Welding Procedure Specifications

What the Engineer Needs to Know

By Kenneth W. Coryell, SCWI

The welding procedure specification, or WPS as it is commonly called, is a crucial element in the control of welding quality. Structural welding is governed by AWS D1.1/D1.1M-*Structural Welding Code-Steel*, which is published by the American Welding Society. The Engineer is responsible for development of the contract documents for work performed under this Code, and must address provisions for the WPS's. Engineers that are familiar with welding and welding requirements will be more effective in avoiding some of the vagueness that often appears in a number of contracts. This helps improve overall welding quality, reduces costs, and reduces probability of weld failures.

Why a WPS?

This is a straightforward question that elicits different answers from different people. Some fabricators will simply say that they need WPS's in order to get through an audit so they can be added to the approved suppliers list. Some auditors might say that the WPS provides detailed instructions on how a welder is to set up their machines. Some welders might not know why WPS's are required. In fact, if you have a welder, a welding machine, welding filler metal, some pieces that must be welded, but you don't have a WPS, chances are that the pieces will be welded anyway. But will the welded joint perform as intended? That we cannot say. There are just too many unknowns.

The WPS, therefore is one of the principal methods for ensuring that the welded joint will perform as the Engineer intends. By eliminating the unknowns that can affect metallurgical properties and structural performance, the Engineer and Contractor have taken a major step towards avoidance of welding problems.

What is a WPS?

A WPS is a written description of the important welding details necessary to fulfill the weld joint performance expectations of the Engineer. It is the responsibility of the Contractor to prepare the WPS in compliance with the Engineer's requirements, but it should be reviewed by the Engineer and a qualified inspector as appropriate. It is written and not verbal. The format is flexible, but the Code requires that it be written. *Figure 1* (see page 51) shows a format suggested in AWS D1.1, but other convenient formats are used. Computer software is now available and is becoming a popular way to prepare WPS's. The format may be flexible, the content may be brief or long, but certain content is somewhat standardized.

Welding consists of many detailed variables which affect mechanical properties and structural performance. The term "soundness" is sometimes used with respect to structural performance. Soundness is a qualitative assessment of how free the deposited weld metal is from flaws and imperfections. Some of the common variables recorded in the WPS that influence properties and soundness include:

Joint Design – joint type and dimensions, treatment of joint backside, method of preparation and gouging, and use of backing.
Base Metal – material type and group, thickness range, diameter
Welding Process – such as shielded metal arc, flux cored, submerged arc, etc., and whether manual, semi automatic, or automated
Filler Metal – specification, classification, special grouping. diameter, flux classification
Position – welding positions and direction (upwards or downards) for vertical welding
Preheat and Interpass – minimum preheat temperature, maximum interpass temperature, maintenance of preheat
Heat Treatment – temperature and time
Shielding Gas – gas composition and flow rate
Electrical – amperage (or wire feed speed), current type, polarity, voltage range
Other – travel speed range, metal transfer mode, stringer or weave beads

Variables not listed above may need to be added. The level of detail will vary. Because the WPS communicates a fulfillment of engineering expectations, standardized terminology is used. The Code identifies the standard terminology reference document to be used to ensure precise communication.

What assures that the WPS will work?

To assure the fulfillment of engineering expectations, WPS's must either have sufficient prior use and proven experience, or they must be qualified by testing. Both approaches are used in structural welding. Because of differing opinions on what constitutes sufficient prior use and proven experience, and what testing should be sufficient to qualify a WPS, the Code has provided detailed requirements for each case. WPS's that are based on sufficient prior use and proven experience are called prequalified WPS's. These are more commonly used due to the obvious cost savings associated with qualification testing.

What are the different types of WPS's?

