

Guide for the Evaluation of Thermoplastic Welds



Documents

Document Sharing Hub

AWS G1.10M: 2016
An American National Standard

Approved by
American National Standards Institute
April 21, 2016

Guide for the Evaluation of Thermoplastic Welds

2nd Edition

Supersedes [AWS G1.10M:2016](#)

Prepared by the
American Welding Society (AWS) G1 Committee on Joining of Plastics and Composites

Under the Direction of the
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This standard lists and describes flaws and defects in hot gas, hot gas extrusion, heated tool butt fusion, socket fusion, electrofusion, and flow fusion welded joints in thermoplastics. Its intent is to make possible a generally valid evaluation giving consideration to graded quality requirements. This standard encompasses the classification, requirements, testing, evaluation, and acceptance of the welds. Details in recording engineering data are described. Tables illustrating cracks, voids, solid inclusions, lack of fusion, flaws and defects of shape, and other flaws and defects in thermoplastic welds are included. Flaw and defect features with descriptions and illustrations are compiled into tables to aid in the evaluation of welds.



ISBN: 978-0-87171-884-6
©2016 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 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 is entrusted to appropriately qualified and competent personnel.

This standard may be superseded by new editions. This standard may also be corrected through publication of amendments or errata, or supplemented by publication of addenda. Information on the latest editions of AWS standards including amendments, errata, and addenda is posted on the AWS web page (www.aws.org). Users should ensure that they have the latest edition, amendments, errata, and addenda.

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.

AWS does not monitor, police, or enforce compliance with this standard, nor does it have the power to do so. 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, 8669 NW 36 St, # 130, Miami, FL 33166 (see Annex M). 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 G1 Committee on Joining of Plastics and Composites. 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 G1 Committee on Joining of Plastics and Composites 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 G1 Committee on Joining of Plastics and Composites 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, 8669 NW 36 St, # 130, Miami, FL 33166.

This page is intentionally blank.

Personnel

G1 Committee on Joining of Plastics and Composites

L. T. Hutton, Chair	<i>ARKEMA Incorporated</i>
D. Ziegler, 1st Vice Chair	<i>Wegener Welding LLC</i>
S. P. Hedrick, Secretary	<i>American Welding Society</i>
J. L. Frantz	<i>Branson Ultrasonics Corp.</i>
B. E. Gourley	<i>Sonics & Materials, Inc.</i>
G. Hopkins	<i>Plastek Werks</i>
W. E. Kenney	<i>Consultant</i>
W. McMaster	<i>BASF Corp.</i>
H. L. Mikeworth	<i>H. Mikeworth and Associates</i>

Advisors to the AWS G1 Committee on Joining of Plastics and Composites

A. Benatar	<i>The Ohio State University</i>
D. Grewell	<i>Iowa State Univeristy</i>
F. He	<i>Eastman Kodak Company</i>
V. A. Kagen	<i>SI-Smart Interface, LLC</i>
H. Moore	<i>Eastman Kodak Company</i>
T. O'Toole	<i>Dukane Corp.</i>
J. Park	<i>Visteon Corp.</i>
D. L. Pochardt	<i>3M Company</i>
A. Savitski	<i>Baxter Healthcare</i>
E. S. Stumpek	<i>Consultant</i>
C. Y. Wu	<i>Varroc Lighting Systems</i>

AWS G1A Subcommittee on Hot Gas Welding and Extrusion Welding

J. Leary, Chair	<i>Widos LLC</i>
R. Basile, Vice Chair	<i>AB Plastics</i>
S. P. Hedrick, Secretary	<i>American Welding Society</i>
K. Argasinski	<i>Solvay Specialty Polymers</i>
S. M Gardiner	<i>IPS Corporation</i>
C. Goad	<i>Goad Company</i>
G. Hopkins	<i>Plastek Werks</i>
L. T. Hutton	<i>ARKEMA Incorporated</i>
J. Johnston	<i>McElroy Manufacturing Incorporated</i>
A. Rickert	<i>Quadrant</i>
G. Sample	<i>Georg Fischer</i>
K. C. Thomas	<i>Quadrant EPP</i>
M. J. Troughton	<i>TWI</i>
D. Ziegler	<i>Wegener Welding LLC</i>
P. Zitkus	<i>Wegener Welding LLC</i>

