

I CAN DO THAT: WPS's, PQR's AND WQ's

AWS D1.5

A Tour Through Qualifications - 101



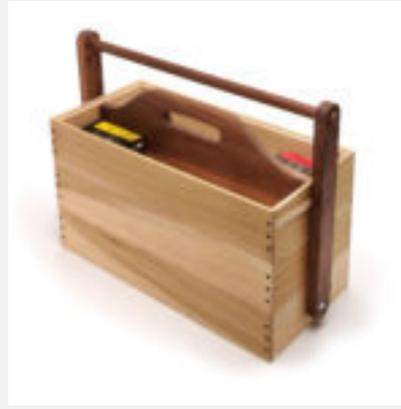
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The Building Blocks – Some Definitions



- ◆ **WPS – Welding Procedure Specification:** A document providing the required welding variables for a specific application to assure repeatability by properly trained welders and welding operators.
- ◆ **PQR – Procedure Qualification Record:** A record of welding variables used to produce an acceptable test weldment and the results of tests conducted on the weldment to qualify a welding procedure specification.
- ◆ **Welder –** One who performs manual or semiautomatic welding.
- ◆ **Welding Operator –** One who operates adaptive control, automatic, mechanized, or robotic welding equipment.
- ◆ **Tack Welder –** One who performs manual or semiautomatic welding to produce tack welds.
- ◆ **Tack weld –** A weld made to hold parts of a weldment in proper alignment until the final welds are made.

The Building Blocks – The Goal



- ◆ From AWS D1.2 Aluminum, Clause 3
- ◆ The qualification requirement of this code is to assure that the fabrication procedures actually used in production meet a recognized standard with an objective of producing consistent quality product. To accomplish this objective, each contractor, fabricator, or manufacturer shall, prior to the start of production, perform the following:

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 - ❖ Prepare a written WPS.

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 - ❖ Prepare a written WPS.
 - ❖ Qualify the welders, welding operators, and tack welders.
 - ❖ Conduct the tests required by code to qualify the WPS's, welders, operators, and tack welders who will apply these WPS's.

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 - ❖ Supply the written WPS to all welders, welding operators, tack welders, and QC personnel engaged in the work.

The Building Blocks – The Goal

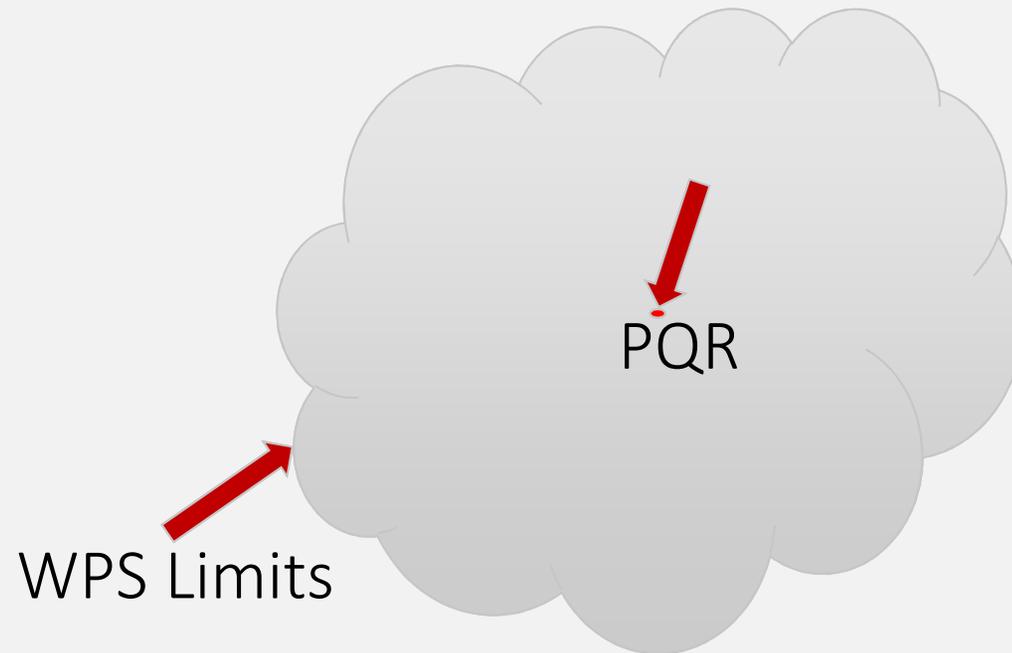


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 - ❖ Conduct the tests required by code to qualify the WPS's, welders, operators, and tack welders who will apply these WPS's.
 - ❖ Supply the written WPS to all welders, welding operators, tack welders, and QC personnel engaged in the work.
 - ❖ Certify and maintain records of all such tests and WPS's and make available such records to those authorized to use them.

The Building Blocks - Procedure Qualification and WPS Limits



- ◆ Venn Diagram



The Building Blocks – WPS's



- ◆ D1.5 Clause 1.9 – Weld Procedure Specifications
- ◆ All production welding shall be performed in conformance with the provisions of an approved WPS, which is based on successful test results as recorded in a PQR unless qualified in conformance with 1.3.2 (*SMAW Prequalified*).

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- ◆ All WPS's shall reference the PQR that is the basis for acceptance.

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- ◆ A copy of the proposed WPS shall be submitted to the Engineer for approval.

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- ◆ All WPS's shall reference the PQR that is the basis for acceptance.
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- ◆ Recommended forms for WPS's and PQR's are provided in Annex O.

The Building Blocks – WPS Sample Form



WELDING PROCEDURE SPECIFICATION (WPS)
PREQUALIFIED QUALIFIED BY TESTING
or PROCEDURE QUALIFICATION RECORDS (PQR) Yes
AASHTO/AWS D1.5 Qualification Type 5.12.1 – 5.12.2 – 5.12.4

Contractor/ Organization _____
 Welding Process(es) _____
 Type: Manual Semiautomatic
 Mechanized Automatic
 Tandem Parallel

JOINT DESIGN USED
 Single Double Weld
 Backing: Yes No Material _____
 Root Opening _____ Root Face Dimension _____
 Groove Angle _____ Radius (J-U) _____
 Backgouging: Yes No Method _____
 Root Treatment _____

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

FILLER METALS
 AWS Specification _____
 AWS Classification _____
 Manufacturer Trade Name _____

SHIELDING
 Flux _____ Mfg. Trade Name _____
 Electrode-Flux (Class) _____
 Gas Composition _____
 Flow Rate _____ Gas Cup Size _____

Identification _____
 Revision _____ Date _____ By _____
 Authorized by _____ Date _____
 Supporting PQR No.(s) _____

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

ELECTRICAL CHARACTERISTICS
 Transfer Mode (GMAW): Globular Spray
 Current: AC DCEP DCEN Pulsed
 Electrical Stick Out _____
 Other _____

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

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

POSTWELD HEAT TREATMENT
 Temp. _____ Hold Time _____
 Heating/Cooling Rate _____

HEAT INPUT
 Calculated Heat Input Value: kJ/in kJ/mm
 Max. Heat Input _____ Min. Heat Input _____

WELDING PROCEDURE

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

Form Q-2

Form Q-2—Sample Welding Procedure Specification

The Building Blocks – WQ Sample Form



WELDER AND WELDING OPERATOR QUALIFICATION RECORD

Welder or welding operator's name _____ Identification no. _____
 Welding process _____ Manual _____ Semiautomatic _____ Mechanized _____
 Position _____
 (Flat, horizontal, overhead or vertical—if vertical, state whether upward or downward)
 In conformance with WPS no. _____
 Material specification _____
 Thickness range this qualifies _____

FILLER METAL

Specification no. _____ Classification _____ F no. _____
 Describe filler metal (if not covered by AWS specification) _____
 Is backing used? _____
 Filler metal diameter and trade name _____ Flux for SAW or gas for GMAW or FCAW-G _____

VISUAL INSPECTION (6.26.1)

Appearance _____ Undercut _____ Piping porosity _____

Guided Bend Test Results

Type	Result	Type	Result

Test conducted by _____ Laboratory test no. _____
 per _____ Test date _____

Fillet Test Results

Appearance _____ Fillet size _____
 Fracture test root penetration _____ Macroetch _____
 (Describe the location, nature, and size or any crack or tearing of the specimen.)
 Test conducted by _____ Laboratory test no. _____
 per _____ Test date _____

RADIOGRAPHIC TEST RESULTS

Film Identification	Results	Remarks	Film Identification	Results	Remarks

Test witnessed by _____ Test no. _____
 per _____

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in conformance with the requirements of AASHTO/AWS D1.5M/D1.5, (_____) *Bridge Welding Code*.
 (year)

Manufacturer or Contractor _____
 Authorized By _____
 Date _____

Form Q-5

Form Q-5—Welder and Welding Operator Qualification Record

The Building Blocks – WPS's



- ◆ D1.5 Clause 1.9 – Weld Procedure Specifications
- ◆ All production welding shall be performed in conformance with the provisions of an approved WPS, which is based on successful test results as recorded in a PQR unless qualified in conformance with 1.3.2 (*SMAW Prequalified*).
- ◆ All WPS's shall reference the PQR that is the basis for acceptance.
- ◆ A copy of the proposed WPS shall be submitted to the Engineer for approval.
- ◆ Recommended forms for WPS's and PQR's are provided in Annex O.
- ◆ WPS's for SMAW that meet the requirements of 5.11 shall be considered prequalified and exempt from qualification testing.
 - ❖ 5.11 – SMAW WPS's using electrodes listed in Table 4.1(Except E100XX and E110XX) and operated within the current range recommended by the manufacturer, and that conform to the requirements of this code shall be considered prequalified and exempt from WPS testing. Note: Clause 12 for FCM restricts this to E7016, E7018, E7018-1 and E8018-X

