GUIDELINES FOR WELDING PROCEDURE SPECIFICATIONS

Prepared by the
SEAONC Construction Quality Assurance Committee
Board of Directors, 2006

Andrew Merovich, President
Douglas Hohbach, Vice President
Jamison Curry, Secretary
Michael Fretz, Treasurer
Simin Nasseh, Past President
William Andrews, Director
Gary Mochizuki, Director
David McCormick, Director
David Murphy, Director

Disclaimer

While the information presented in the document is believed to be correct, SEAONC and its Board and Committees assume no liability for its accuracy or for the opinions expressed herein. The material presented in this document should not be used or relied upon for any specific application without competent examination and verification of its accuracy, suitability, and applicability by qualified professionals. Users of information from this document assume all liability arising from such use.
Guidelines for Welding Procedure Specifications

These guidelines were written by members of the SEAONC Construction Quality Assurance Committee.

Construction Quality Assurance Committee

The committee acknowledges the following SEAONC members for their comments, suggestions, and assistance.

Peter Bank
A.L. Collin
Ronald O. Hamburger
Bret Lizundia
Ronald F. Middlebrook
Peter Revelli
Joseph R. Sutton
Andrew Whittaker
Introduction

Although the engineer of record (EOR) is not expected to be an expert in welding, the responsibility of the EOR extends beyond the completion of the plans and specifications to the as-erected condition of a structure. This is particularly the case for seismically loaded structures, where the performance may depend on the properties and geometry of the erected structure. The 2002 AISC Seismic Provisions for Structural Steel Buildings (Section 7.3), for example, requires the EOR to approve each welding procedure specification (WPS) used in fabrication and erection. The need for this requirement was demonstrated by the 1994 Northridge earthquake, in which steel moment frames and other welded connections fractured with minimal ductility, instead of absorbing plastic strains as expected. The causes of these fractures included inadequate oversight, insufficient toughness in the connection weldment, and WPSs that either did not exist or did not conform to the welding code, AWS D1.1. As a result, the EOR is now expected to take an active role in the review of welding documents. AWS D1.1 describes welding as an engineered process. Requirements are specified for welding electrode and usage parameters, equipment, steels to be joined, joint configurations, welder (performance) qualifications, and workmanship for the purpose of producing a sound weld joining the steel materials.

AWS provisions for confirming the workmanship ability of the individual welder, called welder qualification (also known as “certification”), are well known and widely enforced. The importance of the welder in the process is critical and is usually addressed by steel fabricators, erectors, and inspectors during the production process. The materials and parameters of the welding process are often taken for granted and not properly documented in the required written form known as the Welding Procedure Specifications (hereafter referred to as WPSs). Use of a prequalified joint without any further documentation is often mistakenly thought to be all that is required. Welders and inspectors often work without a written WPS and rely on their experience to produce apparently good welds. As a result, welding is typically performed and inspected without the written WPS “recipe” that AWS D1.1 requires to help ensure the consistent production of sound welds. All references in these guidelines to AWS D1.1 are to the 2004 edition.

Purpose

This document has been produced to inform and educate structural engineers about WPSs and their role in the quality assurance of welded connections. Welding consists of complicated and specialized processes. The structural engineer must have an understanding of the organizational relationships and processes by which a specified weld on a drawing is converted to a finished connection. The structural engineer should be aware of the definition, use, purpose of, and difference between, WPS, procedure qualification, welding procedure, and welder qualification.

Understanding these provisions, the engineer should specify submittal of WPSs analogous to other submittals such as concrete mix designs and shop drawings. The contractor is responsible for preparing the WPSs. AWS D1.1 states that WPSs that require qualification by testing be approved by the engineer, and further states that “The Engineer shall determine the suitability of all joint details to be used in a welded assembly.”
This document is intended to help engineers perform the review without additional specialized expertise in the detailed requirements of welding. It is not recommended that the engineer attempt such reviews if he or she does not feel technically qualified. A welding, metallurgical, or testing agency consultant can be called in for a more technical review if necessary. Approval by the engineer should be based on his or her own expertise, or the recommendations of a qualified consultant.

Definitions and Terminology

**Essential variable:** A welding process, base metal or joint detail parameter that must be specified and limited in the WPS. Information on essential variables are in AWS D1.1, Sections 3.6 and 4.7.1 and Table 4.5. For prequalified procedures, changes outside the limits of essential variables require additional qualification testing, new PQR(s) and a revised WPS.

**Joint:** A single element of a connection where two or more ends, surfaces, or edges are attached by welding, or according to AWS D1.1: The junction of members or the edges of members that are to be joined or have been joined.

**Nonessential variable:** A welding process, base metal or joint detail parameter that must be specified in the WPS but may be changed during use. A change outside the limits of a nonessential variable does not require a revision to the WPS.

**Prequalified WPS:** A WPS that is exempt from qualification testing according to AWS D1.1.

**Procedure Qualification:** The demonstration by specified tests that welds made by a specific procedure can meet prescribed standards.

