Brazing Handbook

Fifth Edition

Supersedes Brazing Handbook, 4th Edition, 1991

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
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Dedications

Robert L. Peaslee—“Mr. Brazing”

Mr. Bob Peaslee is recognized for his tireless effort and generous contributions in making this new edition not only possible but technically sound. Bob questioned every person and paragraph written to ensure the technical accuracy of its content. The legacy of Mr. Peaslee and his “fingerprints” are found throughout the book. This handbook has been instrumental in transferring his years of experience and knowledge into a practical experience for all of us.

Cynthia L. Jenney

This edition of the *Brazing Handbook* is dedicated to the memory of Cynthia Jenney in recognition of her tireless efforts on this project. Cynthia took this book to heart. Besides her duties as committee secretary, Cynthia coordinated the chapter contributions as well as provided valuable suggestions and encouragement to the individual authors. She put in countless hours editing the text as well as organizing the artwork that came from numerous sources around the country. The C3 committee will be forever grateful to Cynthia for all of her hard work on the handbook, for serving as a wonderful secretary, and for simply being a very dear friend to all of our committee members.

John J. Stephens

This handbook is also dedicated to the memory of C3 committee member John J. Stephens, Ph.D., of Sandia National Laboratories (Albuquerque, NM) who passed away during its completion. John was a world-recognized leader in the areas of metal-ceramic brazing and filler metal properties. He freely offered his expertise, not only through his contributions to this handbook, but also in the many efforts undertaken by the committee. John’s upbeat attitude and willingness to help provided an inspiration to everyone in this industry who had the opportunity to work with him.

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Foreword

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

Welcome to the new and improved *Brazing Handbook*, 5th edition.

The *Brazing Handbook* has been substantively updated from the previous edition. For your convenience, the current edition has been reorganized into three main sections—Fundamentals, Processes, and Applications. There are two new chapters, Chapter 11, "Introduction to the Brazing Processes" and Chapter 36, "Diamond." The new edition covers cutting edge process technologies and new materials. Updating and expanding the chapter on brazing and operator safety has also been a key initiative.

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.

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 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.

Carmen Paponetti
Chair, C3A Subcommittee for the Brazing Handbook

Errata

AWS BRH:2007, *Brazing Handbook*

The following Erratum has been identified and will be incorporated into the next reprinting of this document.

- Page 61, under Inspection, 3rd, 4th, and 5th paragraphs:

  Replace the following:

  Class A joints are those joints subjected to high stresses, cyclic stresses, or both, the failure of which could result in significant risk to persons or property or significant operational failure.

  Class B joints are those joints subjected to low or moderate stresses, cyclic stresses, or both, the failure of which could result in significant risk to persons or property significant operational failure.

  Class C joints are those joints subjected to low or moderate stresses, cyclic stresses, or both, the failure of which could result in significant risk to persons or property, or significant operational failure.

  With the following:

  Class A is typically chosen for joints subjected to high stresses, cyclic stresses, or both, the failure of which could result in significant risk to persons or property, or in significant operational failure.

  Class B is frequently chosen for joints subjected to low or moderate stresses, cyclic stresses, or both, the failure of which could result in significant risk to persons or property, or in significant operational failure.

  Class C is frequently chosen for joints subjected to low or moderate stresses, cyclic stresses, or both, the failure of which would have no significant detrimental effect.

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 Fifth Edition of the *Brazing Handbook* (formerly the *Brazing Manual*) addresses the fundamental concepts of brazing and incorporates the many advances made since the *Brazing Manual* was first published.

The American Welding Society defines brazing as "a group of joining processes that produces coalescence of materials by heating them to the brazing temperature in the presence of a filler metal having a liquidus above 840°F (450°C) and below the solidus of the base metal. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action."

Brazing then 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, 550 N.W. LeJeune Road, Miami, FL 33126.

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CHAPTER 1

BASICS OF BRAZING

Photograph courtesy of *The Gold Bulletin*

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Contents

CHAPTER 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 quantities.

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 that produce the coalescence of materials by heating them to the brazing temperature in the presence of a brazing filler metal that has a liquidus temperature above 840°F (450°C) and below the solidus temperature of the base materials. The brazing filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action.[1,2] The term *brazing temperature* refers to the temperature to which a material is heated to enable the brazing filler metal to spread and adhere to, or wet, the base metal and form a brazed joint.[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 performed above 840°F (450°C), while *soldering* refers to the joining processes performed 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, both the brazing filler metals and the base metals are melted to effect 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 must be designed so that when the components are properly aligned a capillary is

1. American Welding Society (AWS) Committee on Definitions, 2001, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, and Thermal Spraying*, AWS A3.0:2001, Miami: American Welding Society, p. 5.
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, 2001, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, and Thermal Spraying*, AWS A3.0:2001, Miami: American Welding Society, p. 6.