The Building Blocks - Part A WPS Qualification



- ◆ D1.5 Clause 5 – Covers Qualifications, Part A WPS and Part B Personnel
- ◆ Part A Purpose: The WPS Qualification tests required by this code are designed to provide assurance that the weld metal produced by welding in conformance with the provisions of this code shall produce weld metal strength, ductility, and toughness conforming to Table 5.1.
 - ❖ Example: A709 Grade 50
 - ❖ Min Yield 50 ksi, Min Tensile 65 ksi, Min Elong. 22%, Min CVN 20 ft lbs @ 0 F (Zone I and II)

Table 5.1
Test Requirements for WPSs Qualified in Conformance with 5.12^{a, b, c}

Base Metal AASHTO [ASTM] Designation	Minimum Yield Strength, [ksi]	Minimum Tensile Strength, MPa [ksi]	Minimum Elongation in 50 mm [2 in], %	Minimum CVN, J [ft-lb] AASHTO Temperature Zones ^d	
				I and II	III ^e
M 270M/M 270 (A709/A709M) Gr. 250 [36]	300 [45]	415 [60]	22	27 @ -20°C [20 @ 0°F]	27 @ -30°C [20 @ -20°F]
M 270M/M 270 (A709/A709M) Gr. 345 [50] Type 1, 2, 3; Gr. 345S [50S]	345 [50]	450 [65]	22	27 @ -20°C [20 @ 0°F]	27 @ -30°C [20 @ -20°F]

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 - ❖ Example: A709 Grade 50
 - ❖ Min Yield 50 ksi, Min Tensile 65 ksi, Min Elong. 22%, Min CVN 20 ft lbs @ 0 F (Zone I and II)
- ◆ 5.2.2 – Contractor shall prepare a WPS based upon the parameter limitations imposed by Part A of this Clause and within these limits shall specify welding variables that will produce the welding conditions, characteristics, weld sizes, and contours required in the work.

The Building Blocks – Part A WPS Qualification



- ◆ Clause 5.12 - Three Main methods available for Procedure Qualifications. Each Method comes with it's own set of limitations.
- ◆ 5.12.1 – Maximum Heat Input Qualification
- ◆ 5.12.2 – Maximum-Minimum Heat Input Qualification
- ◆ 5.12.4 – Production Procedure Qualification

The Building Blocks – Heat Input Qualifications



- ◆ 5.12 - Heat input is determined using the formula:
 - ❖ Heat Input = Amperage x Voltage X 0.06/Travel Speed (IPM), kJ/inch, or
 - ❖ Heat Input = Amperage x Voltage X 60/(1000 x Travel Speed) (IPM), kJ/inch, or
 - ❖ Heat Input = Amperage x Voltage X 60/Travel Speed (IPM), J/inch

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 - ❖ Heat Input = Amperage x Voltage X 60/Travel Speed (IPM), J/inch
- ◆ **The heat input for any individual pass shall be within 10% of the average heat input of all the passes in the test. Record the amperage, voltage and travel speed for each pass. Calculate the heat input for each pass. The average heat input shall be calculated using the heat input for all passes (exempting the root and cap passes). That average shall be the WPS heat input.**

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 - ❖ Example – 10 pass weld, adding the heat input of all 10 passes gives 500 kJ/inch. 500kJ/inch divided by 10 passes gives an average heat input of 50 kJ/inch. 10% of that is 5, so each of the 10 passes has to be deposited between 45 and 55 kJ/inch.

The Building Blocks – Heat Input Qualifications



- ◆ 5.12 - Heat input examples:
- ◆ $300 \text{ amps} \times 28 \text{ volts} \times 60 / (1000 \times 9 \text{ ipm}) = 56 \text{ kJ/inch}$, NOT OK

The Building Blocks – Heat Input Qualifications



- ◆ 5.12 - Heat input examples:
- ◆ $300 \text{ amps} \times 28 \text{ volts} \times 60 / (1000 \times 9 \text{ ipm}) = 56 \text{ kJ/inch}$, NOT OK
- ◆ $290 \text{ amps} \times 28 \text{ volts} \times 60 / (1000 \times 9 \text{ ipm}) = 54.1 \text{ kJ/inch}$, OK

The Building Blocks – Heat Input Qualifications



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- ◆ $280 \text{ amps} \times 27 \text{ volts} \times 60 / (1000 \times 10 \text{ ipm}) = 45.4 \text{ kJ/inch}$, OK

The Building Blocks – Heat Input Qualifications

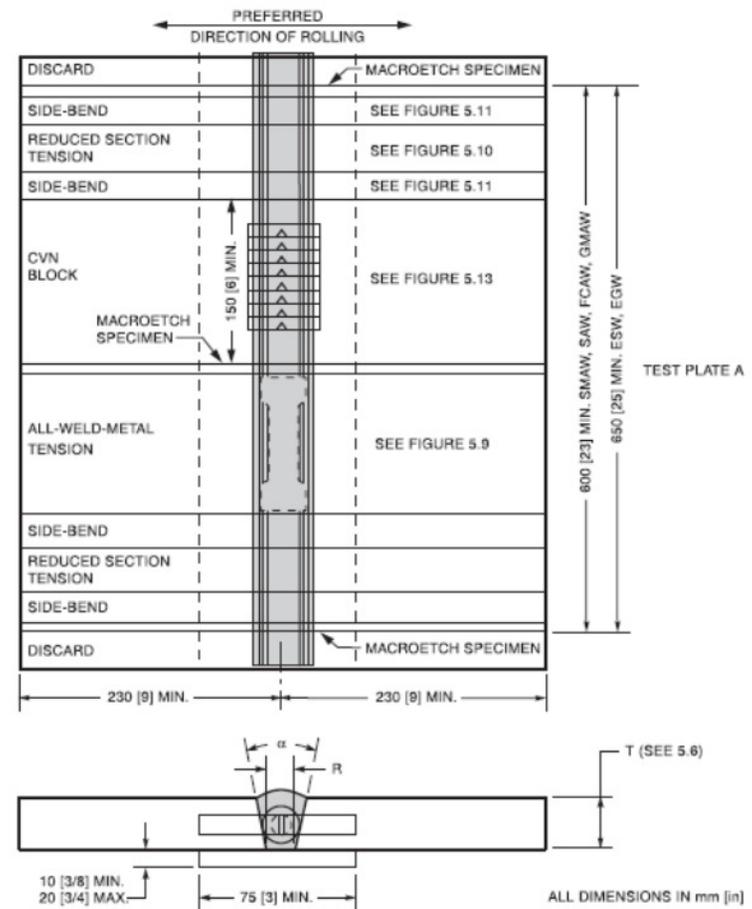


- ◆ 5.12 - Heat input examples:
- ◆ 300 amps x 28 volts x 60/(1000 x 9 ipm) = 56 kJ/inch, NOT OK
- ◆ 290 amps x 28 volts x 60/(1000 x 9 ipm) = 54.1 kJ/inch, OK
- ◆ 280 amps x 27 volts x 60/(1000 x 10 ipm) = 45.4 kJ/inch, OK
- ◆ 260 amps x 27 volts x 60/(1000 x 10 ipm) = 42.1 kJ/inch, NOT OK

The Building Blocks – Maximum Heat Input Qualifications



- ◆ 5.12.1 Qualification Test
 - ❖ GMAW, SAW, FCAW WPS's using Figure 5.1



- Notes:
1. Welding and machining shall be witnessed by a state representative or an independent third party acceptable to the state.
 2. Test specimens and the PQR showing all welding parameters used for the test shall be available to the Engineer. Test specimens need only be retained for examination by the original approving authority.
 3. The joint detail to be used shall be either a B-U2a, B-U2-S, B-U2a-GF, B-U4a, or B-U4a-GF detail, depending on the welding process used and the position of the welding, except that the B-U2a-GF and B-U4a-GF with the 5 mm [3/16 in] root opening and 30° included angle shall not be used.

Figure 5.1—WPS Qualification or Pretest—Test Plate A (see 5.7.1)

The Building Blocks – Maximum Heat Input Qualifications



- ◆ **5.12.1 Qualification Test**

- ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
- ❖ The maximum heat input limit shall be the average heat input from the WPS qualification test.

The Building Blocks – Maximum Heat Input Qualifications



- ◆ **5.12.1 Qualification Test**
 - ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
 - ❖ The maximum heat input shall be the average heat input from the WPS qualification test
 - ❖ Electrode size is not an essential variable in this method

The Building Blocks – Maximum Heat Input Qualifications



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- ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
- ❖ The maximum heat input shall be the average heat input from the WPS qualification test
- ❖ Electrode size is not an essential variable in this method
- ❖ Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- $\frac{3}{4}$ inch for SAW, +/- $\frac{1}{4}$ inch for FCAW, GMAW).

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- ❖ Maximum Current – Meet Table 5.10
 - ❖ *Table 5.10 For SAW Solid Electrode, 1/8 inch electrode diameter prescribes limit of 300 to 800 amps*

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 - ❖ *Table 5.10 For SAW Solid Electrode, 1/8 inch electrode diameter prescribes limit of 300 to 800 amps*
- ❖ Maximum Voltage – Any voltage as long as the individual pass heat input requirements are met.

The Building Blocks – Maximum Heat Input Qualifications



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- ❖ Shielding Gas Flow Rate shall be the minimum to be used in the production WPS

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- ❖ Shielding Gas Flow Rate shall be the minimum to be used in the production WPS
- ❖ Travel speed – Any Travel Speed as long as the individual pass heat input requirements are met.
- ❖ Preheat and Interpass Temperature – The test plate shall be welded with the minimum preheat and interpass temperature of 100 C (210 F).