**Procedure Qualification Test Record (PQR):** Written documentation of the welding details and test results demonstrating that welds using a particular WPS meet prescribed standards. A PQR is not required for prequalified WPSs.

**Weldment:** An assembly whose components are joined by welding.

**Welder Qualification:** The demonstration, by specified tests, of a welder’s ability to produce welds meeting prescribed standards.

**Welding Procedure:** Detailed methods and practices required to produce an acceptable weldment, including weld processes, connections, joint welding procedures, joint details, preheat, inspection requirements, sequence, shrinkage allowance, postheat, and any other factors.

**Welding Procedure Specification (WPS):** A document detailing the method and the welding variables required to produce a welded joint. It directs the welder how to weld a specific joint, and includes requirements such as joint preparation, weld process, electrode type and diameter, voltage and current, and travel speed. Its purpose is to assure consistent production of sound welds. **The WPS is the focus of these guidelines.**

Qualification Requirements

AWS D1.1, section 4 defines the qualification requirements for both WPSs and individual welders.

**WPS**

Documenting welding processes and variables in a written WPS provides a standard method for reproducing welds. A qualified WPS establishes that a weld joint proposed for fabrication meets AWS D1.1 requirements for weld quality. WPSs are qualified by testing according to procedures outlined in the code. However, some WPSs that use established procedures are “prequalified” and exempt from testing.

**Prequalified WPS**

In AWS D1.1, a WPS is considered to be prequalified if the selected joint configuration, welding process and variables, and other parameters conform to the mandatory code requirements. A WPS that meets the criteria AWS D1.1, Section 3 is exempt from qualification testing.
Although prequalified procedures are exempt from tests, AWS D1.1 does require that the contractor prepare **written** WPSs for the joints to be used in fabrication. These specifications indicate the limits and requirements for material and welding variables, providing documentation that the joint welding meets the requirements for prequalified status. A sample prequalified WPS is included as Exhibit 1.

**WPS Qualified by Testing**

A WPS that is not prequalified must be qualified by testing according to the requirements of AWS D1.1, Section 4.1.1. Qualification tests can demonstrate that a welded joint using a specific WPS meets the prescribed standards of the code. The contractor or fabricator is required to make a test sample, typically a butt-jointed plate using the joint in the proposed WPS, for mechanical testing and evaluation. In preparing the test plate, the welder must follow the written details in the proposed WPS. A sample WPS qualified by testing is included as Exhibit 2.

The test plate configurations and dimensions are shown in AWS D1.1, Tables 4.2-4.4. Tests may include visual inspection, tensile strength, guided bends, macroetches, radiography, and impact tests. If the test results do not meet the requirements of AWS D1.1 or project specifications, then a new WPS must be prepared and qualified by testing.

**Procedure Qualification Record**

A procedure qualification record (PQR) is written to document the actual welding variables used and the test results for a proposed WPS. Each WPS qualified by testing is supported by one or more PQRs. A sample PQR supporting the WPS in Exhibit 2 is included as Exhibit 2A.

**Revision and Requalification**

If any welding variables are changed in a WPS, then a new WPS may have to be written to reflect the changes. Depending on which variables are changed, the revised WPS may have to be requalified by testing. AWS D1.1 specifies the type of changes requiring requalification.

**Welder Qualification**

Individual welders must be qualified to perform specific welds. The contractor or fabricator qualifies each welder for each WPS and position. The Commentary in AWS D1.1, section C4.18 states, “The welder qualification test is specifically designed to determine a welder’s ability to produce sound welds in any given test joint. After successfully completing the welder qualification tests, the welder should be considered to have minimum acceptable qualifications.”

AWS D1.1 defines welder qualification requirements. Each welder’s qualification remains in effect indefinitely unless (1) the welder is not engaged in a given process of welding for which the welder is qualified for a period exceeding six months, or (2) there is some specific reason to question a welder’s ability. A sample welder qualification test record is included as Exhibit 3.

**Engineers’ Project Specifications for WPS**

The structural engineer needs to request WPSs for each type of weld joint to be used on a project. The structural engineer’s request for WPS will typically appear in the structural steel section of the project specifications. To ensure that WPSs are used, references need to be included in several places in the section. Sample project requirements for WPS are included as Exhibit 4.

An important item to consider for inclusion in the project specifications is a requirement that the manufacturer and specific electrode be stated in the WPS. AWS uses the concept of “essential variable”, which for our purposes can be considered a parameter that cannot be changed without resubmittal by the contractor. Manufacturer and specific electrode are not essential variables in AWS D1.1. The code thus allows electrode substitution by the contractor during fabrication. The structural engineer can require the electrode be defined in the submittal, and certainly should in the case of critical structural welds. This will prohibit substitution of an electrode with parameters that might not comply with the WPS. Many in the welding industry recommend the electrode be defined in all submittals.
Project specifications may also describe methods or preparation, welding parameters, inspection requirements, and mitigation methods for rejected welds. Additional requirements, such as steel chemical analysis and sequence of welded construction may also be included in the project specifications. These are often referred to as welding procedures but should not be confused with WPSs.

