

Specification for Welding Procedure and Performance Qualification for Thermoplastics



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Specification for Welding Procedure and Performance Qualification for Thermoplastics

2nd Edition

Supersedes AWS B2.4:2006

Prepared by the
American Welding Society (AWS) B2 Committee on Welding Qualification

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification provides the requirements for qualification of welding procedure specifications, welders, and welding operators for manual, semiautomatic, mechanized, and automatic welding. The welding processes included are electrofusion, hot gas, socket fusion, butt contact fusion, infrared, extrusion welding, flow fusion welding, and solvent cement welding. Base materials, filler materials, qualification variables, and testing requirements are also included.



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Foreword

This foreword is not part of [AWS B2.4:2012](#), *Specification for Welding Procedure and Performance Qualification for Thermoplastics*, but is included for informational purposes only.

This specification provides requirements for welding procedure and welding performance qualification. It is the intent that this specification be referenced by other documents, such as codes, standards, specifications, and contracts. This specification defines and establishes qualification variables. The criterion for determining if a welding condition is a procedure qualification variable is whether or not a change in that condition beyond the allowable tolerance affects the properties of a sound weld to the extent that the properties may not meet the specified minimum. Qualification requirements are based on the premise that the referencing document will specify fabrication, design, base material, filler material, preheat, interpass temperature, nondestructive examination, and test requirements applicable to the product. Welding procedure and performance qualifications which meet the requirements of other documents are acceptable, provided they also meet the requirements of this specification. This revision is the second edition of *Specification for Welding Procedure and Performance Qualification for Thermoplastics* and supersedes the edition published in 2006. The major change from the first edition is the inclusion of the solvent cement welding process. Revisions are identified by a vertical line in the margin next to the text. The matrices in 4.7 and 4.8 were changed to reflect the changes in the listing of thermoplastic welding processes in 1.1. Changes were also made to Tables 4.1, 5.1, 5.2, and 5.3. Table 4.6 was renumbered as Table 4.7, and a new Table 4.6 was added. Tables A.1 and A.2 in Annex A were changed and a new Annex B with new PQTR and WPS samples was added. Figures 4.6, 4.7, 4.8, and 4.19 were changed.

Welding Procedure Qualification

The purpose of a welding procedure qualification is to provide test data for assessing the properties of a welded joint. The proof of production weld soundness is determined by the type and extent of testing and examination applied to the production product. Product acceptance criteria must be detailed in the referencing document. This specification also provides for welding procedure qualification of special test weldment/coupons by performing tests simulating service conditions, which may include impact loading, flexural loading, static loading, or cyclic loading. The details of testing and examination of special test weldment/coupons shall be specified by the referencing document.

Welding Performance Qualification

The purpose of welder qualification testing is to determine the ability of welders to make sound welds and the ability of welding operators to operate the welding equipment. Performance qualification for welders and welding operator shall be determined by mechanical testing and visual examination of weldment/coupons.

Materials

Base materials and filler materials have been grouped into categories that will minimize the number of performance qualification tests required. Substitution of one base material or filler material for another, even when within the allowable rules, should only be made after an evaluation of the factors involved. For some materials, additional tests may be required. Materials not listed require separate qualification.

Comments and suggestions for the improvement of this standard are welcomed. They should be sent to the Secretary, AWS B2 Committee on Welding Qualification, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Specification for Welding Procedure and Performance Qualification for Thermoplastics

1. Scope and General Provisions

1.1 Scope. This standard provides the requirements for qualification for welding thermoplastic materials. It addresses requirements for procedure and performance qualifications. This standard is intended for use where referenced by product or fabrication code, specification, contract document, or internal documents such as quality control or quality assurance manuals. The requirements imposed by the Referencing Document supersede the requirements of this standard.

This standard is intended for use with the following thermoplastic welding processes:

- Socket Fusion Welding (SFW)
- Heated Tool Butt Welding (HT)
- Flow Fusion Welding (FFW)
- Electrofusion Welding (EFW)
- Infrared Welding (IRW)
- Hot Gas Welding (HGW)
- Speed Welding (HS)
- Fan Welding (HF)
- Extrusion Welding (EX)
- Solvent Cement Welding (SCW)

This standard is intended for use with new construction but may be applicable for retrofit, reconstruction, or repair procedures. Thermoplastic applications that are bonded to backing materials are not addressed in this standard.