The Building Blocks – Maximum Heat Input Qualifications



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- ❖ Travel speed – Any Travel Speed as long as the individual pass heat input requirements are met.
- ❖ Preheat and Interpass Temperature – The test plate shall be welded with the minimum preheat and Interpass temperature of 100 C (210 F).
- ❖ Maximum Interpass Temperature – Upper limit to be used in production.

The Building Blocks – Maximum Heat Input Qualifications



- ◆ **5.12.3 Limits for Production**

- ❖ WPS shall not exceed 100% or be less than 60% of the heat input used in the qualification test as recorded on the PQR.

The Building Blocks – Maximum Heat Input Qualifications



◆ 5.12.3 Limits for Production

- ❖ WPS shall not exceed 100% or be less than 60% of the heat input used in the qualification test as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.9.2.1 – For Single Wire Submerged Arc Welding, the maximum current to be used in making a groove weld for any pass that has fusion to both faces shall be 600 amps.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*

The Building Blocks – Maximum Heat Input Qualifications



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 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within +/- 10% of the average value used in the qualification test.
 - ❖ *Except when using alloy or active flux, not to exceed 100% of the qualification test*

The Building Blocks – Maximum Heat Input Qualifications



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 - ❖ *Example 4.9.2.1 – For Single Wire Submerged Arc Welding, the maximum current to be used in making a groove weld for any pass that has fusion to both faces shall be 600 amps.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within +/- 10% of the average value used in the qualification test.
 - ❖ *Except when using alloy or active flux, not to exceed 100% of the qualification test*
- ❖ Any Travel Speed may be listed, within the heat input limits

The Building Blocks – Maximum Heat Input Qualifications



◆ 5.12.3 Limits for Production

- ❖ WPS shall not exceed 100% or be less than 60% of the heat input used in the qualification test as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.9.2.1 – For Single Wire Submerged Arc Welding, the maximum current to be used in making a groove weld for any pass that has fusion to both faces shall be 600 amps.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within +/- 10% of the average value used in the qualification test.
 - ❖ *Except when using alloy or active flux, not to exceed 100% of the qualification test*
- ❖ Any Travel Speed may be listed, within the heat input limits
- ❖ Refer back to 5.12.1 for the rest: Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- 3/4 inch for SAW, +/- 1/4 inch for FCAW, GMAW).

The Building Blocks – Maximum Heat Input Qualifications



◆ 5.12.3 Limits for Production

- ❖ WPS shall not exceed 100% or be less than 60% of the heat input used in the qualification test as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.9.2.1 – For Single Wire Submerged Arc Welding, the maximum current to be used in making a groove weld for any pass that has fusion to both faces shall be 600 amps.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within +/- 10% of the average value used in the qualification test.
 - ❖ *Except when using alloy or active flux, not to exceed 100% of the qualification test*
- ❖ Any Travel Speed may be listed, within the heat input limits
- ❖ Refer back to 5.12.1 for the rest: Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- ¾ inch for SAW, +/- ¼ inch for FCAW, GMAW).
- ❖ Shielding Gas Flow Rate minimum shall be the minimum used in the PQR
- ❖ Minimum Preheat – Table 4.3, Maximum Interpass Temperature – Upper limit used in test. (except for HPS 70W and 100W)

The Building Blocks – Maximum/Minimum Heat Input Qualifications



- ◆ **5.12.2 Qualification Test**
 - ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
 - ❖ The maximum heat input test per 5.12.1 and the minimum heat input test per 5.12.2,

The Building Blocks – Maximum/Minimum Heat Input Qualifications



- ◆ **5.12.2 Qualification Test**
 - ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
 - ❖ The maximum heat input test per 5.12.1 and the minimum heat input test per 5.12.2 (below)
 - ❖ Electrode size is not an essential variable in this method
 - ❖ Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- $\frac{3}{4}$ inch for SAW, +/- $\frac{1}{4}$ inch for FCAW, GMAW).

The Building Blocks – Maximum/Minimum Heat Input Qualifications



◆ 5.12.2 Qualification Test

- ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
- ❖ The maximum heat input test per 5.12.1 and the minimum heat input test per 5.12.2, (below)
- ❖ Electrode size is not an essential variable in this method
- ❖ Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- 3/4 inch for SAW, +/- 1/4 inch for FCAW, GMAW).
- ❖ Current –Meet Table 5.10
 - ❖ *Table 5.10 For SAW Solid Electrode, 1/8 inch electrode diameter prescribes limit of 300 to 800 amps*

The Building Blocks – Maximum/Minimum Heat Input Qualifications



- ◆ 5.12.2 Qualification Test
 - ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
 - ❖ The maximum heat input test per 5.12.1 and the minimum heat input test per 5.12.2, (below)
 - ❖ Electrode size is not an essential variable in this method
 - ❖ Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- 3/4 inch for SAW, +/- 1/4 inch for FCAW, GMAW).
 - ❖ Current – Meet Table 5.10
 - ❖ *Table 5.10 For SAW Solid Electrode, 1/8 inch electrode diameter prescribes limit of 300 to 800 amps*
 - ❖ Voltage – Any voltage as long as the individual pass heat input requirements are met.

The Building Blocks – Maximum/Minimum Heat Input Qualifications



◆ 5.12.2 Qualification Test

- ❖ GMAW, SAW, FCAW WPS's using Figure 5.1
- ❖ The maximum heat input test per 5.12.1 and the minimum heat input test per 5.12.2, (below)
- ❖ Electrode size is not an essential variable in this method
- ❖ Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- 3/4 inch for SAW, +/- 1/4 inch for FCAW, GMAW).
- ❖ Current – Meet Table 5.10
 - ❖ *Table 5.10 For SAW Solid Electrode, 1/8 inch electrode diameter prescribes limit of 300 to 800 amps*
- ❖ Voltage – Any voltage as long as the individual pass heat input requirements are met.
- ❖ Travel speed – Any Travel Speed as long as the individual pass heat input requirements are met.
- ❖ Preheat and Interpass Temperature – The test plate shall be welded with the minimum preheat of 50 F and Maximum preheat/Interpass of 100 F.

The Building Blocks – Maximum/Minimum Heat Input Qualifications



- ◆ **5.12.3.4 Limits for Production**
 - ❖ WPS shall not exceed the maximum heat input test value nor be less than the minimum heat input test value as recorded on the PQR.

The Building Blocks – Maximum/Minimum Heat Input Qualifications



◆ 5.12.3.4 Limits for Production

- ❖ WPS shall not exceed the maximum heat input test value nor be less than the minimum heat input test value as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.13 – For Single Wire FCAW, Maximum single pass fillet size in the horizontal position is 3/8 inch.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*

The Building Blocks – Maximum/Minimum Heat Input Qualifications



◆ 5.12.3.4 Limits for Production

- ❖ WPS shall not exceed the maximum heat input test value nor be less than the minimum heat input test value as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.13 – For Single Wire FCAW, Maximum single pass fillet size in the horizontal position is 3/8 inch.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within the range bounded by 110% of the average voltage in the maximum heat input qualification test and 90% of the average value used in the minimum heat input qualification test, and within the heat input limits.
 - ❖ *Except when using alloy or active flux, the voltage is not to exceed 100% of the average voltage in the maximum heat input qualification test*

The Building Blocks – Maximum/Minimum Heat Input Qualifications



◆ 5.12.3.4 Limits for Production

- ❖ WPS shall not exceed the maximum heat input test value nor be less than the minimum heat input test value as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.13 – For Single Wire FCAW, Maximum single pass fillet size in the horizontal position is 3/8 inch.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within +/- 10% of the average value used in the qualification test, and within the heat input limits.
 - ❖ *Except when using alloy or active flux, not to exceed 100% of the qualification test*
- ❖ Any Travel Speed may be listed within the heat input limits.

The Building Blocks – Maximum/Minimum Heat Input Qualifications



◆ 5.12.3.4 Limits for Production

- ❖ WPS shall not exceed the maximum heat input test value nor be less than the minimum heat input test value as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.13 – For Single Wire FCAW, Maximum single pass fillet size in the horizontal position is 3/8 inch.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within +/- 10% of the average value used in the qualification test, and within the heat input limits.
 - ❖ *Except when using alloy or active flux, not to exceed 100% of the qualification test*
- ❖ Any Travel Speed may be listed within the heat input limits.
- ❖ Refer back to 5.12.1 for the rest: Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- ¾ inch for SAW, +/- ¼ inch for FCAW, GMAW).