**Review of WPS**

Submittal of WPSs should be in a timely manner to allow for adequate review. WPSs should be included with any shop drawings referencing welds. The structural engineer should review WPSs for completeness and conformance to project specifications. The structural engineer need not be a welding specialist to be able to review the completeness and accuracy of WPSs. As a minimum the structural engineer should verify that the joint details, material thickness and grades, and welding positions in the design documents are covered by the submitted WPSs. If the structural engineer determines additional review is necessary, the documents can be forwarded to a testing agency or welding consultant. The consultant should provide comments to the structural engineer for incorporation in the WPS submittal response.

The testing agency verifies individual welder qualifications during steel fabrication and erection. Welder qualifications do not ordinarily need to be submitted to the structural engineer for review. Structural engineers should be alert to the possibility of receiving welder qualifications when WPS submittals are required.

**Use During Project**

The use of written WPSs during appropriate phases of a project provides the welder with the basic welding and weld joint requirements and the inspector and structural engineer with the criteria to evaluate the quality of welding. AWS D1.1, Sections 3.6 and 4.2.3 requires WPSs to be available to those “authorized to use or examine them”. Written WPSs should be available at the work site for both welders and inspectors. The WPSs provide the welder and inspector the information necessary to set and monitor the variables essential to each welding process and weld joint configuration. The inspector can then assure that proper welding parameters are being followed or note deviations. The structural engineer should promptly address any nonconformance to an approved WPS.
Exhibits

Exhibit 1  PREQUALIFIED Welding Procedure Specification
Exhibit 2  QUALIFIED BY TESTING Welding Procedure Specification
Exhibit 2A  Procedure Qualification Record
Exhibit 3  Welder Performance Qualification Test Record
Exhibit 4  Project Specification
PREQUALIFIED Welding Procedure Specification

WPS P-1

COMPANY Pacific Fabrication Inc.

WELDING PROCESS  Flux Cored Arc Welding (FCAW) 

WELDING CODE AWS D1.1-XX 

SUPPORTING PQRS not required for prequalified WPS 

DATE June 6, XXXX


WELDING POSITIONS

POSITION OF GROOVE Vertical (3G)  

POSITION OF FILLET  

VERTICAL PROGRESSION: ☐ Up  ☒ Down 

ELECTRICAL CHARACTERISTICS

TRANSFER MODE (GMAW): n/a  

TRANSFER MODE (GTAW): n/a  

CURRENT: ☐ AC  ☐ DCEP  ☒ DCEN

OTHER: electrical stickout: 3/4” to 1”

TUNGSTEN ELECTRODE (GTAW): n/a

SIZE 

TECHNIQUE

STRINGER or WEAVE BEAD Stringer Passes ☒

MULTI-PASS or SINGLE PASS (per side) Multi-pass ☒

NUMBER OF ELECTRODES 1 ☒

ELECTRODE SPACING: LATERAL n/a ☒

ANGLE n/a ☒

CONTACT TUBE TO WORK DISTANCE n/a ☒

PEENING optional, may be performed with slag hammer when weld pass is hot, peening not allowed on root or cover passes ☒

INTERPASS CLEANING needle gun, wire brush ☒

POSTWELD HEAT TREATMENT

TEMPERATURE none ☒

TIME n/a 

PREHEAT

PREHEAT TEMP. MIN. up to 3/4” thickness: none  

over 3/4” to 1”: 150°F ☒

INTERPASS TEMP. MIN. same as preheat temp. ☒

WELDING PROCEDURE

<table>
<thead>
<tr>
<th>PASS OR LAYER</th>
<th>PROCESS</th>
<th>FILLER METALS</th>
<th>CURRENT</th>
<th>VOLTS</th>
<th>TRAVEL SPEED, ipm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>FCAW</td>
<td>E71T-8</td>
<td>DCEN</td>
<td>195-220</td>
<td>18-20 6-9</td>
</tr>
<tr>
<td>3 to 17</td>
<td>FCAW</td>
<td>E71T-8</td>
<td>DCEN</td>
<td>200-240</td>
<td>19-22 7-11</td>
</tr>
<tr>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
</tr>
</tbody>
</table>

Approved for production by Fabricator Date
Type of welding process to be used.

AWS D1.1-XX is titled Structural Welding Code – Steel. Other structural welding codes for sheet steel and rebar are, respectively, AWS D1.3-XX and AWS D1.4-XX.

For a prequalified WPS, a procedure qualification record (PQR) is not required.

In this sample WPS, FCAW is a semi-automatic process using a hand-held welding gun with an automated electrode feed.

A single welded joint is welded from one side only. A double welded joint is welded from both sides.

Backing is a material or device placed against the back side of the joint, or at both sides of the weld (for electrogas welding (EGW) and electroslag welding (ESW) to support and retain molten weld metal.

The root opening is a separation at the joint root between the workpieces. The nonstandard term is root gap.

The root face is the portion of the groove face at the weld root.

The groove angle is the total included angle of the groove between the workpieces.

Groove radius in a J-groove or a U-groove joint weld.