Three types of WPS's can be used for structural welding; Prequalified WPS's, Qualified WPS's, and Standard WPS's

Prequalified WPS

By strictly complying with a series of precisely defined welding variables, the contractor can avoid performing a qualification test. The variables include:

- Welding Process
- Filler Metal/Base Metal Combinations
- Minimum Preheat and Interpass Temperatures
- Welding Techniques and Heat Ranges
- Prequalified Joint Details

The processes, joint details, and other pertinent variables have been thoroughly tested with many years of proven experience behind them. Some fabricators incorrectly believe that a prequalified WPS is not written. This is not the case. The prequalified WPS must be written in a convenient format just as any type of WPS is written. It just does not need to be tested by the contractor.

Qualified WPS

Procedure qualification determines that the WPS will produce sound welds with adequate mechanical properties by performing a test weld and evaluating the weld. The Code describes the test weld configuration and specifies the type and number of evaluations that must be performed on the test weld. These qualification tests may or may not simulate actual conditions for a given project. Usually welds are performed in conventional butt joints between plates, but other configurations can be used. The base metals, welding consumables, thermal treatments, heat ranges, and other important welding variables should follow the production welding plans.

After a visual examination and either a radiographic or ultrasonic examination, specimens are removed from the weld for destructive testing. Usually, the tests include tensile and bend tests to evaluate strength, ductility, and soundness, but other tests may be required. A Procedure Qualification Record (PQR) is used to document all welding variables and test results. Again, the format is flexible. The suggested format in *Figure 1* (see page 51) can be used to record actual test weld conditions. *Figure 2* (see page 52) illustrates a suggested format for recording test results.

If a fabricator wishes to make changes to a qualified WPS at some later date, it may be necessary to conduct additional qualifying tests. Not all changes to a WPS will alter the mechanical properties or weld soundness, and therefore will not require additional testing. The welding variables that cannot be changed beyond certain limitations without requiring additional tests are called Essential Variables. The Code provides a detail description of these Essential Variables. Some welding variables are essential only when the Engineer has specified Charpy V-Notch (CVN) testing. These are called Supplementary Essential Variables. The Engineer is responsible for specifying CVN testing requirements since the Code does not contain specific acceptance criteria or test temperatures.

Standard WPS

The American Welding Society publishes *Standard Welding Procedure Specifications*. They are prepared by the Welding Procedures Committee of the Welding Research Council from PQR's submitted by various companies and organizations. Standard WPS's differ from Prequalified WPS's in that they are developed from actual PQR's rather than long term acceptable experience. The Standard WPS's are balloted by the American Welding Society as American National Standards.

The user of a Standard WPS pays a nominal license fee and must accept responsibility for production application of the WPS. The user may supplement the Standard WPS with additional information or requirements, provided that all welding variables remain within the ranges shown in the Standard WPS.

Standard WPS's were recently recognized as being an acceptable way to comply with the Code and are becoming more popular. This is due to the modest cost and reduction in review/comment cycles between the Engineer, Contractor, and Inspector. Standard WPS's are prepared in compliance with AWS B2.1, *Specification for Welding Procedure and Performance Qualification*. Their acceptance on a project is the responsibility of the Engineer.

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What is the difference between a WPS and a PQR?

A number of people are confused about this. The WPS and PQR, although similar in format, are two distinctly different documents. The WPS states the allowable ranges to the welding variables that may be used in production welds. It is a document that can be revised as necessary to suit project needs, provided all rules for Prequalified WPS's and Essential Variables are satisfied. The PQR records the actual welding variables used during testing and not the allowable production ranges. In addition, results of testing are included. The PQR is a record of what happened and as such is not subject to revision.