Advisors to the AWS G1A Subcommittee on Hot Gas Welding and Extrusion Welding

S. Chandler	<i>Engiplast Incorporated</i>
J. J. Fluckiger	<i>Idaho National Laboratory</i>
J. Hessel	<i>Hessel Ingenieurtechnik GmbH</i>
P. F. Martin	<i>United Association</i>

This page is intentionally blank.

Foreword

This foreword is not part of this standard but is included for informational purposes only.

The purpose of plastics welding inspection is to determine if a plastics weldment meets the acceptance criteria of a specific code, other standard, or other document. The plastics welding inspector must be thoroughly familiar with plastics welding processes, plastics welding procedures, plastics welder qualifications, materials, the limitation of plastics weld testing, be able to read drawings, prepare and keep records, prepare and make reports and make responsible judgments. For plastics welding inspectors to be effective, the activities performed should be consistent with the requirements, and technical and ethical principles.

The AWS G1 Committee on Joining Plastics and Composites was formed in 1989 by industry and academic experts interested in providing process information and test standards for rating the weldability of plastic and composite materials. The G1A Subcommittee on Hot Gas Welding and Extrusion Welding was formed in 1993 to create standards for the qualification of hot gas and heated tool plastic welding personnel. DVS 2202-1, Imperfections in thermoplastic welding joints; features, descriptions, evaluation, was used extensively in the creation of this standard.

This is the second edition of this specification. The title of the document was changed and editorial changes were made to the Scope (Clause 1). Weld flaws and defects for socket fusion, electrofusion, and flow fusion are new to this edition.

SUGGESTIONS

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, G1 Committee on Joining of Plastics and Composites, American Welding Society, 8669 NW 36 Street #130, Miami, FL 33166.

This page is intentionally blank.

Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	vii
1. Scope, Purpose, and Range of Application	1
2. Referenced Documents	2
3. Definitions	2
4. Evaluation Groups	3
5. Requirements for Welded Joints	4
6. Details in Engineering Data	4
7. Testing and Evaluation	5
8. Acceptance	5
Annex A (Normative)—Cracks	7
Annex B (Normative)—Voids	9
Annex C (Normative)—Solid Inclusions	11
Annex D (Normative)—Lack of Fusion	13
Annex E (Normative)—Flaws of Shape	15
Annex F (Normative)—Other Flaws	17
Annex G (Normative)—Acceptance Criteria for Evaluation Groups for Hot Gas Fan and Speed Welds	19
Annex H (Normative)—Acceptance Criteria for Evaluation Groups for Hot Gas Extrusion Welds	27
Annex I (Normative)—Acceptance Criteria for Evaluation Groups for Heated Tool Butt Fusion Welds	33
Annex J (Normative)—Acceptance Criteria for Evaluation Groups for Heated Tool Socket Welds	37
Annex K (Normative)—Acceptance Criteria for Evaluation Groups for Electrofusion Welds	41
Annex L (Normative)—Acceptance Criteria for Evaluation Groups for Flow Fusion Welds	47
Annex M (Informative)—Requesting an Official Interpretation on an AWS Standard	49

This page is intentionally blank.

Guide for the Evaluation of Thermoplastic Welds

1. Scope, Purpose, and Range of Application

1.1 These guidelines list and describe defects and flaws in welded joints in thermoplastic materials. The objective is to make possible a generally valid evaluation giving consideration to graded quality requirements. This guide is meant to aid those responsible for the evaluation of thermoplastic welds. The final determination of what is an acceptable weld should be the responsibility of the engineer, owner or user.

1.2 By classification into one of the evaluation groups in 4.1, specific flaws may be excluded or kept within limits when welded joints are produced.

