


AWS C4.4/C4.4M:2007
An American National Standard



Recommended Practices for Heat Shaping and Straightening with Oxyfuel Gas Heating Torches



American Welding Society



**AWS C4.4/C4.4M:2007
An American National Standard**

**Approved by the
American National Standards Institute
September 11, 2007**

Recommended Practices for Heat Shaping and Straightening with Oxyfuel Gas Heating Torches

2nd Edition

Supersedes AWS C4.4/C4.4M:2004

Prepared by the
American Welding Society (AWS) C4 Committee on Oxyfuel Gas Welding and Cutting

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This second edition of Recommended Practices for Heat Shaping and Straightening covers the shaping of metal products by prudent use of heat to obtain a desired configuration. The text reviews the theory and analytical calculations that explain how heat shaping and straightening occurs. Sample calculations and tables are presented for typical materials. General heating patterns and heat shaping and straightening techniques are discussed. Specific heating applications are illustrated for various sections.



American Welding Society

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

International Standard Book Number: 978-0-87171-079-6
American Welding Society
550 N.W. LeJeune Road, Miami, FL 33126
© 2007 by American Welding Society
All rights reserved
Printed in the United States of America

Photocopy Rights. No portion of this standard may be reproduced, stored in a retrieval system, or transmitted in any form, including mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright owner.

Authorization to photocopy items for internal, personal, or educational classroom use only or the internal, personal, or educational classroom use only of specific clients is granted by the American Welding Society provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, tel: (978) 750-8400; Internet: <www.copyright.com>.

Statement on the Use of American Welding Society Standards

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society (AWS) are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute (ANSI). When AWS American National Standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

AWS American National Standards are developed through a consensus standards development process that brings together volunteers representing varied viewpoints and interests to achieve consensus. While the AWS administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its standards.

AWS disclaims liability for any injury to persons or to property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this standard. AWS also makes no guarantee or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this standard available, AWS is neither undertaking to render professional or other services for or on behalf of any person or entity, nor is AWS undertaking to perform any duty owed by any person or entity to someone else. Anyone using these documents should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. It is assumed that the use of this standard and its provisions are entrusted to appropriately qualified and competent personnel.

This standard may be superseded by the issuance of new editions. Users should ensure that they have the latest edition.

Publication of this standard does not authorize infringement of any patent or trade name. Users of this standard accept any and all liabilities for infringement of any patent or trade name items. AWS disclaims liability for the infringement of any patent or product trade name resulting from the use of this standard.

Finally, the AWS does not monitor, police, or enforce compliance with this standard, nor does it have the power to do so.

On occasion, text, tables, or figures are printed incorrectly, constituting errata. Such errata, when discovered, are posted on the AWS web page (www.aws.org).

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the appropriate technical committee. Such requests should be addressed to the American Welding Society, Attention: Managing Director, Technical Services Division, 550 N.W. LeJeune Road, Miami, FL 33126 (see Annex C). With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. These opinions are offered solely as a convenience to users of this standard, and they do not constitute professional advice. Such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS C4 Committee on Oxyfuel Gas Welding and Cutting. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are required and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS C4 Committee on Oxyfuel Gas Welding and Cutting and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS C4 Committee on Oxyfuel Gas Welding and Cutting to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

This page is intentionally blank.

Personnel

AWS C4 Committee on Oxyfuel Gas Welding and Cutting

A. T. Sheppard, Chair	<i>The DuRoss Group</i>
M. J. Hogan, 1st Vice Chair	<i>The Harris Products Group, A Lincoln Electric Company</i>
D. B. Overvaag, 2nd Vice Chair	<i>Smith Equipment Company, Division of ITW</i>
A. M. Alonso, Secretary	<i>American Welding Society</i>
J. D. Compton	<i>JD & Associates</i>
J. D. Karow	<i>American General Corporation</i>
L. L. Liston, Jr.	<i>Consultant</i>
C. R. McGowan	<i>McGowan Technical Services</i>
D. Mirgliotta	<i>Forest City Erectors, Incorporated</i>
D. A. Pryor	<i>Thermadyne Industries, Incorporated</i>
R. A. Smith	<i>Compressed Gas Association</i>

Advisors to the AWS C4 Committee on Oxyfuel Gas Welding and Cutting

J. G. Dawson, Jr.	<i>Consultant</i>
D. Hambleton	<i>Smith Equipment Company, Division of ITW</i>
C. M. Hightower	<i>BMS, Incorporated</i>
R. E. Holt	<i>Retired</i>

This page is intentionally blank.