This standard makes sole use of U.S. Customary Units. Approximate mathematical equivalents in the International System of Units (SI) are provided for comparison in parentheses or in appropriate columns in tables and figures.

1.2 Responsibilities

1.2.1 Employers shall be responsible for the welding performed by their organization, including the use of the general provisions of this standard, the use of qualified welding procedures, the use of qualified welders, and the use of qualified welding operators.

1.2.2 It is the employer's responsibility to assure that Welding Procedure Specifications meet all requirements of the Referencing Document.

1.3 Effective Date. When not otherwise specified by the Referencing Document, the edition of this specification to be used should be established in accordance with the following:

- (1) Editions may be used at any time after the effective date of issue;
- (2) Latest edition of this document should be used for new contracts; and
- (3) Editions established by contract date may be used during the entire term of the contract, or the provisions of later editions may be used when agreed upon by the contracting parties.

1.4 Safety

1.4.1 Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein.

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

Applicable Regulatory Agencies

Other safety documents:

(1) *Guide to the Safe Handling of Fluoropolymer Resins*,¹ should be referred to when processing fluoropolymer materials.

(2) ASTM F 402, *Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings*,² should be referred to when the solvent cement welding process.

1.4.3 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. Normative References

The standards listed below contain 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 documents³

- (1) [AWS A3.0M/A3.0](#), *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*
- (2) [AWS G1.10M](#), *Guide for the Evaluation of Hot Gas, Hot Gas Extrusion, and Heated Tool Butt Thermoplastic Welds*
- (3) [AWS B4.0](#), *Standard Methods for Mechanical Testing of Welds*

Other documents

- (4) [ASTM C 904](#), *Terminology Relating to Chemical-Resistant Nonmetallic Materials*
- (5) [ASTM F 412](#), *Standard Terminology Relating to Plastic Piping Systems*

¹ Published by the Society of Plastic Industry, 1801 K Street NW, #600, Washington, DC 20006.

² ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

³ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(6) [ASTM D 2855](#), *Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings*

(7) [ASTM C 1147](#), *Testing of Welded Joints of Thermoplastics*

(8) [ASTM D 1599](#), *Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings*

(9) ASME RTP-1, *Reinforced Thermoset Plastic Corrosion Resistant Equipment*⁴

(10) [ASME B31.3](#), *Process Piping*

(11) EN 13067, *Plastics Welding Personnel—Qualification Testing of Welders—Thermoplastics Welded Assemblies*⁵

(12) EN 12814-1, *Testing of welded joints of thermoplastics semi-finished products—Bend test*

(13) ISO 13955, *Plastics pipes and fittings — Crushing decohesion test for polyethylene (PE) electrofusion assemblies*⁶

(14) ISO 13954, *Plastics pipes and fittings — Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90 mm.*

3. Terms and Definitions

3.1 The welding terms used in this specification are defined in AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, [ASTM C-904](#), *Terminology Relating to Chemical-Resistant Nonmetallic Materials*, and [ASTM F 412](#), *Standard Terminology Relating to Plastic Piping Systems*.

3.2 Supplemental Definitions. Some AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, exceptions, within the context of this standard, are listed below with their definitions.

ABS (acrylonitrile butadiene styrene). A common thermoplastic used to make light, rigid, molded products such as piping. It is a copolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene.

ambient temperature. Environmental conditions corresponding to the usual atmospheric conditions in laboratories with uncontrolled temperature and humidity. Generally, the air temperature range extends from 69°F to 77°F (20°C to 25°C).

bladder. A device that can be used in the flow fusion or electrofusion welding process that is pressurized to make contact with the inner walls of the weld zone prior to the commencement of the weld process to ensure a bead free weld zone on the inner diameter of the pipe.

control specimen. The specimen from the base material tested to determine the tensile strength for the purpose of determining an acceptable tensile.

CPVC (chlorinated polyvinyl chloride). A PVC (polyvinyl chloride) that has been chlorinated via a free radical chlorination reaction.

crystallinity. A state of molecular orientation in some resins which denotes an orderly compact structure of the molecular chains forming the polymer. Normally can be attributed to the formation of solid crystals having a definite geometric form.

elastic deformation. The part of the deformation under load which is recoverable when the load is removed.

⁴ ASME standards are available from ASME International, Three Park Avenue, New York, NY 10016.

⁵ European standards are published by the European Committee for Standardization, 38 rue de Stassart, B-1050, Brussels, Belgium.

