

Chapter 11. Qualification of Welding Procedure Specifications

The mechanical and metallurgical properties of a welded joint may be altered by the welding procedure specifications selected for the job. It is the responsibility of each manufacturer or contractor to conduct the tests required by the applicable codes and contractual documents; it is the duty of the engineer or inspector to review and evaluate the results of such qualifications. These qualification activities should be completed prior to any production welding to assure that the selected combination of materials and methods is capable of achieving the desired results. This is accomplished by any of the following three concepts or a combination thereof:

(1) Employment of prequalified welding procedures. This concept is based on the reliability of certain proven procedures spelled out by the applicable code or specification. Any deviation outside specified limits voids such prequalifications. It must be noted that only a few codes, such as AWS D1.1, Structural Welding Code, recognize the concept of prequalified welding procedures.

(2) Employment of standard qualification tests. Such tests may or may not stimulate the actual welding condition anticipated for a given project. Usually, such standard tests involve conventional butt joints on pipes or plates, or fillet welds between two plates. Base metals, welding consumables, and thermal treatments follow production welding plans within specific plus-minus tolerances. However, other variables such as

joint geometry, welding position, and accessibility are not considered essential by Section IX of the ASME Boiler and Pressure Vessel Code. Thus, they may bear little resemblance to production conditions and must be changed by revision of the welding procedure specification. Other documents, such as API 1104, Standard for Welding Pipelines and Related Facilities, require qualification tests that resemble production conditions quite closely.

(3) Employment of mock-up tests. Such tests simulate actual production conditions to the extent necessary to ascertain that a sound plan with proper tooling and inspection has been selected. While none of the conventional welding codes and specifications mandate such mock-up qualifications, contractual documents, or troubleshooting activities may require such tests. Especially for the latter, a mock-up qualification is a valuable tool to demonstrate specific quality levels under difficult or otherwise restrictive welding conditions.

Four controls combine to ensure the production of satisfactory welds: (1) qualification of a welding procedure; (2) qualification of the welders and welding operators to determine their ability to deposit sound welds; (3) suitable supervision; and (4) suitable inspection prior to, during, and following completion of welding. All four are vital elements in the production chain. Through these controls, it is possible to achieve, repeatedly, welds of suitable quality and known properties.

Description

There are five basic steps in the qualification of a welding procedure:

- (1) Preparation and welding of suitable samples
- (2) Testing of representative specimens
- (3) Evaluation of overall preparation, welding, testing, and end results
- (4) Possible changes in procedure
- (5) Approval

Preparation of Procedure Qualification

Sample Joints: Plate or pipe assemblies with a representative welded joint are usually used for procedure qualification testing. The size, type, and thickness are governed by the thickness and type of material to be welded in production and the type, size, and number of specimens to be removed for testing. The latter are usually prescribed by the applicable code or specifications. The materials used and all details associated with the welding of the sample joints should be in accordance with the particular welding procedure specifications that are to be qualified.

Testing of Procedure Qualification Welds:

Test specimens are usually removed from the sample joints for examination to determine certain properties. The type and number of specimens removed and the tests made thereon depend upon the requirements of the particular application or specification. Usually, the tests include tensile and guided bend specimens to determine strength, ductility, soundness, and adequacy of fusion. If only fillet welds are tested, tensile shear tests and break specimens or macroetch specimens are usually employed. Additional tests may be specified by the applicable codes or contract documents to meet specific needs. These may include:

- (1) Impact tests to determine notch ductility of the weld and the HAZ to minimize the risk of brittle fracture at specified temperatures. While Charpy-V specimens are most commonly used for such tests, many other concepts, including drop weight and crack-opening-displacement (COD) tests, are sometimes employed.
- (2) Nick-break tests to determine weld soundness at randomly selected locations.
- (3) Free bend tests to determine the elongation of deposited weld metal.

(4) Shear tests to determine the shear strength of fillet welds or clad bonding.

(5) Hardness tests to determine adequacy of heat treatment and suitability for certain service conditions. Such tests may be performed on surfaces or on cross sections of the weld.

(6) All-weld-metal tension tests to determine the mechanical properties of the deposited weld metal with minimum influence due to base metal dilution.

(7) Elevated temperature tests to determine mechanical properties at temperatures resembling service conditions.

(8) Restraint or "torture" tests to determine crack susceptibility and the ability to achieve sound welds under highly restrained conditions.

(9) Corrosion tests to determine the properties needed to withstand aggressive environments including high temperature, hydrogen, chlorides, etc.

(10) Nondestructive tests and macro or micro samples to determine the soundness of a weld and to evaluate the inspectability of production welds.

(11) Delayed cracking tests to detect resistance to hydrogen cracking in HSLA (high strength, low alloy) steels and some other materials.

Most of the detailed specimen preparation and testing procedures can be found in other chapters.