The Building Blocks – Maximum/Minimum Heat Input Qualifications



◆ 5.12.3.4 Limits for Production

- ❖ WPS shall not exceed the maximum heat input test value nor be less than the minimum heat input test value as recorded on the PQR.
- ❖ Current shall be within the limits of Clause 4 and Table 5.10. Can be higher or lower than tested.
 - ❖ *Example 4.13 – For Single Wire FCAW, Maximum single pass fillet size in the horizontal position is 3/8 inch.*
 - ❖ *Table 5.10 For FCAW Gas Shielded, 1/16 inch electrode diameter prescribes limit of 200 to 480 amps*
- ❖ Voltage shall be within +/- 10% of the average value used in the qualification test, and within the heat input limits.
 - ❖ *Except when using alloy or active flux, not to exceed 100% of the qualification test*
- ❖ Any Travel Speed may be listed within the heat input limits.
- ❖ Refer back to 5.12.1 for the rest: Current type, polarity, and specified electrical extension shall be the same as will be used in production. (+/- 3/4 inch for SAW, +/- 1/4 inch for FCAW, GMAW).
- ❖ Minimum preheat per Table 4.3 or Clause 12 (FCM)
- ❖ Maximum Interpass Temperature – Upper limit used in test. (except for HPS 70W and 100W)

The Building Blocks – Production Procedure Qualifications



- ◆ **5.12.4 Qualification Test**

- ❖ SAW with active fluxes for other than single or two pass applications
- ❖ Groove welds that do not use the standard joint details
- ❖ WPS's that use matching filler metals for HPS 100W steel
- ❖ May be used at the contractors option instead of 5.12.1 or 5.12.3
- ❖ Preheat and Interpass Temperature – Follow the requirements of 4.2

The Building Blocks – Production Procedure Qualifications



◆ 5.12.3.4 Limits for Production

- ❖ Variables controlled by Table 5.4, three pages of essential variables.
 - ❖ *Example: amperage can vary +/- 10%, voltage +/- 7%, heat input +/-20% from the qualification test value.*
- ❖ Preheat and Interpass Temperature – Follow the requirements of 4.2

The Building Blocks – Procedure Qualifications



◆ 5.4.1 Base Metal Qualification Requirements

- ❖ A709 Grade 36 Test Plate qualifies A709 Grade 36 production
- ❖ A709 Grade 50 Test Plate qualifies A709 Grade 36 and 50 production
- ❖ A709 Grade 50W Test Plate qualifies A709 Grade 50W and may or may not qualify A709 Grade 50 or 36 production.
 - ❖ *Check the test plate and backing plate for conforming chemistry per 5.4.2, minimums*
 - ❖ *Carbon 0.15*
 - ❖ *Manganese 1.0*
 - ❖ *Silicon 0.25*
 - ❖ *Chromium 0.50*
 - ❖ *Vanadium 0.03*
 - ❖ *OR Carbon Equivalent of 0.45% minimum by $CE = C + (Mn+Si)/6 + (Cr+Mo+V)/5 + (Ni+Cu)/15$ with Carbon at 0.12% minimum*

The Building Blocks – Procedure Qualifications



- ◆ **5.4.6 Undermatching Base Metal Qualification Requirements**
 - ❖ WPS's that undermatch the base metal strength shall use the undermatching filler metal and the higher strength base metal to be used in production.
 - ❖ *Example: A709 Grade HPS 70W welded using a E81T1 FCAW or an E8018 SMAW*
- ◆ **5.4.7 Base Metal for Hybrid WPS's Qualification Requirements**
 - ❖ WPS's that use two base metals of different specified yield strengths shall be qualified using the lower strength steel to be used in production.
 - ❖ *5.5.4 Use a filler metal appropriate for the lower strength base metal*
 - ❖ *Example: A709 Grade HPS 70W joined to A709 Grade 50. Use Grade 50 as the base metal and an E7XXX or E8XXX filler metal*

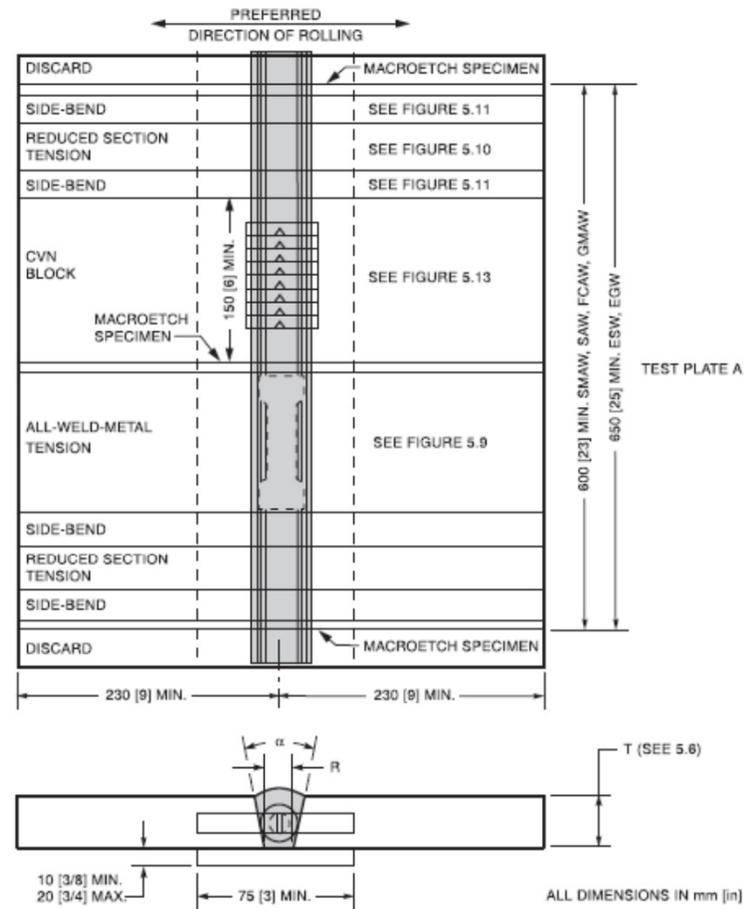
The Building Blocks – Test Requirements



◆ 5.15.1 Groove Welds

- ❖ All weld metal tension, 5.19.4, meet or exceed Table 5.1 values
- ❖ CVN, 5.19.5, meet or exceed Table 5.1 values, (FCM have different values, See Clause 12)
- ❖ Macro Etch, 5.19.3, visual, no cracks, thorough fusion, nothing prohibited by 3.6, no undercut $>1/32''$
- ❖ Visual, 5.19.6, meet 6.26.1
- ❖ Radiographic , 5.17, meet 6.26
- ❖ Reduced Section Tension, 5.19.1, no less than the specified tensile range of the base metal of the WPS
- ❖ Side bends, 5.19.2

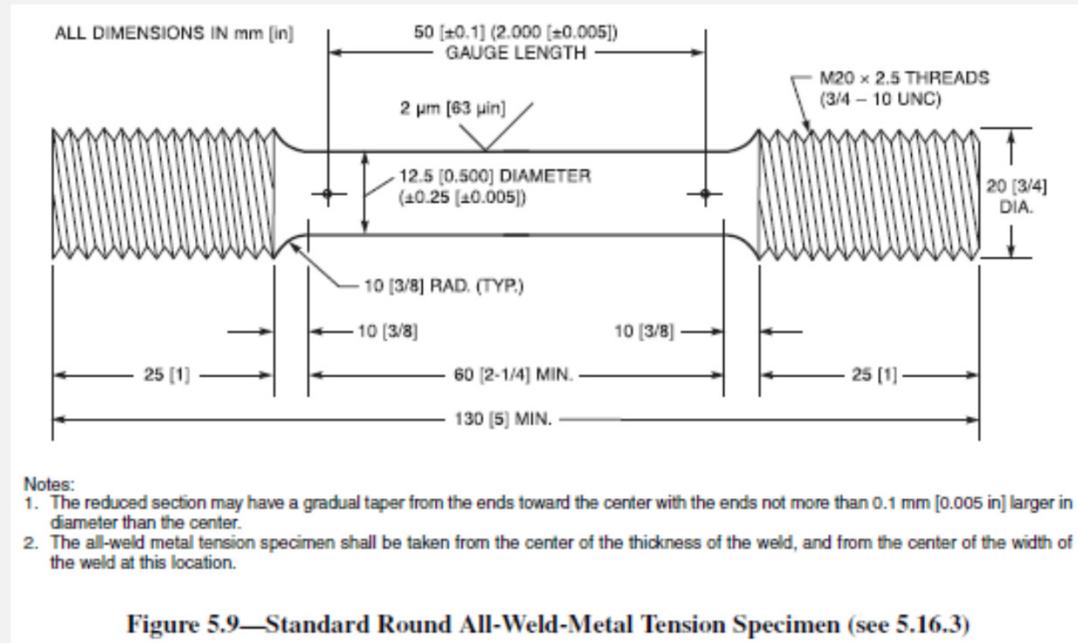
The Building Blocks - Part A WPS Qualification



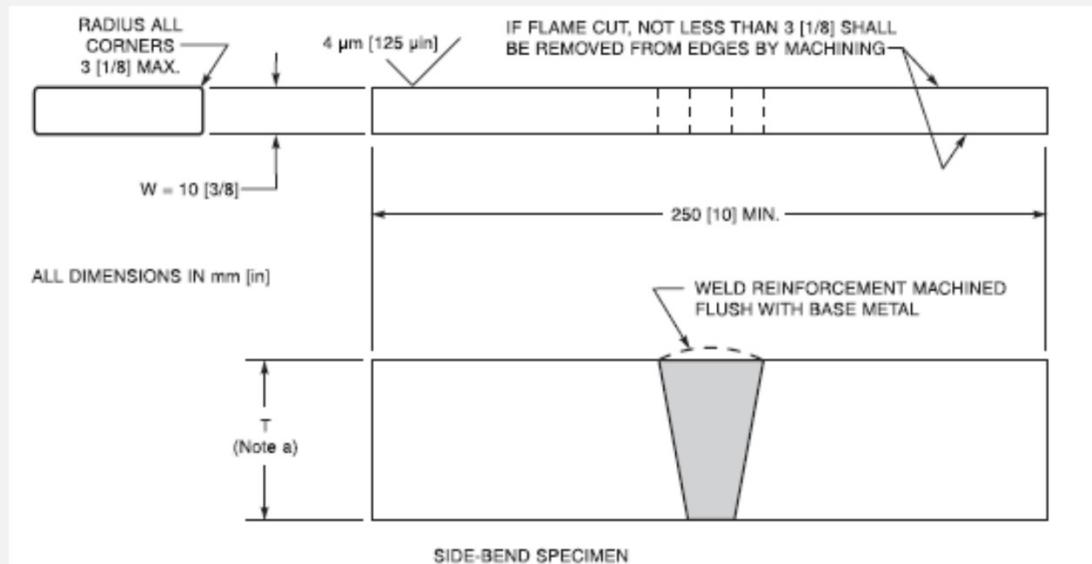
- Notes:
1. Welding and machining shall be witnessed by a state representative or an independent third party acceptable to the state.
 2. Test specimens and the PQR showing all welding parameters used for the test shall be available to the Engineer. Test specimens need only be retained for examination by the original approving authority.
 3. The joint detail to be used shall be either a B-U2a, B-U2-S, B-U2a-GF, B-U4a, or B-U4a-GF detail, depending on the welding process used and the position of the welding, except that the B-U2a-GF and B-U4a-GF with the 5 mm [3/16 in] root opening and 30° included angle shall not be used.