Backgouging is the removal of weld metal and base metal from the weld root back side of a welded joint to facilitate complete fusion and complete joint penetration upon subsequent welding from that side.

A prequalified WPS for complete and partial joint penetration groove welds is valid only for the permitted groove weld positions shown in AWS D1.1, Figures 3.3 and 3.4. See Figures 4.1, 4.3 and 4.4 for types of groove weld positions.

A prequalified WPS for fillet welds shall meet the requirements of AWS D1.1, section 3.9. See Figures 4.5 and 4.6 for types of fillet weld positions.

Welding in the vertical position for a prequalified WPS requires the progression of passes to be in the upwards direction. Welding in the vertical down position would require the WPS to be qualified by testing. Note: welding of tubulars may be upwards or downwards but only in the direction for which the welder is qualified.

For Gas Metal Arc Welding (GMAW) there are four types of transfer modes of molten metal from the electrode tip to the work: short-circuiting (which is not prequalified), globular, axial spray, and pulsed.
Exhibit 1 - cont.

j DCEN indicates the power source is DC and the welding leads are arranged so that the electrode is the negative pole, i.e., the polarity is “straight”.

See 3.

For Gas Tungsten Arc Welding (GTAW), the size and type of the tungsten electrode shall be recorded. GTAW is not prequalified.

; ASTM, ABS, or API designation for the base metal material(s). If applicable, the type or grade should be included. Base metals approved for prequalified WPSs are listed in AWS D1.1, Table 3.1.

2 Base metal thickness range for groove welds.

2 Base metal thickness range for fillet welds.

2 Size or diameter range of pipe.

2 A5.20-XX is the AWS specification no. for Carbon Steel Electrodes for Flux Cord Arc Welding.

2 E71T-8 is the AWS classification no. of electrode listed in the specification A5.20-XX. Electrodes are classified according to as-welded mechanical properties, suitable welding positions, and usability characteristics, such as the use or absence of shielding gas. In this sample the manufacturer’s name and type of electrode are provided for information only.

2 An external flux is not required for FCAW but would be specified for Submerged Arc Welding (SAW).

2 External shielding gases are used with GMAW, GTAW, EGW, and some FCAW electrodes. For the E71T-8 classification electrode in this sample, shielding is provided by the flux contained in the electrode core.

2 Percentage composition of any shielding gas(es).

2 Flow rate of shielding gases.

2 AWS classification of electrode/flux combinations for ESW and SAW.

2 Size of a gas cup or nozzle which directs the shielding gas (es) to the weld zone from the end of the welding gun for FCAW-G and GMAW.

2 A weave bead is a weld bead or layer made with transverse oscillation. A stringer bead is made without appreciable oscillation.

2 A single pass weld is made with one weld bead. Multiple passes consist of multiple weld beads.
For machine or automatic purposes, multiple electrodes may be used.

Longitudinal spacing between multiple electrodes.

Lateral spacing between multiple electrodes.

Angle of multiple electrodes.

Distance from the contact tube in welding gun to the work for SAW. Electrical stickout, which is the electrode length between the point of electrical contact in the welding gun and the arc can be indicated for FCAW and GMAW.

Peening is the mechanical working of metals using impact blows to relieve shrinkage stresses. If peening is performed, the method, such as striking with a hammer or using pneumatic tools, should be indicated.

After each weld pass, the weld surface should be cleaned to remove any deleterious material such as slag, spatter, etc.

Preheating is the application of heat to the base metal prior to welding. Proper preheat (and elevated interpass temperatures) reduces the possibility of cracking by slowing the cooling rate in a workpiece. Preheating also equalizes the temperature in the workpiece to reduce local expansion and the tendency to warp or distort. Methods of preheating include using an oxyfuel torch, electrical resistance equipment, and induction heating. Prequalified minimum preheat and interpass temperature requirements for different base metals, thicknesses and welding processes are shown in AWS D1.1, Table 3.2.

The minimum interpass temperature must conform to minimum preheat requirements as discussed in 4.

Maximum interpass temperature must conform to minimum preheat requirements as discussed in 4.

Postweld heat treatment may be required for stress relieving the weldment.

Designates the weld pass.

See 2.

Electrode size(s).

See j.
The amperage is an essential variable for FCAW. To be prequalified, the amperage must be within the electrode manufacturer's recommended range. A single amperage value has a +10% tolerance for FCAW. Each range specified should not exceed this tolerance. See AWS D1.1, Section 3.6 and Table 4.5, item 13. In this sample WPS, an acceptable range of amperages is provided for each electrode size.

The voltage is an essential variable for FCAW. To be prequalified, the voltage must be within the electrode manufacturer's recommended range. A single voltage value has a +7% tolerance for FCAW. Each range specified should not exceed this tolerance. See AWS D1.1, Section 3.6 and Table 4.5, item 15. In this sample WPS, an acceptable range of voltages is provided for each electrode size.

Travel speed is the rate of travel of the arc in the direction of the weld progression. Travel speed is an essential variable for FCAW. A new or revised WPS must be written if there is an increase or decrease from the mean travel speed by 25 percent. See AWS D1.1, Section 3.6 and Table 4.5, item 17. In this sample WPS, an acceptable range of travel speeds is provided for each electrode size.