Foreword

This foreword is not part of AWS C4.4/C4.4M:2007, *Recommended Practices for Heat Shaping and Straightening with Oxyfuel Gas Heating Torches*, but is included for informational purposes only.

The shaping of metals by the use of heat has a long history of successful applications. This shaping has been used to curve, camber, or otherwise shape a product as well as to correct members that have become distorted or damaged by accident or fire.

This second edition of *Recommended Practices for Heat Shaping and Straightening with Oxyfuel Gas Heating Torches* presents methods and techniques used by engineers and technicians to shape and straighten metal parts by careful application of heat.

All revisions to the 2004 edition are identified by a vertical line in the margin next to the text.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS C4 Committee on Oxyfuel Gas Welding and Cutting, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

This page is intentionally blank.

Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	vii
<i>List of Tables</i>	xi
<i>List of Figures</i>	xi
1. Scope	1
2. Normative References	1
3. Terms and Definitions	2
4. Theory of Heat Shaping	2
5. Distortion	6
6. Fundamentals and Precautions	7
7. Equipment and Supplies	8
7.1 Standard Equipment.....	8
7.2 Special Equipment.....	8
7.3 Oxygen Supply.....	8
7.4 Fuel Supply.....	8
7.5 Maximum Acetylene Pressure.....	9
7.6 Pressure Regulators.....	9
7.7 Hoses and Fittings.....	11
7.8 Heating Torches.....	12
7.9 Heating Tip/Head.....	12
7.10 Maintenance of Heating Tips or Heads.....	12
7.11 Personal Protective Equipment (PPE).....	13
7.12 Safe Use, Handling, and Storage of Gas Cylinders.....	14
8. Startup and Shutdown Procedure	15
8.1 Setting Up Equipment.....	15
8.2 Lighting the Torch.....	16
8.3 Equipment Shutdown.....	17
8.4 Equipment Not in Use.....	17
8.5 Reuse of Equipment Already Connected.....	17
9. Flame Adjustment	17
9.1 Types of Flames.....	17
9.2 Flashback Arrestors and Check Valves.....	18
10. General Technique	19
11. Procedures for General Applications	20
11.1 Mechanically Restrained Structures.....	20
11.2 Freestanding Unrestrained Members.....	21
11.3 Shaping of Plate.....	23
11.4 Flattening Plates.....	23
11.5 Plate Tightening.....	23

	Page No.
12. Procedures for Specific Applications	23
12.1 Bending of Flat Bar, V Heat.....	23
12.2 Bending of Channel, V Heat.....	26
12.3 Bending of Beams.....	26
12.4 Bending of Angle.....	27
12.5 Bending of T Sections	27
12.6 Bending of Plate	30
12.7 Pipe	30
13. Line Heating and Flame Bending in Shipyards	30
13.1 Background.....	30
13.2 Basic Concepts.....	32
13.3 Planning and Methods	32
13.4 Recommended Practices.....	33
13.5 Code Compliance.....	33
13.6 Conclusions	33
14. Safety and Health	33
Annex A (Informative)—Informative References	35
Annex B (Informative)—Fuel Gas Withdrawal Rates	39
Annex C (Informative)—Guidelines for the Preparation of Technical Inquiries.....	41
List of AWS Documents on Oxyfuel Gas Welding and Cutting.....	43

List of Tables

Table	Page No.
B.1 Acetylene Withdrawal.....	39
B.2 Methylacetylene-Propadiene Stabilized (MPS) Withdrawal	39
B.3 Propylene Withdrawal.....	40
B.4 Propane Withdrawal.....	40