Figure 5.1—WPS Qualification or Pretest—Test Plate A (see 5.7.1)

The Building Blocks - Part A WPS Qualification



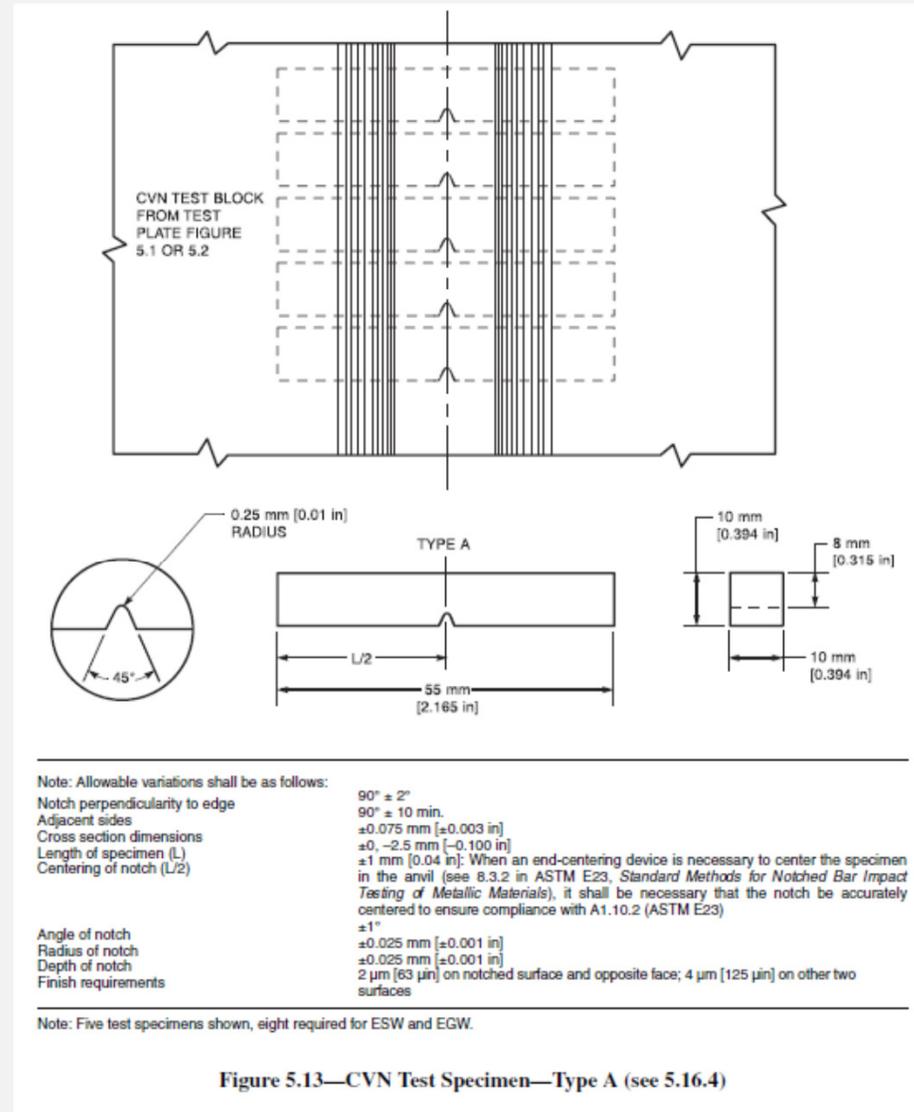
The Building Blocks - Part A WPS Qualification



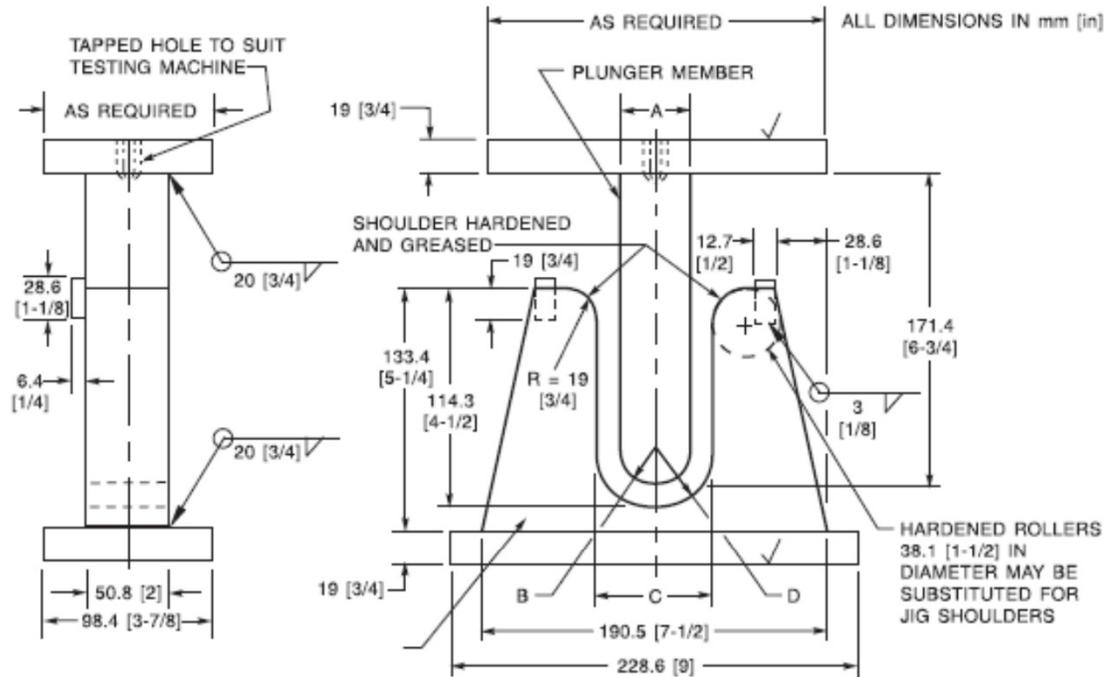
^a T depends on the thickness of test plate shown in Figures 5.1, 5.2, and 5.3; see 5.6. If $T > 40$ mm [1-1/2 in], see AWS B4.0 for guidance on cutting the specimen into strips between 20 mm and 40 mm [3/4 in to 1-1/2 in] wide.

Figure 5.11—Side-Bend Specimen (see 5.16.3)

The Building Blocks - Part A WPS Qualification



The Building Blocks - Part A WPS Qualification



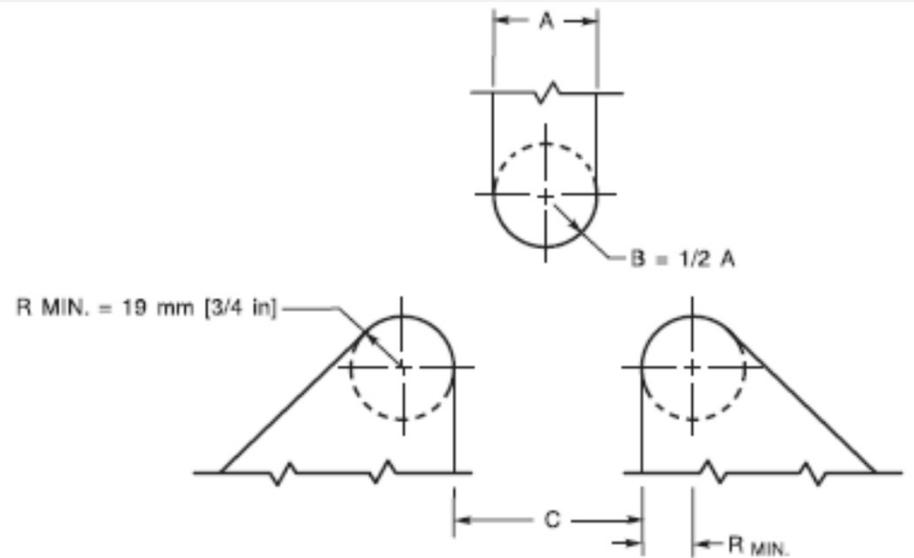
Minimum Specified Base Metal Yield Strength, MPa [ksi]	A		B		C		D	
	mm	[in]	mm	[in]	mm	[in]	mm	[in]
345 [50] and under	38.1	[1-1/2]	19.0	[3/4]	60.3	[2-3/8]	30.2	[1-3/16]
Over 345 [50] to 620 [90]	50.8	[2]	25.4	[1]	73.0	[2-7/8]	36.6	[1-7/16]
620 [90] and over	63.5	[2-1/2]	31.8	[1-1/4]	85.7	[3-3/8]	42.9	[1-11/16]

Notes:

1. Plunger and interior die surfaces shall be machine-finished.
2. The diameter A of the plunger shall equal or exceed the weld face width (after machining). If this requirement cannot be met, see AWS B4.0M or B4.0 for guidance on adjusting the specimen thickness and fixture dimensions.