Evaluation of Test Results: Once a welding procedure has been prequalified or has been tested in accordance with the applicable codes and contractual documents, the relevant data must be recorded in detail. Recommended forms are offered by some specifications and representative samples have been reproduced in the chapter. Figure 11.1 illustrates the prequalified joint welding procedure suggested by AWS D1.1, while Fig. 11.2 is a copy of the ASME Section IX Procedure Qualification Record (PQR).

In evaluating any welding procedure or any test results, the applicable codes provide general guidance and some specific acceptance-rejection criteria. For instance, the minimum tensile strength and the maximum number of inclusions or other discontinuities is specified by many documents. The acceptability of some other properties represents a different problem. In general, it is best if the weld matches the mechanical and metallurgical properties of the base

Material specification _____
Welding process _____
Manual or machine _____
Position of welding _____
Filler metal specification _____
Filler metal classification _____
Flux _____
Weld metal grade* _____
Shielding gas _____ Flow rate _____
Single or multiple pass _____
Single or multiple arc _____
Welding current _____
Polarity _____
Welding progression _____
Root treatment _____
Preheat and interpass temperature _____
Postheat treatment _____

* Applicable only when filler metal has no AWS classification.

WELDING PROCEDURE

Pass no.	Electrode size	Welding current		Travel speed	Joint detail
		Amperes	Volts		

This procedure may vary due to fabrication sequence, fit-up, pass size, etc., within the limitation of variables given in 4B, C, or D of AWS D1.1, Structural Welding Code.

Procedure no. _____ Manufacturer or contractor _____

Revision no. _____ Authorized by _____

Date _____

Form E-1

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Fig. 11.1—Form E-1, AWS D1.1

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metal, but this is not always possible. In addition to weld metal and base metal being different product forms, they often have somewhat different chemical compositions and mechanical properties. It requires engineering judgment to select the most important properties for each individual application. This is especially important for service at high temperature, low temperature, and under corrosive conditions.

Changes in a Qualified Procedure: If a fabricator who has qualified a welding procedure desires at some later date to make a change in that procedure, it may be necessary to conduct additional qualifying tests. These tests establish that the changed welding procedure will produce

satisfactory results.

Such requalification tests are not usually required when only minor details of the original procedure have been changed. They are required, however, if the changes might alter the properties of the resulting welds. Reference should always be made to the governing code or specification to determine whether a given change in the welding procedure requires requalification.

Approval of Qualification Tests and Procedure Specifications: As a rule, inspection agency or customer approval of procedure qualification tests, test results, and specifications is required before any production welding is done under the provisions of a procedure specification.

QW-483 PROCEDURE QUALIFICATION RECORD (PQR)
 (See QW-201.2, Section IX, 1974 ASME Boiler and Pressure Vessel Code)

Company Name _____
 Procedure Qualification Record No. _____ Date _____
 WPS No. _____
 Welding Process(es) _____
 Types (Manual, Automatic, Semi-Auto.) _____

JOINTS (QW-402)

Groove Design Used

BASE METALS (QW-403)

Material Spec. _____
 Type or Grade _____
 P No. _____ to P. No. _____
 Thickness _____
 Diameter _____
 Other _____

POSTWELD HEAT TREATMENT (QW-407)

Temperature _____
 Time _____
 Other _____

GAS (QW-408)

Type of Gas or Gases _____
 Composition of Gas Mixture _____
 Other _____

FILLER METALS (QW-404)

Weld Metal Analysis A No. _____
 Size of Electrode _____
 Filler Metal F No. _____
 SFA Specification _____
 AWS Classification _____
 Other _____

ELECTRICAL CHARACTERISTICS (QW-409)

Current _____
 Polarity _____
 Amps. _____ Volts _____
 Other _____

POSITION (QW-405)

Position of Groove _____
 Weld Progression (Uphill, Downhill) _____
 Other _____

TECHNIQUE (QW-410)

Travel Speed _____
 String or Weave Bead _____
 Oscillation _____
 Multipass or Single Pass (per side) _____
 Single or Multiple Electrodes _____
 Other _____

PREHEAT (QW-406)

Preheat Temp. _____
 Interpass Temp. _____
 Other _____

This form may be obtained from the Order Dept., ASME, 345 E. 47th St., New York, N.Y. 10017

Fig. 11.2(A)—ASME Section IX PQR form

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QW-483 (Back)**Tensile Test (QW-150)**

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb.	Ultimate Unit Stress psi	Character of Failure & Location

Guided Bend Tests (QW-160)

Type and Figure No.	Result

Toughness Tests (QW-170)

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	Lateral Exp.		Drop Weight	
					% Shear	Mils	Break	No Break

Fillet Weld Test (QW-180)

Result — Satisfactory: Yes _____ No _____ Penetration into Parent Metal: Yes _____ No _____
 Macro — Results _____

Other Tests

Type of Test _____
 Deposit Analysis _____
 Other _____

Welder's Name _____ Clock No. _____ Stamp No. _____

Tests conducted by: _____ Laboratory Test No. _____

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Date _____ Manufacturer _____
 By _____

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

Fig. 11.2(B)—Reverse of PQR form