Conclusion

A properly prepared WPS cannot eliminate all potential welding problems on a project. The absence of a properly prepared WPS certainly indicates that welding is not under control. The Engineer has important responsibilities for specifying welding requirements and for accepting WPS for use on projects. A future article will deal with what an Engineer needs to know about welder qualifications.▪

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Further Reading

AWS D1.1/D1.1M-2004, Structural Welding Code-Steel

AWS A3.0-2001, Standard Welding Terms and Definitions

AWS B2.1-2005, Specification for Welding Procedure and Performance Qualification

The Professional Advisor on Procedure

Qualification Variables/Cross Reference Tables for AWS D1.1, AWS D1.5, AWS B2.1, ASME IX, and API 1104, published by the American Welding Society

Figure 1: AWS D1.1 Sample Format for WPS and PQR Weld Data

WELDING PROCEDURE SPECIFICATION (WPS) Yes ☐
PREQUALIFIED _____ QUALIFIED BY TESTING _____
or PROCEDURE QUALIFICATION RECORDS (PQR) Yes ☐

Identification # _____
Revision _____ Date _____ By _____
Company Name _____ Authorized by _____ Date _____
Welding Process(es) _____ Type—Manual ☐ Semi-Automatic ☐
Supporting PQR No.(s) _____ Machine ☐ Automatic ☐

JOINT DESIGN USED
Type:
Single ☐ Double Weld ☐
Backing: Yes ☐ No ☐
Backing Material:
Root Opening _____ Root Face Dimension _____
Groove Angle: _____ Radius (J–U) _____
Back Gouging: Yes ☐ No ☐ Method _____

BASE METALS
Material Spec. _____
Type or Grade _____
Thickness: Groove _____ Fillet _____
Diameter (Pipe) _____

FILLER METALS
AWS Specification _____
AWS Classification _____

SHIELDING
Flux _____ Gas _____
Composition _____
Electrode-Flux (Class) _____ Flow Rate _____
_____ Gas Cup Size _____

PREHEAT
Preheat Temp., Min _____
Interpass Temp., Min _____ Max _____

POSITION
Position of Groove: _____ Fillet: _____
Vertical Progression: Up ☐ Down ☐

ELECTRICAL CHARACTERISTICS
Transfer Mode (GMAW) Short-Circuiting ☐
Globular ☐ Spray ☐
Current: AC ☐ DCEP ☐ DCEN ☐ Pulsed ☐
Other _____
Tungsten Electrode (GTAW)
Size: _____
Type: _____

TECHNIQUE
Stringer or Weave Bead: _____
Multi-pass or Single Pass (per side) _____
Number of Electrodes _____
Electrode Spacing Longitudinal _____
Lateral _____
Angle _____
Contact Tube to Work Distance _____
Peening _____
Interpass Cleaning: _____

POSTWELD HEAT TREATMENT
Temp. _____
Time _____

WELDING PROCEDURE

Pass or Weld Layer(s)	Process	Filler Metals		Current		Volts	Travel Speed	Joint Details
		Class	Diam.	Type & Polarity	Amps or Wire Feed Speed			

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Figure 2: AWS D1.1 Sample Format for PQR Test Results

Procedure Qualification Record (PQR) # _____
Test Results

TENSILE TEST

Specimen No.	Width	Thickness	Area	Ultimate Tensile Load, lb	Ultimate Unit Stress, psi	Character of Failure and Location

GUIDED BEND TEST

Specimen No.	Type of Bend	Result	Remarks

VISUAL INSPECTION
Appearance_____
Undercut _____
Piping porosity _____
Convexity_____
Test date _____
Witnessed by_____

Radiographic-ultrasonic examination
RT report no.: _____ Result_____
UT report no.:_____ Result_____

FILLET WELD TEST RESULTS

Minimum size multiple pass		Maximum size single pass	
Macroetch		Macroetch	
1. _____	3. _____	1. _____	3. _____
2. _____		2. _____	

Other Tests

All-weld-metal tension test
Tensile strength, psi _____
Yield point/strength, psi _____
Elongation in 2 in., % _____
Laboratory test no. _____

Welder's name _____ Clock no. _____ Stamp no._____

Tests conducted by _____ Laboratory

Test number _____

Per _____

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in conformance with the requirements of Section 4 of AWS D1.1/D1.1M, (_____) Structural Welding Code—Steel.
(year)

Signed _____
Manufacturer or Contractor
By _____
Title _____
Date _____

Form E-1 (Back)