⁶ ISO standards are published by the International Organization for Standards, 1 rue de Varembé, Case postale 56, CH-1221 Geneva 20, Switzerland.

elasticity. The property of a substance which enables it to return to its original shape and size after removal of a deforming force.

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

employer. The contractor or manufacturer that adopts this specification for welding procedure and performance qualification. Closely related companies, including those with different names, for which effective control of welding is as one organization, shall be considered as one employer.

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.

flow fusion welding (FFW). A thermoplastic welding process for sheets or pipe where the melt is constrained during the welding process.

freehand welding. See **fan welding (HF)**.

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 from a welding gun and joined together.

infrared welding (IRW). A thermoplastic welding method in which the heat for welding is generated by infrared radiation.

NPS. Nominal pipe size.

performance qualification variable. A controllable detail which, if changed beyond the limitations specified in this specification, requires requalification of the welder or welding operator.

pipe. Used to refer to thermoplastic pipe and tube.

pipe group (PG). A category of thermoplastic pipe dimensions with similar physical attributes requiring similar welding parameters and skills.

polymerization. A chemical reaction in which the molecules of a monomer are linked together to form large molecules whose molecular weight is a multiple of that of the original substance. When two or more monomers are involved, the process is called copolymerization or heteropolymerization.

PP (polypropylene). A tough, lightweight polyolefin plastic made by the polymerization of high-purity propylene gas in the presence of an organometallic catalyst at relatively low pressures and temperatures.

PE (polyethylene). A polyolefin composed of polymers of ethylene. It is normally a translucent, tough, waxy solid which is unaffected by water and by a large range of chemicals. There are three general classifications: low-density, medium-density, and high-density.

Performance Qualification Test Record (PQTR). A written record of a test administered to a welder or a welding operator to determine their capacity to perform a specific welding application. Welding performance qualification tests are specific to a WPS.

preheat temperature. The temperature of the base material in the welding area immediately before any welding is performed.

procedure qualification variable. A controllable detail which, if changed beyond the limitations of Essential Procedure Qualification Variables, requires requalification of the WPS.

PVC (polyvinyl chloride). A thermoplastic compound, pipe, and fittings material composed of vinyl chloride; a colorless solid with outstanding resistance to water, alcohols, and concentrated acids and alkalis. Classified as: plasti-

cized, unplasticized, and high impact: PVC-P, PVC-U, and PVC-HI. (This document does not address PVC-P and PVC-HI.)

PVDF (polyvinylidene fluoride). A thermoplastic prepared from vinylidene fluoride. It has substantially higher strength, wear resistance, and creep resistance than other fluoropolymers but relatively high dielectric constant and loss factor.

PVDF-C (polyvinylidene fluoride copolymer). Copolymer of PVDF.

qualification variable. See **performance qualification variable** and **procedure qualification variable**.

qualified welding procedure. A welding procedure specification (WPS) meeting the qualification requirements of this specification based on qualification tests of weldments. Welding procedures qualified by an employer shall be for the employer's own use.

qualifier. The employer, organization, or individual specified by the referencing document as responsible for conducting and supervising qualification testing.

Referencing Document. The fabrication code, specification, contract document, or internal document such as quality control or quality assurance manuals that invokes this specification.

sheet. Used to refer to calendared, extruded, and/or compression molded products.

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.

solvent cement welding (SCW). A method for joining certain thermoplastic (PVC, CPVC, and ABS) pipe and fittings in which primer and solvent cement containing chemical solvents are used to dissolve the surfaces of the pipe OD and the fitting socket to fuse the surfaces together to form a pipe joint assembly.

solvent welding (SC). See **solvent cement welding (SCW)**.

specimen blank. That portion of a test weldment/coupon removed for the production of a specimen. In some cases, the specimen blank is also the specimen.

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.

stress crack. External or internal crack in plastic caused by tensile stresses less than that of its short term mechanical strength. The development of such cracks is frequently accelerated by the environment to which the plastic is exposed. The stresses which cause cracking may be present internally or externally or may be combinations of these stresses. The appearance of a network of fine cracks is crazing. Also see **environmental stress cracking** and **thermal stress cracking (TSC)**.

test weldment/coupon. Workpieces joined by welding to qualify welding procedures, welders, or welding operators.

thermal stress cracking (TSC). Crazing and cracking of some thermoplastic polymers which results from overexposure to excessive temperatures.

thermoplastic. (*Adjective*) Capable of being repeatedly softened by heat and hardened by cooling. (*Noun*) A material that will repeatedly soften when heated and harden when cooled. Most polymers used for bottles are thermoplastics.