Prequalified joint details and the limitations for weld processes, base metal thicknesses, groove dimensions, welding positions, and weld sizes for partial and complete joint penetration groove welds are given in AWS D1.1, Figures 3.3 and 3.4.
QUALIFIED BY TESTING
Welding Procedure Specification
WPS P-2

COMPANY: Pacific Fabrication Inc.

WELDING PROCESS: Shielded Metal Arc Welding (SMAW)

WELDING CODE: AWS D1.1-XX

SUPPORTING PQRs: P-2

DATE: January 11, XXXX


WELDING POSITIONS

POSITION OF GROOVE: Flat (1G), Horizontal (2G)

POSITION OF FILLET:

VIRTUAL PROGRESSION: ☐ Up ☐ Down

ELECTRICAL CHARACTERISTICS

TRANSFER MODE (GMAW): n/a

OTHER:

TUNGSTEN ELECTRODE (GTAW): n/a

SIZE

TYPE

TECHNIQUE

STRINGER or WEAVE BEAD: Stringer Passes

MULTI-PASS or SINGLE PASS (per side): Multi-pass

NUMBER OF ELECTRODES: 1

ELECTRODE SPACING:

CONTACT TUBE TO WORK DISTANCE: n/a

PEENING: n/a

INTERPASS CLEANING: needle gun, wire brush

PREHEAT

PREHEAT TEMP., MIN.: 40°F

INTERPASS TEMP., MIN.: 40°F MAX.

POSTWELD HEAT TREATMENT

TEMPERATURE: none

TIME: n/a

WELDING PROCEDURE

<table>
<thead>
<tr>
<th>PASS OR WELD LAYER</th>
<th>PROCESS</th>
<th>CLASS</th>
<th>DIA.</th>
<th>TYPE &amp; POLARITY</th>
<th>AMPS</th>
<th>VOLTS</th>
<th>TRAVEL SPEED, ipm</th>
<th>JOINT DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>SMAW</td>
<td>E7018</td>
<td>1/8''</td>
<td>DCEP</td>
<td>130-140</td>
<td>20-21</td>
<td>8-10</td>
<td></td>
</tr>
<tr>
<td>3 to 9</td>
<td>SMAW</td>
<td>E7018</td>
<td>5/32''</td>
<td>DCEP</td>
<td>150-180</td>
<td>23-26</td>
<td>10-15</td>
<td></td>
</tr>
</tbody>
</table>

Approved for production by __________________________ Fabricator  Date
Type of welding process to be used.

AWS D1.1-XX is titled Structural Welding Code – Steel. Other structural welding codes for sheet steel and rebar are, respectively, AWS D1.3-XX and AWS D1.4-XX.

A WPS qualified by testing is supported by a procedure qualification record (PQR). See Exhibit 2A: PQR P-2.

SMAW is a manual process whereby the welder uses a hand-held holder to grip the electrode.

A single welded joint is welded from one side only. A double welded joint is welded from both sides.

Backing is a material or device placed against the back side of the joint, or at both sides of the weld (for electrogas welding (EGW) and electroslag welding (ESW) to support and retain molten weld metal.

The root opening is a separation at the joint root between the workpieces. The nonstandard term is root gap.

The root face is the portion of the groove face at the weld root.

The groove angle is the total included angle of the groove between the workpieces.

Groove radius in a J-groove or U-groove joint weld.

Backgouging is the removal of weld metal and base metal from the weld root back side of a welded joint to facilitate complete fusion and complete joint penetration upon subsequent welding from that side.

This sample WPS for the joint designation TC-U4a was qualified by testing for a corner joint welded in the horizontal position. See AWS D1.1, Figures 4.1, 4.3 and 4.4 for types of groove weld positions. Because the WPS was qualified by welding the PQR test plate in the horizontal position (See Exhibit 2A: PQR P-2), the 1996 AWS D1.1, Table 4.1, also qualifies the WPS for groove and fillet welds in the flat position.

See AWS D1.1, Figures 4.2, 4.5 and 4.6 for types of fillet weld positions.

A WPS qualified by testing for the vertical position must indicate the direction of the weld progression – up or down. A change from up to down, or vice versa, would require requalification, i.e, another PQR test.

For Gas Metal Arc Welding (GMAW) there are four types of transfer modes of molten metal from the electrode tip to the work: short-circuiting, globular, axial spray, and pulsed. Any WPS using GMAW with the short-circuiting transfer mode requires qualification by testing.
DCEP indicates the power source is DC and the welding leads are arranged so that the electrode is the positive pole, i.e., the polarity is "reverse".

For Gas Tungsten Arc Welding (GTAW), the size and type of the tungsten electrode shall be recorded. Any WPS using GTAW requires qualification by testing.

ASTM, ABS, API or other designation for the base metal material(s) qualified by testing. If applicable, the type or grade should be included.