1.3 The application of these guidelines and the measures through which they can be met should be included in contractual specification or form part of the generally recognized specifications.

1.4 Welding Processes. Defects and flaws produced by the following welding processes are addressed. This guide applies to the following processes:

	<u>Abbreviation</u>	<u>Annex</u>
Hot Gas Welding	(HGW)	
Fan Welding	(HF)	G
Speed Welding	(HS)	G
Extrusion Welding	(EX)	H
Heated Tool Butt Fusion Welding	(HT)	I
Socket Fusion Welding	(SFW)	J
Electrofusion Welding	(EFW)	K
Flow Fusion Welding	(FFW)	L

1.5 Materials. These guidelines apply to welded joints on components and systems made from the engineering thermoplastics listed below:

Table 1.1
Base Materials

<u>Abbreviation</u>	<u>Name</u>
PVC	Polyvinyl Chloride
CPVC	Chlorinated Polyvinylchloride
PP	Polypropylene
PE	Polyethylene
PVDF	Polyvinylidene Fluoride
ECTFE	Ethylene Chlorotrifluoroethylene
ETFE	Ethylene Tetrafluoroethylene
FEP	Perfluoro (ethylene propylene)
PFA	Perfluoroalkoxy
ABS	Acrylonitrile-Butadiene-Styrene

1.6 The use of these guidelines for welding other thermoplastic materials should be agreed upon between the customer and the fabricator.

1.7 This standard makes use of the International System of Units (SI).

1.8 Safety and health issues and concerns are beyond the scope of this standard and therefore are not addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Referenced Documents

Reference should be made to the latest edition of the following documents:

[ASTM C 904](#), *Standard Terminology Relating to Chemical-Resistant Nonmetallic Materials*¹

[ASTM D 5162](#) Test Method B, *Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrates*¹

AWS A3.0, *Standard Welding Terms and Definitions*²

[AWS B2.4](#), *Specification for Welding Procedure and Performance Qualification for Thermoplastics*²

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

3. Definitions

The terms used in this specification are defined in [ASTM C 904](#), *Terminology Relating to Chemical-Resistant Nonmetallic Materials*, and AWS A3.0, *Standard Welding Terms and Definitions*. Exceptions, within the context of this standard, are listed below with their definitions.

back welding. An addition of a secondary external hot gas or extrusion weld on a socket fusion welded joint, electrofusion welded joint, or solvent cement welded joint.

beadless welding. See **flow fusion welding**.

bead-start/stop crack. A crack occurring at the start/stop of a weld due to the thermal characteristics of an overstressed weld rod. Thermoplastic materials exhibit thermal characteristics that contribute to this condition.

defect. A flaw of a size or configuration exceeding the limitations of the applicable acceptance criteria.

¹ Published by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428; Phone 610-832-9500 (website: www.astm.org)

² Published by the American Welding Society, 8669 NW 36 Street #130, Miami, FL 33166; Phone 800-443-9353; (website: www.aws.org).

electrofusion welding (EFW). A thermoplastic welding process where the heat for welding is provided by energizing an electrically resistive coil in the weld zone.

extrusion welding (EX). A joining process in which molten thermoplastic material is forced against preheated workpieces to produce the weld.

fan welding (HF). A hot gas welding method where the weld rod is fed into the joint without the aid of a welding nozzle; the pressure is applied directly to the welding rod by the welder.

flaw. An interruption of the typical structure of a material, such as lack of homogeneity in its structure or physical characteristics. A flaw is not necessarily a defect.

flow fusion welding. A variety of beadless welding techniques in which resultant joints are free from internal and external beads and crevices. The primary method of beadless welding involves careful diffusion of heat through the external surfaces while maintaining internal support of material as it becomes molten. The Welding Procedure Specification (WPS) specifies the heating temperature and heating cycle during which the molten material readily joins as a single piece.

heated tool butt welding (HT). A method for joining the ends of thermoplastic pipe or fittings in which a hot tool is placed between the pipe ends for a predetermined heating time and then the ends are pushed together with a predetermined amount of force until the joint cools.