TPM Number. A designation used to group like thermoplastic materials based on weldability consistent with the M Number established in the AWS B2.1 standard.

ultimate strength. The maximum unit stress a material will withstand subjected to an applied load in compression, tension or shear test.

virgin material. A plastic material that has not been subjected to use or processing other than that required for its initial manufacture.

waisted specimen. Tensile test specimen for butt fusion joints which has a minimum in width at the weld line in order to promote failure in the weld.

welding variable. Any controllable detail of a welding procedure which is required to be addressed on the WPS.

4. Procedure Qualification

4.1 General

4.1.1 The employer is responsible for qualifying their welding procedures.

4.1.2 Tests previously approved for use by an employer that meet other codes or specifications may be used by the employer to support a WPS in accordance with this specification. The procedure qualification record(s) (PQR) shall address all qualification variables (see 4.8 Procedure Qualification Variables) applicable to the welding process(es) used and the test results shall meet all requirements of this specification. If all the requirements are not met, another qualification test must be conducted for the additional requirements, following the qualification variables of the original PQR. A PQR supplement shall be prepared to document the additional tests results.

4.1.3 There are no required formats for WPSs or PQRs. Any format may be used providing all applicable information is recorded, including a certifying statement acknowledging the validity of the data and certifying that the weldments were made and tested in accordance with the requirements of [AWS B2.4, Specification for Welding Procedure and Performance Qualification for Thermoplastics](#) (see Annex B). A matrix indicating data to be included in the WPS for a process or combination of processes is provided in 4.7 Welding Procedure Specification Data.

4.1.4 PQRs shall not be revised except to correct errors or add new or omitted information. All such changes shall be identified, authorized, and dated on the PQR.

4.1.5 A WPS may require the support of more than one PQR, while one PQR may support a number of WPSs. Compatible PQRs using different qualification variables may be combined to support one WPS. Compatibility shall be determined based on either experience or testing, or both.

4.1.6 WPSs and PQRs shall be identified according to a system that allows permanent traceability from the WPS to its supporting PQRs.

4.1.7 A change in a WPS beyond that allowed in 4.8 Procedure Qualification Variables shall require requalification of the procedure and preparation of a new or revised WPS. Other changes shall not require requalification, provided such changes are documented either in a new or revised WPS.

4.2 Welding Procedures Qualified by Employers

4.2.1 The qualification variables for the various processes used in making a procedure qualification test weld are listed in 4.8 Procedure Qualification Variables.

4.2.2 [ASTM C-1147, Testing of Welded Joints of Thermoplastics](#), [ASME RTP-1, Reinforced Thermoset Plastic Corrosion Resistant Equipment](#), and [ASTM D 2855, Standard Practice for Making Solvent-Cemented Joints with Poly\(Vinyl Chloride\) \(PVC\) Pipe and Fittings](#), may be used for mechanical testing of welds made for Procedure Qualification. However, in instances where the provisions of [AWS B2.4](#) are in conflict, the provisions of [AWS B2.4](#) shall take precedence. The test results shall be recorded on or appended to a PQR containing the actual qualification variables.

4.2.3 If the test results meet the acceptance criteria specified, the employer shall sign and date the PQR indicating that the PQR is an accurate record of the welding and testing of the procedure qualification test weldment/coupon. The employer may then prepare and issue an approved WPS. The employer shall sign and date the WPS to signify acceptance of responsibility for use of the WPS in production.

4.2.4 Each WPS shall be supported by one or more PQRs, and shall specify a range or a single value for each welding variable applicable to the welding process identified in 4.7 Welding Procedure Specification Data. Additionally, a WPS shall specify a range or a single value for each qualification variable for the weld process used as identified in 4.8 Procedure Qualification Variables.

4.2.6 Special test weldment/coupons may be used for procedure qualification, when permitted by the Referencing Document, and shall be governed by the limits on qualification variables given in 4.8 Procedure Qualification Variables.

4.2.7 This specification recognizes two types of special test weldment/coupons:

(1) *Simulated Service Test Weldment/Coupons*. These are test weldment/coupons in which qualification requires tests simulating service conditions. Tests may include chemical compatibility, and thermal stability, and/or static, or cyclic loading to simulate the type of loading that the weldment will encounter in service. Proof tests such as hydrostatic or leak tests may also be appropriate.