Figure 5.14—Guided Bend Test Jig (see 5.18.3)

The Building Blocks - Part A WPS Qualification



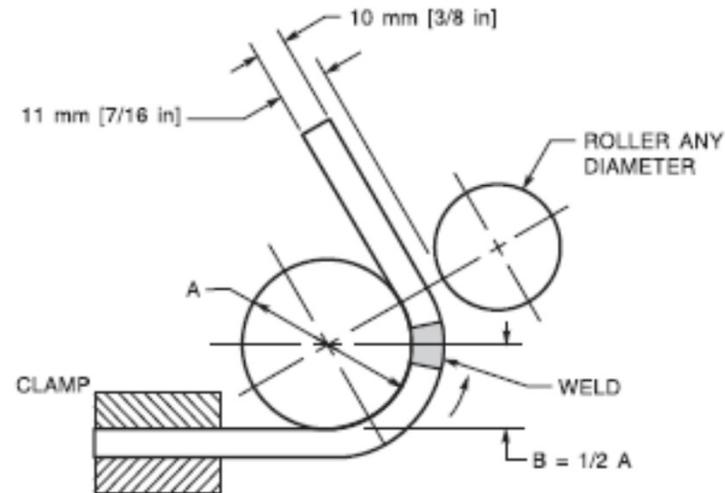
Minimum Specified Base Metal Yield Strength, MPa [ksi]	A		B		C	
	mm	[in]	mm	[in]	mm	[in]
345 [50] and under	38.1	[1-1/2]	19.0	[3/4]	60.3	[2-3/8]
Over 345 [50] to 620 [90]	50.8	[2]	25.4	[1]	73.0	[2-7/8]
620 [90] and over	63.5	[2-1/2]	31.8	[1-1/4]	85.7	[3-3/8]

Notes:

1. Minimum roller length (or shoulder width) shall be 50 mm [2 in].
2. Diameter A shall equal or exceed the weld face width (after machining). If this requirement cannot be met, see AWS B4.0M or B4.0 for guidance on adjusting the specimen thickness and fixture dimensions.

Figure 5.16—Alternate Roller-Equipped Guided Bend Test Jig for Bottom Ejection of Test Specimen (see 5.18.3)

The Building Blocks - Part A WPS Qualification



Minimum Specified Base Metal Yield Strength, MPa [ksi]	A		B	
	mm	[in]	mm	[in]
345 [50] and under	38.1	[1-1/2]	19.0	[3/4]
Over 345 [50] to 620 [90]	50.8	[2]	25.4	[1]
620 [90] and over	63.5	[2-1/2]	31.8	[1-1/4]

Notes:

1. Minimum roller length shall be 50 mm [2 in].
2. Diameter A shall equal or exceed the weld face width (after machining). If this requirement cannot be met, see AWS B4.0M or B4.0 for guidance on adjusting the specimen thickness and fixture dimensions.

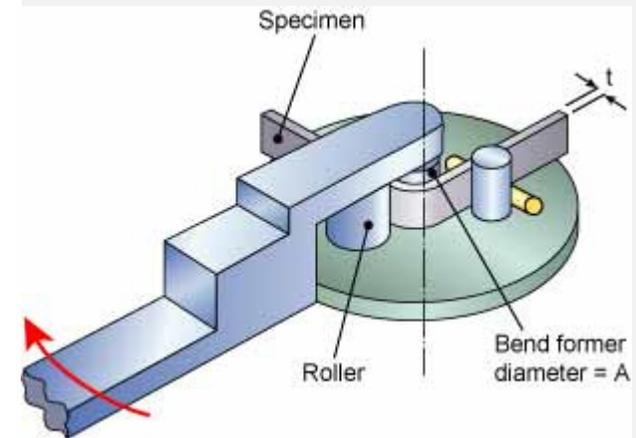


Figure 5.15—Alternate Wraparound Guided Bend Test Jig (see 5.18.3)

The Building Blocks – What about Fillet Welds?



◆ 5.10 Fillet Welds

- ❖ Fillet Welds WPS's shall be qualified by groove welds in accordance with Clause 5.12 using Figure 5.1. Groove weld testing is not required to qualify a WPS;
 - ❖ *for a single pass fillet weld,*
 - ❖ *for a SMAW prequalified WPS,*
 - ❖ *for Ancillary products*
- ❖ Fillet Weld Soundness Test – All fillet WPS's (except SMAW prequalified or Ancillary Product) are subject to fillet weld soundness macroetch qualification for each weld size and position.

The Building Blocks – I am not smart enough to remember all that



◆ ...so I made a form

PENNONI AWS D1.5 - 2015 Bridge Code WPS/PQR Review Form

WPS ID				
PQR ID				
PQR Expiration date	5.3 - None	12.7.4 - FCM - 60 months		
FCM	No	Yes		
PQR Method	5.12.1 - Maximum Heat Input			
	5.12.2 - Maximum/Minimum Heat Input			
	5.12.3 Production Procedure Qualification			
Welding Process	SMAW - 4.5, 4.6	FCAW - 4.11-4.13	GMAW - 4.11-4.13	SAW - 4.7-4.10
Test Position	5.8			
Base Metal Grade	5.4.1	36	50	50W
Thickness	5.6			
MTR Acceptable				
Plate Chem Acceptable for (5.4.2)	36 & 50	50W only	36, 50 & 50W	
Backing Chem Acceptable for (5.4.2):	36 & 50	50W only	36, 50 & 50W	
Mechanical Testing	5.19	Yield	Tensile	Elongation, %
				RA, %
Tensile WM Longitudinal	5.19.4			
Tensile Transverse	5.19.1	N/A	N/A	N/A
Side Bends	5.19.2		N/A	N/A
Charpys	5.19.5		N/A	N/A
Macro	5.19.3		N/A	N/A
Consumables				
AWS Classification	5.5, Table 4.1			
AWS Specification	5.5, Table 4.1			
Electrode Brand/Type	5.5, Table 4.1			
Flux Brand/Type	5.5, Table 4.1			
Gas Shielding	5.5, Table 4.1			
Parameters				
Amperage				
Voltage				
Travel Speed				
Heat Input				
Heat Input Range Qualified	Min		Max	
Preheat Interpass correct?				
Gas Flow Rate OK?				
Electrode Extension				
Electrode Diameter				
Non-Destructive Testing				
UT				
RT				
Test Witness				
Test Results OK				
Summary by:				Date:

The Building Blocks – I am not smart enough to remember all that



◆ ...filled one out

PENNONI AWS D1.5 - 2015 Bridge Code WPS/PQR Review Form

WPS ID: Fillet Weld - FCAW - FCM
 PQR ID: 403FC & 403A
 PQR Expiration date: 5.3 - None, 12.7.4 - FCM - 60 months
 FCM: No, Yes
 PQR Method: 5.12.1 - Maximum Heat Input, 5.12.2 - Maximum/Minimum Heat Input, 5.12.3 Production Procedure Qualification

Handwritten notes: FWS, 5/16 SP, 3/2 AMP, Fix Record

Welding Process	SMAW - 4.5, 4.6	FCAW - 4.11-4.13	GMAW - 4.11-4.13	SAW - 4.7-4.10	
Test Position	FLAT - 1G				
Base Metal Grade	36	50	50W		
Thickness	1"				
MTR Acceptable	✓ CE				
Plate Chem Acceptable for (5.4.2)	36 & 50	50W only	36, 50 & 50W		
Backing Chem Acceptable for (5.4.2):	36 & 50	50W only	36, 50 & 50W		
Mechanical Testing	Yield	Tensile	Elongation, %	RA, %	
Tensile WM Longitudinal	80	83	27	69	
Tensile Transverse	N/A	859, 857	N/A	N/A	
Side Bends	✓	N/A	N/A	N/A	
Charpys	33 ft/lb - 20F	N/A	N/A	N/A	
Macro	✓	N/A	N/A	N/A	
Consumables					
AWS Classification	E81NiC-H4				
AWS Specification	A5.29				
Electrode Brand/Type	Lincoln Ultra Core Type?				
Flux Brand/Type	N/A				
Gas Shielding	CO2				
Parameters					
Amperage	370		200-480		
Voltage	31.4				
Travel Speed	11.5				
Heat Input	60.61				
Heat Input Range Qualified	Min 60%	36.36	Max 100%	60.61	
Preheat Interpass correct?	→ NOT for FCM				
Gas Flow Rate OK?	→ NO 40 min				
Electrode Extension	→ 1" + 1/4"				
Electrode Diameter	1/16"				
Non-Destructive Testing					
UT	no				
RT	yes				
Test Witness	yes				
Test Results OK	yes				
Summary by:	JSM			Date:	12/12/17