Base metal thickness range for groove welds. This sample WPS is written only for complete joint penetration groove welds for plate thicknesses of ½ to ¾". However, PQR P-2 in Exhibit 2A qualifies a WPS for a plate thickness range of 1/8" to 1-1/2", for complete joint penetration and partial penetration groove welds, and fillet welds, based on the PQR test plate thickness of ¾". Refer to AWS D1.1, Table 4.2 for qualified plate, pipe, and tube thicknesses.

Base metal thickness range for fillet welds.

Size or diameter range of pipe.

A5.1-XX is the AWS specification no. for Carbon Steel Electrodes for Shielded Metal Arc Welding.

E7018 is the AWS classification no. for a low hydrogen type of electrode listed in the specification no. A5.1-XX. Electrodes are classified according to as-welded mechanical properties, suitable welding positions, and usability characteristics. In this sample the manufacturer’s name and type of electrode are provided for information only.

An external flux is not used with SMAW. The Submerged Arc Welding (SAW) process would require specifying an external flux.

External shielding gases are used with GMAW, GTAW, EGW, and some FCAW electrodes. The covering on the SMAW electrode creates a gas during the welding to shield the arc and prevent excessive atmospheric contamination of the weld metal.

Percentage composition of any shielding gas(es).

Flow rate of any changing gases.

AWS classification of electrode/flux combinations for ESW and SAW.

Size of gas cup or nozzle which directs the shielding gas (es) to the weld zone from the end of the welding gun for FCAW-G or GMAW.

A weave bead is a weld bead or layer made with transverse oscillation. A stringer bead is made without appreciable oscillation.
A single pass weld is made with one weld bead. Multiple passes consist of multiple weld beads.

For machine or automatic processes, multiple electrodes may be used.

Longitudinal spacing between multiple electrodes.

Lateral spacing between multiple electrodes.

Angle of multiple electrodes.

Distance from the contact tube in welding gun to the work for SAW. Electrical stickout, which is the electrode length between the point of electrical contact in the welding gun and the arc, can be indicated for FCAW and GMAW.

Mechanical working of metals using impact blows to relieve shrinkage stresses. If peening is performed, the method, such as striking with a hammer or using pneumatic tools, should be indicated.

After each weld pass, the weld surface may be cleaned to remove any deleterious material such as slag, spatter, etc.

The minimum preheat temperature for a FCAW, GMAW, SAW, or SMAW WPS qualified by testing is 25°F less than the preheat temperature used during the welding of the PQR test plate. See Exhibit 2A: PQR P-2. Refer to AWS D1.1, Table 45, and Section 5.6 for allowable decreases in preheat temperatures.

The minimum interpass temperature is equal to the minimum preheat temperature. Refer to AWS D1.1, Table 4.5, note 7, and Section 5.6.

Maximum interpass temperatures may be specified for welding of steels with toughness requirements, high strength steels, quenched and tempered steels, etc.

Postweld heat treatment may be required for stress relieving the weldment.

Designates the weld pass.

See Exhibits 2.

Electrode size(s). See Exhibits 2.

A SMAW WPS qualified by testing must be re-qualified if the amperage, an essential variable, is outside the range recommended by the electrode manufacturer. For other processes, re-qualification is required if the amperage varies from that used in the PQR test by more than the tolerance given in AWS D1.1, Table 4.5.
A SMAW WPS qualified by testing must be re-qualified if the voltage, an essential variable, is outside the range recommended by the electrode manufacturer. For other processes, re-qualification is required if the voltage varies from that used in the PQR test by more than the tolerance given in AWS D1.1, Table 4.5.

Travel speed is the speed of the arc in the direction of the weld progression. Travel speed is not an essential variable for SMAW. However, for other processes, requalification is required if the travel speed varies from that used in the PQR test by more than the tolerance given in AWS D1.1, Table 4.5.

Joint details for the corner weld joint.
**Guided Bend Tests**

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Type of Bend</th>
<th>Result</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Side</td>
<td>Passed</td>
<td>complete fusion, no discontinuities</td>
</tr>
<tr>
<td>2</td>
<td>Side</td>
<td>Passed</td>
<td>complete fusion, no discontinuities</td>
</tr>
<tr>
<td>3</td>
<td>Side</td>
<td>Passed</td>
<td>complete fusion, no discontinuities</td>
</tr>
<tr>
<td>4</td>
<td>Side</td>
<td>Passed</td>
<td>complete fusion, no discontinuities</td>
</tr>
</tbody>
</table>

**Tensile Tests**

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Width, in.</th>
<th>Thickness, in.</th>
<th>Area, sq. in.</th>
<th>Ultimate Tensile Load, lbs.</th>
<th>Ultimate Tensile Stress, psi</th>
<th>Fracture Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.751</td>
<td>0.747</td>
<td>0.561</td>
<td>35,900</td>
<td>64,000</td>
<td>Base Metal</td>
</tr>
<tr>
<td>2</td>
<td>0.748</td>
<td>0.747</td>
<td>0.599</td>
<td>35,100</td>
<td>62,800</td>
<td>Base Metal</td>
</tr>
</tbody>
</table>

Tests conducted by Acme Testing Laboratory, Lab No. Z-1957-24-23.

