0M/A3.0:2020, Miami: American Welding Society, p. 12.
2. At the time of the preparation of this chapter, the referenced standards were valid. If a standard is cited without a date of publication, it is understood that the latest edition of the document referred to applies. If a standard is cited with the date of publication, the citation refers to that edition only, and it is understood that any future revisions or amendments to the code or standard are not included; however, as standards undergo frequent revision, the reader is encouraged to consult the most recent edition.
3. American Welding Society (AWS) Committee on Definitions. 2020. *Standard Welding Terms and Definitions*, *Including Terms for Adhesive Bonding, Brazing, Soldering, and Thermal Spraying*, AWS A3.0M/A3.0:2020, Miami: American Welding Society, p. 13.