The Building Blocks – Welder Qualifications Part B

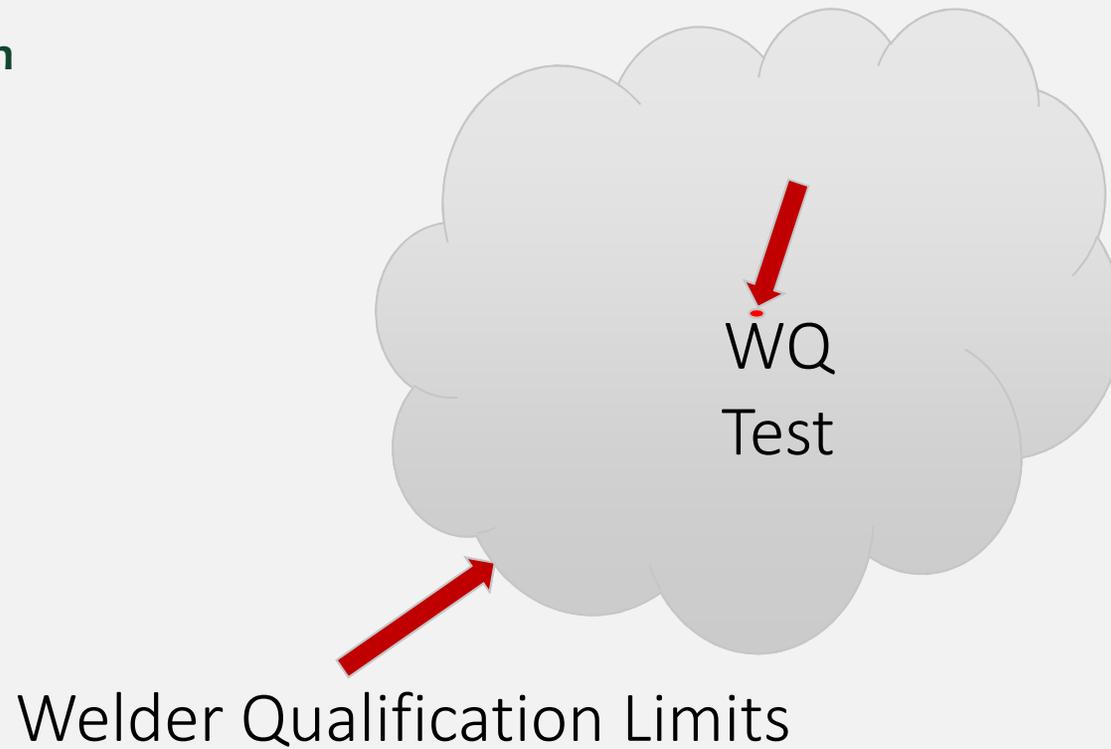


- ◆ **5.21 Welders, Welding Operators, and Tack Welders using SMAW, SAW, GMAW, FCAW, ESW, and EGW shall be qualified by test.**
 - ❖ Purpose: to determine the ability to produce sound welds.
- ◆ **5.21.3 Use one of the AASHTO approved steels from 1.2.2.**
- ◆ **5.21.4 Period of Effectiveness**
 - ❖ Indefinite unless not welding with the process for a period exceeding 6 months,
 - ❖ Some specific reason to question ability
- ◆ **5.21.5 Weld Cleaning**
 - ❖ Hand Chip or Hand Wire Brush only, no power chipper or grinding during the weld test.
 - ❖ After visual inspection, may use power tools to make flush to facilitate testing

The Building Blocks



- ◆ Venn Diagram



The Building Blocks – Welder Qualifications Part B



- ◆ **5.22.1 Production Positions Qualified – Groove Welds, Welder**
 - ❖ 1G Flat – Qualifies for Flat groove welding and Flat and Horizontal fillet welding.
 - ❖ 2G Horizontal – Qualifies for Flat and Horizontal groove and Flat and Horizontal fillet welding.
 - ❖ 3G Vertical – Qualifies for Flat, Horizontal and Vertical groove and Flat, Horizontal and Vertical fillet welding
 - ❖ 4G Overhead – Qualifies for Flat and Overhead groove welding and Flat, Horizontal, and Overhead Fillet welding.

The Building Blocks – Welder Qualifications Part B



- ◆ **5.22.1 Production Positions Qualified – Groove Welds, Welder**
 - ❖ 1G Flat – Qualifies for Flat groove welding and Flat and Horizontal fillet welding
 - ❖ 2G Horizontal – Qualifies for Flat and Horizontal groove and fillet welding
 - ❖ 3G Vertical – Qualifies for Flat, Horizontal and Vertical groove and fillet welding
 - ❖ 4G Overhead – Qualifies for Flat and Overhead groove welding and Flat, Horizontal, and Overhead Fillet welding.
- ◆ **5.22.2 Production Positions Qualified – Fillet Welds, Welder**
 - ❖ 1F Flat – Qualifies for Flat position fillet welding
 - ❖ 2F Horizontal – Qualifies for Flat and Horizontal position fillet welding
 - ❖ 3F Vertical – Qualifies for Flat, Horizontal and Vertical position fillet welding
 - ❖ 4F Overhead – Qualifies for Flat, Horizontal, and Overhead position fillet welding

The Building Blocks – Welder Qualifications Part B



- ◆ **5.22.3 Production Positions Qualified – Welding Operator**
 - ❖ Qualify for each position of production welding
- ◆ **5.22.4 Production Positions Qualified – Tack Welder**
 - ❖ With the fillet break test the tack welder is qualified to tack weld all types of grooves and fillets using the process and welding position tested.

The Building Blocks – Welder Qualifications Part B



- ◆ 5.23.1 – Ways to get there
 - ❖ 5.23.1.1 – Successfully weld a CJP groove weld Procedure Qualification Test Plate

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- ◆ 5.23.1 – Ways to get there
 - ❖ 5.23.1.1 – Successfully weld a CJP groove weld Procedure Qualification Test Plate
 - ❖ 5.23.1.2 - Groove for plate of unlimited thickness, 1" thick, single V, 45 Degree included angle, 1/4" root opening with backing, or single bevel for horizontal position. RT or Bend Test
 - ❖ 5.23.1.3 - Groove for plate of limited thickness, 3/8" thick, single V, 45 Degree included angle, 1/4" root opening with backing, or single bevel for horizontal position. RT or Bend Test

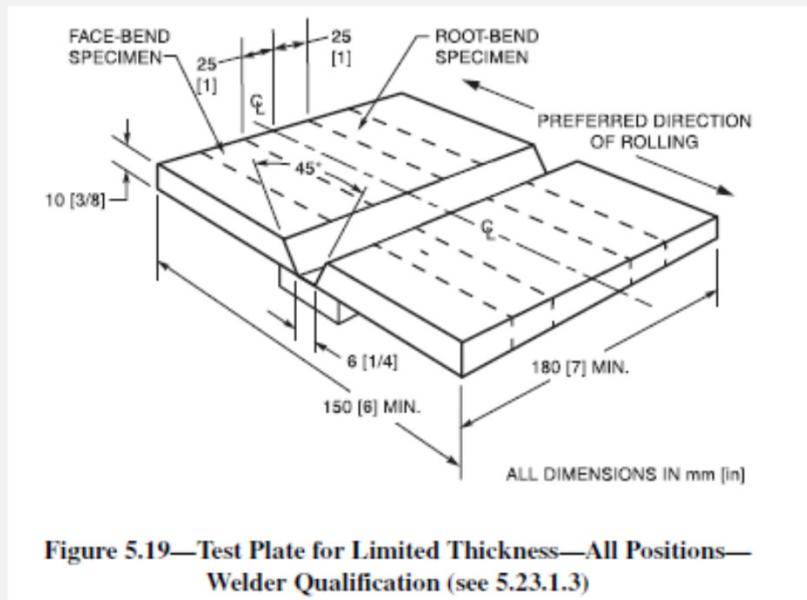
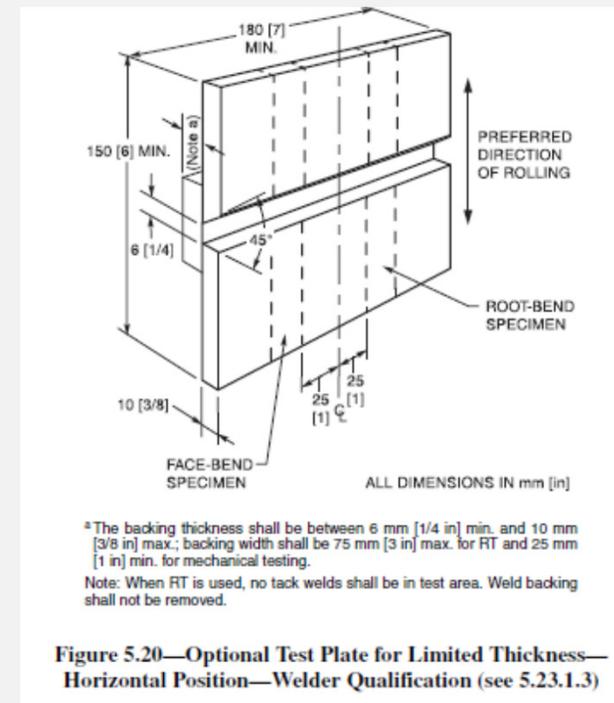


Figure 5.19—Test Plate for Limited Thickness—All Positions—Welder Qualification (see 5.23.1.3)



^a The backing thickness shall be between 6 mm [1/4 in] min. and 10 mm [3/8 in] max.; backing width shall be 75 mm [3 in] max. for RT and 25 mm [1 in] min. for mechanical testing.
Note: When RT is used, no tack welds shall be in test area. Weld backing shall not be removed.