List of Figures

Figure	Page No.
1 Shortening of Bar from Application of Heat	3
2 Variation in Yield Strength and Modulus of Elasticity with Respect to Temperature for ASTM A 36 Steel.....	4
3 Imperceptible Welding Distortion of a Thick Steel Plate	5
4 Welding Distortion of a Thin Steel Plate	7
5 Oxygen Cylinder	9
6 Typical Fuel Gas Cylinders.....	9
7 Pressure Regulators.....	10
8 Hoses and Fittings.....	11
9 Manual Heating Torch	12
10 Multi-Flame Heating Heads.....	13
11 Water-Cooled Flame Hardening Head.....	13
12 Carburizing Flame.....	18
13 Neutral Flame.....	18
14 Oxidizing Flame.....	18
15 Basic Heating Patterns	20
16 Externally Restrained Plate	21
17 Externally Restrained Beam.....	21
18 V Shape Heat Pattern for Straightening or Shaping a Flat Bar.....	22
19 Dimensions for Calculating Upset	23
20 Behavior of ASTM A 36 Steel Perfectly Confined in One Axis as a Function of Temperature.....	24
21 Heat Patterns in Rolled Shapes	25
22 Spot Heat Repair of Dent in Plate	25
23 Spot Heat Repair (Tightening) on Irregular Plate.....	26
24 Application of V Shape Heat Pattern and Direction of Movement	26
25 Bending of Channel Toward Flange	27
26 Bending of Channel Toward Web	27
27 Bending of Channel Toward Open Side	27
28 Bending of Beam Toward Open Side	28
29 Bending of Beam Toward Flange	28
30 Bending of Angle Toward Face of Leg	28
31 Bending of Angle Toward Edge of Leg.....	29
32 Bending of T Section Toward Web	29

Figure		Page No.
33	Bending of T Section Toward Flange	29
34	Bending of Plate	29
35	Bending of Plate (More Movement)	30
36	Decreasing Diameter of Heavy Wall Pipe	31
37	Straightening of Pipe or Round	31
38	Straightening Pipe or Round Stock—V Shape Heating with Serpentine Path	31
39	Straightening Pipe or Round Stock—V Shape Heating with Line Heating Pattern	32

Recommended Practices for Heat Shaping and Straightening with Oxyfuel Gas Heating Torches

1. Scope

This publication describes some causes of distortion and corrective actions through the use of heat. It also describes some heat shaping techniques and the direction of movement expected in the heated metal. Equations are provided to aid in estimating the amount of movement for a given heating technique. The methods discussed are specifically applicable to ferrous metals, but many of the methods can be applied to nonferrous metals as well. For a more comprehensive description of specific applications, see Annex A, Informative References.

Heat has been used to shape and straighten structural elements in bridges, buildings, and marine constructions for over a hundred years. Since the late 1930s, the use of oxyfuel gas torches to do this work has become more prevalent. This publication is a recommended practice for using the torch process for work on bridges and buildings, and to some extent, shipbuilding.

Mechanical forces in fabrication and erection, forces occurring in service, accidental impacts from external forces, fire, and explosion, all cause stress in a structural member or a part of a member. If that stress exceeds the elastic limit of the material, distortion will occur, and the member will not conform to its desired shape. Heat shaping and straightening is an economical method to produce the desired movement to bring the member into conformance.

The shipbuilding industry throughout the world has taken heat shaping to new heights in shaping technology. Particularly, the use of line heating to shape complex curves in hull structures has become an integral part of a group technology in shipbuilding which also includes product work packages and accuracy control.

Basically, straightening and shaping involves controlled thermal expansion and contraction of a structural element. The method, location, and shape of the heat application are covered briefly in this publication. This

recommended practice is limited to fundamentals and simple applications (see Annex A for additional information).

This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets [] or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

Safety and health issues may not be fully addressed by this standard. Users of this standard should consult ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, applicable federal, state, and local regulations and other relevant documents concerning safety and health issues not addressed herein.

2. Normative References

The following standard contains provisions, which, through reference in this text, constitute mandatory provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS documents:¹

AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*; and

AWS F4.1, *Recommended Safe Practices for Preparation for Welding and Cutting of Containers and Piping*.

Other documents:

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*;²

¹ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

² ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.