We, the undersigned, certify that the information in this record is correct, and that the test weld was prepared, welded, and tested in accordance with the requirements of Section 1, Part B, [Section 5, Part B] of AWS D1.1-XX, **Structural Welding Code - Steel.**

Signed by ________________________________
Joint details for the test assembly. Also shown are the sequence of weld passes. To qualify the corner joint for WPS P-2 in Exhibit 2, a butt jointed PQR test plate, with the same joint configuration to be used in production, is welded. Specimens are removed from the completed test plate to evaluate the mechanical properties of the welded joint. See AWS D1.1, Figure 4.10 for dimensions of the PQR test plate.

In this sample the complete joint penetration groove weld was welded in the horizontal (2G) position. Passing results for the PQR test plate qualifies the WPS for welding in the horizontal and flat positions for groove and fillet welds per the AWS D1.1, Table 4.1.

Base metal material(s) used for the PQR test plate.

Backing is a material or device placed against the back side of the joint, or at both sides of the weld in electroslag and electrogas welding, to support and retain molten weld metal.

Backgouging is the removal of weld metal and base metal from the weld root back side of a welded joint to facilitate complete fusion and complete joint penetration upon subsequent welding from that side.

Preheat temperature used for welding of the PQR test plate. In this sample a preheat was not applied to the test plate. Therefore, the temperature of the test plate, which was at the shop ambient temperature, is recorded.

Interpass temperature during welding of the PQR test plate is recorded.

Postweld heat treatment used on the PQR test plate.

Method used to clean each weld pass.

See AWS D1.1, Figures 4.9, 4.10, and 4.11 for PQR test plate dimensions and locations of test specimens.

AWS filler metal specification no. and classification no.

Size of electrode to weld PQR test plate.

DCEP indicates the power source is DC and the welding leads are arranged so that the electrode is the positive pole, i.e., the polarity is "reverse".

Voltage used during welding of the PQR test plate.

Amperage used during welding of the PQR test plate.

Rate of travel for the arc stream in the direction of the weld progression.
A weave bead is a weld bead or layer made with transverse oscillation. A stringer bead is made without appreciable oscillation.

Technique used to weld the PQR test plate.

Peening is the mechanical working of metals using impact blows to relieve shrinkage stresses. If peening is performed, the method, such as striking with a hammer or using pneumatic tools, should be indicated.

Typical procedure qualification tests include visual inspection, non-destructive testing, and mechanical testing such as guided bend tests and reduced-section tensile tests. Macroetch tests may be required to check weld size and/or fusion. See AWS D1.1, Tables 4.2 – 4.4 for number and type or test specimens required. Charpy V-notch impact tests for toughness shall be performed when required by the contract drawings or the project specifications.

Visual inspection includes checking for items such as appearance, undercut, underfill, porosity, cracks, slag inclusions, excessive reinforcement, etc. Excessive convexity, insufficient throat, overlap, and insufficient leg are other items to be checked for fillet welds.

Non-destructive testing is required, radiographic examination (x-ray) or ultrasonic testing D1.1 – 04 Section 4.8.2.

For groove weld test plates or pipes, four bend tests are required. For base metal thicknesses less than or equal to 3/8 inch, two face bend tests and two root bend tests are performed. For base metal thicknesses greater than 3/8 inch, four side bend tests are conducted.

For groove weld test plates or pipes, two reduced section tensile tests are required.
WELDER PERFORMANCE QUALIFICATION TEST RECORD

WELDER'S NAME: Joseph D. Smith
SOCIAL SECURITY NO. or ID NO.: 555-66-8888

WELDING PROCEDURE SPECIFICATION (WPS) NO.: P-1 (06/06/XX)
REV. NO.: 

WELDING PROCESS: Flux Cored Arc Welding (FCAW)
WELDING METHOD: manual 
semi-automatic automatic automatic automatic

FILLER METAL: AWS A5.20-XX, E71T8
CURRENT: DC t
POLARITY: straight (-)

ELECTRODE SIZE: 0.068" dia.
VOLTS: 20 u
AMPERAGE: 210 i

BASE METAL: ASTM A36-96, plate, 1" thickness

SHIELDING GAS(ES): none
FLUX: n/a

TEST WELD: single V-groove weld w/ backing - AWS D1.1-XX, Fig.4.21 [Fig.5.19] 
TEST POSITION: Vertical (3G) up

TEST RESULTS:

<table>
<thead>
<tr>
<th>VISUAL INSPECTION</th>
<th>Acceptable:</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADIOGRAPHIC EXAMINATION</td>
<td>Acceptable:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>GUIDED BEND TESTS</td>
<td>Side Bend #1: SATISFACTORY</td>
<td>Side Bend #2: SATISFACTORY</td>
<td></td>
</tr>
</tbody>
</table>

The welder is qualified for the welding process, weld types, positions, and material thicknesses shown below.