hot gas welding (HGW). A thermoplastic welding process in which the parts are softened by hot gas and joined together.

lack of fusion. In a weld, any area or zone that lacks melting and coalescence (fusion) of a portion of the weld. This may occur between weld passes or between weld and base materials.

scraping. The process of removing a thin layer of polymer from the surface to be welded in order to eliminate surface contamination and oxidation.

shrinkage groove. Insufficiency of material on the lateral edges of the weld due to the high thermal shrinkage or expansion characteristics of thermoplastics; this resembles an undercut or underfill weld.

socket fusion welding (SFW). A heated tool welding process variation in which the tool is configured to heat the outside of one workpiece and the inside of the other.

speed welding (HS). A hot gas welding process variation in which the welding tip is used to feed and heat the welding filler rod while heating the workpieces and forcing the plasticized filler into the fusion zone.

void. An unfilled space within a weld.

4. Evaluation Groups

4.1 Classification. Specific requirements are established for the intended service of a component, particularly regarding the quality of the welded joints. The following classification is used as a basis, so that the fabricator and inspector know the extent of the measures required for quality control with regard to welding.

<u>Evaluation Group</u>	<u>Requirement Level</u>
I	High requirements for reliability and/or intended service.
II	Medium requirements for reliability and/or intended service.
III	Low requirements for reliability and/or intended service.

The requirements to be established for the welded joints on a component should in each case be restricted to those which are necessary and appropriate for the application.

4.2 Criteria for Establishment. In the establishment of the evaluation groups, the following factors, among others, should be taken into account:

- (1) level and type of stress (e.g., static, dynamic)
- (2) thermoplastic material (e.g., ductile, brittle)
- (3) operating conditions (e.g., stationary, mobile, environmental)
- (4) production conditions (e.g., workshop, construction site)
- (5) potential hazards (e.g., hazardous gases and/or hazardous fluids)

5. Requirements for Welded Joints

5.1 Quality Features for Classification of the Weld (Annexes G through L). The requirements for classifying a welded joint within a particular quality grade are established in the evaluation groups.

In the majority of cases, requirements are established for the joint listing specific features, and describing them with reference to the internal and external state of the joint. By using Annexes G through L, it is possible to specify requirements for the quality of welding. Using individual features, i.e. through the type and extent of the flaws, an evaluation of welded joints can then be undertaken (for example, as part of the acceptance procedure for the component).

5.1.1 Requirements for Characteristics. This covers additional data such as:

- (1) deformation resistance (e.g., welding factor)
- (2) ductility (e.g., bending angle to cracking)
- (3) resistance to chemical attack (e.g., resistance factor)

5.1.2 Requirements for Post Weld Treatment. In certain cases, it is necessary to process the weld joint for the following reasons:

- (1) dynamic stress (e.g., notch-free transitions)
- (2) to smooth weld surfaces (e.g., lining)
- (3) to improve flow behavior (e.g., internal beads)
- (4) for technical inspection

It is advisable to test and/or evaluate the weld both before and after machining.

6. Details in Engineering Data

Requirements for welded joints should be specified in the contract documentation that is binding for fabrication (for example, working drawing, welding diagram), with reference to this standard.

As a rule it is sufficient to identify a weld in accordance with the following example:

WZ-VV-II where

WZ = abbreviation for the welding process

V = welding symbol and measurements

II = evaluation group code

Should all the welded joints on a component come under the same evaluation group, then it can be entered in a space provided for this purpose on the drawing.

Example: All welded joints as per evaluation group **II** (see 4.1).

Additional requirements for specification of the characteristics of welded joints and for machining are also to be noted in the engineering data.

7. Testing and Evaluation

Visual inspection, measurements and, where necessary, suitable non-destructive or destructive testing procedures should be used to verify that the acceptance criteria for the individual welding groups have been met. Testing can be carried out on the welded joints of the component. Specific characteristics can also be verified on test pieces that are fabricated under comparable conditions. The nature and extent of the tests, together with their timing, should be agreed upon between the customer and the fabricator. The test results should be documented.

7.1 Evaluation. The test results form the basis for the classification of welded joints into one of the three evaluation groups by welding process, in accordance with Annexes G through L. Annexes A through F define imperfections in weld joints, and should be used in the evaluation and documentation process. The test reports should be used to determine points where the results do not correspond with the acceptance criteria. Should the component, or individual welded joints, not correspond to the evaluation group specified (4.1), then it or they should be reworked or replaced.

7.2 Reworking Defective Welded Joints. When allowed under the contract and insofar as possible, defective welded joints should be reworked or replaced. The purpose of reworking operations is to obtain the welded joint quality established by the acceptance criteria. If necessary, the results should be determined by additional testing.

7.3 Overlapping Flaws. Should two or more types of flaw arise simultaneously on welded joints, the cumulative effect of the individual flaw can result in more than the sum of the individual flaws. Tests should then be carried out to ascertain whether the welded joint still meets the acceptance criteria established or whether restrictions have to be imposed as regards safety and quality standards because of the accumulation of flaws.

8. Acceptance

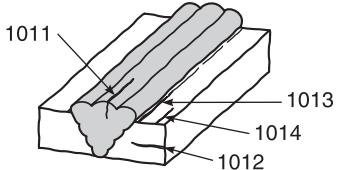
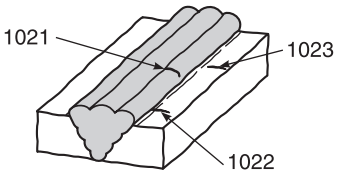
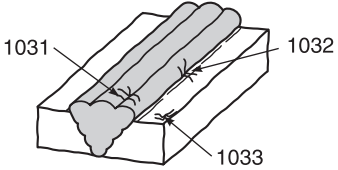
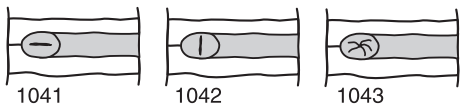
Insofar as tests on the welded component confirm that it meets the acceptance criteria established in the technical documentation, the welded component should be considered as being accepted and documented. Should the acceptance criteria not be met, and should reworking not be possible, then the fabricator and the end user should reach an agreement on the disposition of the welded component.

This page is intentionally blank.

Annex A (Normative)

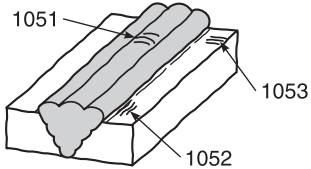
Cracks

This annex is part of this standard and includes mandatory elements for use with this standard.

No.	Designation	Notes	Illustrations
100	Crack	Break in continuity which may occur during cooling or through the action of stress, in the solid state	
1001	Microcrack	Crack having microscopic dimensions	
101 1011 1012 1013 1014	Longitudinal crack	Crack whose main direction is close to that of the axis of the weld. It can be situated: • in the weld • in the fusion zone (weld junction) • in the heat-affected zone • in the base material	
102 1021 1022 1023	Transverse crack	Crack whose direction is more or less perpendicular to the axis of the weld. It can be situated: • in the weld • in the heat-affected zone • in the base material	
103 1031 1032 1033	Radiating crack	Group of cracks issuing from a single point and situated: • in the weld • in the heat-affected zone • in the base material	
104 1041 1042 1043	Bead-start/stop crack	Crack occurring at the bead-start/stop which can be: • parallel • perpendicular • radiating	

(Continued)

Annex A—Cracks (Continued)

No.	Designation	Notes	Illustrations
105 1051 1052 1053	Group of disconnected cracks	Set of grouped cracks of any orientation, which may be situated: • in the weld • in the heat-affected zone • in the base material	
106 1061 1062 1063	Branching crack	Set of interconnected crack in the form of branching and distinguishable from the network of disconnected cracks (105) and from radiating cracks (103). They may be situated: • in the weld • in the heat-affected zone • in the base material	