Welding Process Qualified For: FCAW (without shielding gas)

<table>
<thead>
<tr>
<th>Welding Positions and Material Thicknesses Qualified For:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groove Welds</td>
</tr>
<tr>
<td>Plate</td>
</tr>
<tr>
<td>Pipe</td>
</tr>
<tr>
<td>Material thickness: 1/8&quot; to unlimited</td>
</tr>
<tr>
<td>Fillet Welds</td>
</tr>
<tr>
<td>Plate</td>
</tr>
<tr>
<td>Pipe</td>
</tr>
<tr>
<td>Material thickness: 1/8&quot; to unlimited</td>
</tr>
</tbody>
</table>

The undersigned certifies that the statements in this record are correct and the test welds were prepared, welded, and tested in accordance with the requirements of Section 4 of AWS D1.1-XX, Structural Welding Code - Steel.

Date: January 27, XXXX
Signed by: 

1. **Exhibit 3**
2. **SAMPLE**
Exhibit 3 - cont.

Identifies the fabricator’s WPS that the welder used for welding of the test plate. AWS D1.1-04, Sec. 4.18 requires that a WPS applicable to the performance qualification test be followed.

Welding process used by the welder.

In this sample WPS, FCAW is a semi-automatic process using a hand-held welding gun with an automated electrode feed.

AWS filler metal specification no. and classification no.

DC or AC power source.

The polarity might be “straight” (negative) or “reverse” (positive). In this sample welder qualification, the direct current welding leads are arranged so that the electrode is the negative pole and the workpiece is the positive pole of the welding arc.

Voltage used during the welding test.

Amperage used during the welding test.

Base metal material.

Backing is a material or device placed against the back side of the joint, or at both sides of the weld in electroslag and electrogas welding, to support and retain molten weld metal.

Protective gas used to prevent or reduce atmospheric contamination to molten weld metal.

A material used to hinder or prevent the formation of oxides and other undesirable substances in molten weld metal and on solid metal surfaces, and to dissolve or otherwise facilitate the removal of such substances. In the FCAW process the flux is contained in the electrode. For other processes such as Electroslag Welding (ESW) and Submerged Arc Welding (SAW), the flux is supplied externally to the molten metal.

Joint configuration and test assembly used. For groove welds, see AWS D1.1, Figures 4.21 – 4.22, 4.24 – 4.25 and 4.27 – 4.31. For fillet welds, see Figures 4.19, 4.32, and 4.36. For plug welds, see Figure 4.37. For tack welds, see Figure 4.38.

Position of test assembly used to qualify the welder. See AWS D1.1, Figures 4.3 – 4.6 for positions of groove and fillet welds. In this sample, the welder welded the test plate in the vertical position with the progression of passes in the upwards direction. If the welder must weld vertically with the progression of passes in the downwards direction, the welder shall take another performance qualification test by welding vertically down.
Typical welder performance qualification tests for groove welds include a visual inspection of the welding followed by mechanical testing. Visual inspection includes checking for items such as appearance, undercut, underfill, porosity, cracks, slag inclusions, excessive reinforcement, etc. In this sample, machined specimens were removed from the 1 inch thick welded test plate for two side bend tests. If a test plate is less than or equal to 3/8 inch, one face bend test and one root bend test are required instead of two side bends. In lieu of conducting bend tests, the code states the test assembly can be radiographically examined (x-rayed). Refer to AWS D1.1, Table 4.9 for the required number and type of tests for all configurations of welder performance qualification test assemblies.

The table indicates the welding positions and material thicknesses for both groove and fillet welds that the welder has been qualified to weld. These are based on the passing test results for the 1 inch test plate welded in the vertical (up) position. See AWS D1.1, Table 4.9, for welding positions qualified, Table 4.10 for material thickness range qualified, and Table 4.11 for welder essential variables requiring requalification.
PROJECT SPECIFICATION

SECTION 05120 – STRUCTURAL STEEL

PART 1 GENERAL

1.01 REFERENCES

A. American Welding Society, AWS D1.XX, Structural Welding Code – Steel

1.02 SUBMITTALS

A. Written Welding Procedure Specifications (WPSs) in accordance with AWS D1.1 requirements for each different welded joint proposed for use whether prequalified or qualified by testing.

B. Procedure Qualification Record (PQR) in accordance with AWS D1.1 for all procedures qualified by testing.

C. Electrode manufacturer’s data

1.03 QUALITY ASSURANCE

A. Perform work in accordance with AWS D1.1.
   1. Qualify welders in accordance with AWS D1.1 for each process, position, and joint configuration.
   2. WPSs for each joint type shall indicate proper AWS qualification and be available where welding is performed.

PART 2 PRODUCTS

2.01 SHOP CONNECTIONS (Field similar)

A. Welded connections: Comply with AWS D1.1.
   1. Weld only in accordance with approved WPSs, which are to be available to welders and inspectors during the production process.

PART 3 EXECUTION

3.01 SOURCE QUALITY CONTROL (Field similar)

A. The Owner’s Testing Agency will inspect shop welding for conformance with AWS D1.1 requirements and will verify that welds are made in accordance with approved WPSs.