Figure 5.20—Optional Test Plate for Limited Thickness—Horizontal Position—Welder Qualification (see 5.23.1.3)

The Building Blocks – Welder Qualifications Part B



- ◆ 5.23.1 – Ways to get there
 - ❖ 5.23.1.1 – Successfully weld a CJP groove weld Procedure Qualification Test Plate
 - ❖ 5.23.1.2 - Groove for plate of unlimited thickness, 1" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
 - ❖ 5.23.1.3 - Groove for plate of limited thickness, 3/8" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
 - ❖ Backing sizes requirements change with RT or Bend Test

The Building Blocks – Welder Qualifications Part B



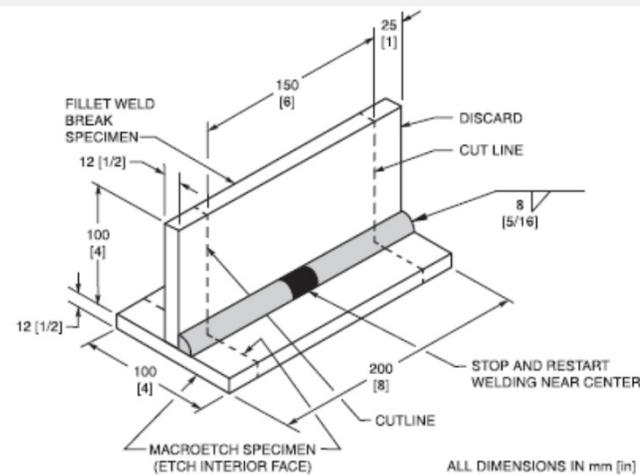
- ◆ 5.23.1 – Ways to get there

- ❖ 5.23.1.1 – Successfully weld a CJP groove weld Procedure Qualification Test Plate
- ❖ 5.23.1.2 - Groove for plate of unlimited thickness, 1" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
- ❖ 5.23.1.3 - Groove for plate of limited thickness, 3/8" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
- ❖ Backing sizes requirements change with RT or Bend Test
- ❖ 5.23.1.4 – For a fillet welder, less than 60 degrees, perform one of the groove weld tests above

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- ◆ 5.23.1 – Ways to get there
 - ❖ 5.23.1.1 – Successfully weld a CJP groove weld Procedure Qualification Test Plate
 - ❖ 5.23.1.2 - Groove for plate of unlimited thickness, 1" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
 - ❖ 5.23.1.3 - Groove for plate of limited thickness, 3/8" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
 - ❖ Backing sizes requirements change with RT or Bend Test
 - ❖ 5.23.1.4 – For a fillet welder, less than 60 degrees, perform one of the groove weld tests above
 - ❖ 5.23.1.4 – For a fillet welder, 60 – 135 degrees, perform the fillet break test or the fillet weld root bend test (Fig 5.22)



Note: Plate thickness and dimensions are minimum.

Figure 5.21—Fillet-Weld-Break and Macroetch Test Plate—
Welder Qualification—Option 1 (see 5.23.1.4)

The Building Blocks – Welder Qualifications Part B



- ◆ 5.23.1 – Ways to get there
 - ❖ 5.23.1.1 – Successfully weld a CJP groove weld Procedure Qualification Test Plate
 - ❖ 5.23.1.2 - Groove for plate of unlimited thickness, 1" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
 - ❖ 5.23.1.3 - Groove for plate of limited thickness, 3/8" thick, single V, 45 Degree included angle, ¼" root opening with backing, or single bevel for horizontal position. RT or Bend Test
 - ❖ Backing sizes requirements change with RT or Bend Test
 - ❖ 5.23.1.4 – For a fillet welder, less than 60 degrees, perform one of the groove weld tests above
 - ❖ 5.23.1.4 – For a fillet welder, 60 – 135 degrees, perform the fillet break test or the fillet weld root bend test
- ◆ 5.23.2 – Test for a Welding Operator follow a similar system, but the joint details are different

The Building Blocks – Welder Qualifications Part B



- ◆ **5.24 Limitations of Variables**

- ❖ 5.24.1.1 – Any base metal, except those with a minimum specified yield strength of 90 ksi or greater.



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- ❖ 5.24.1.1 – Any base metal, except those with a minimum specified yield strength of 90 ksi or greater.
- ❖ 5.24.1.3 – Any approved Electrode and Shielding Medium for the process

The Building Blocks – Welder Qualifications Part B



- ◆ **5.24 Limitations of Variables**

- ❖ 5.24.1.1 – Any base metal, except those with a minimum specified yield strength of 90 ksi or greater.
- ❖ 5.24.1.3 – Any approved Electrode and Shielding Medium for the process
- ❖ 5.24.2.1 – SMAW tests using EXX18 electrodes is qualified to weld with all of the SMAW electrodes allowed in the Code, except welders required to use E100XX or higher to join steels with a minimum specified yield strength of 90 ksi or greater. Must test with E10018-X or E11018-X.

The Building Blocks – Welder Qualifications Part B



◆ 5.24 Limitations of Variables

- ❖ 5.24.1.1 – Any base metal, except those with a minimum specified yield strength of 90 ksi or greater.
- ❖ 5.24.1.3 – Any approved Electrode and Shielding Medium for the process
- ❖ 5.24.2.1 – SMAW tests using EXX18 electrodes is qualified to weld with all of the SMAW electrodes allowed in the Code, except welders required to use E100XX or higher to join steels with a minimum specified yield strength of 90 ksi or greater. Must test with E10018-X or E11018-X.
- ❖ 5.24.2.3 – omission of backing requires requalification.

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◆ 5.24 Limitations of Variables

- ❖ 5.24.1.1 – Any base metal, except those with a minimum specified yield strength of 90 ksi or greater.
- ❖ 5.24.1.3 – Any approved Electrode and Shielding Medium for the process
- ❖ 5.24.2.1 – SMAW tests using EXX18 electrodes is qualified to weld with all of the SMAW electrodes allowed in the Code, except welders required to use E100XX or higher to join steels with a minimum specified yield strength of 90 ksi or greater. Must test with E10018-X or E11018-X.
- ❖ 5.24.2.3 – omission of backing requires requalification.
- ❖ 5.24.3.2 – Welding operator qualified to weld with multiple electrodes is qualified to weld with single electrodes but not vice versa.

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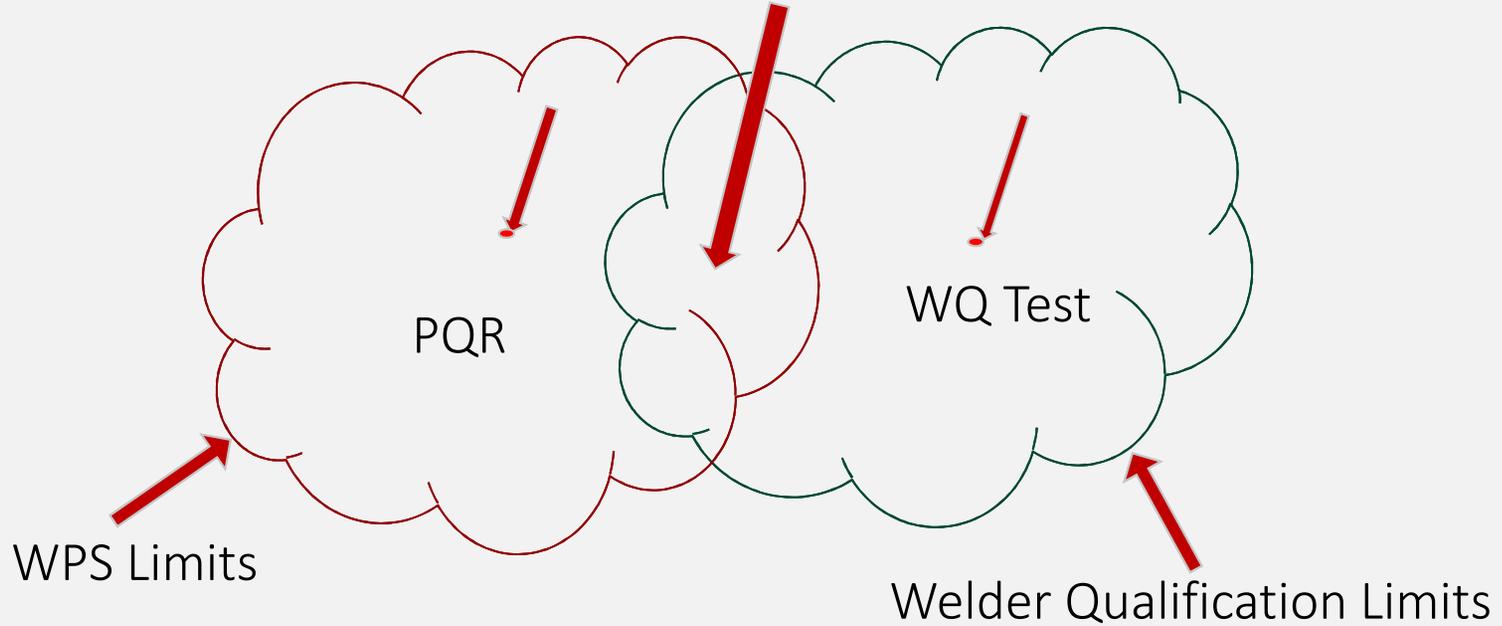


- ◆ 5.24 Limitations of Variables
 - ❖ 5.24.1.1 – Any base metal, except those with a minimum specified yield strength of 90 ksi or greater.
 - ❖ 5.24.1.3 – Any approved Electrode and Shielding Medium for the process
 - ❖ 5.24.2.1 – SMAW tests using EXX18 electrodes is qualified to weld with all of the SMAW electrodes allowed in the Code, except welders required to use E100XX or higher to join steels with a minimum specified yield strength of 90 ksi or greater. Must test with E10018-X or E11018-X.
 - ❖ 5.24.2.3 – omission of backing requires requalification.
 - ❖ 5.24.3.2 – Welding operator qualified to weld with multiple electrodes is qualified to weld with single electrodes but not vice versa.
 - ❖ 5.24.3.4 – Welders qualified for SAW with multiple electrodes shall be considered qualified for single electrode mechanized welding, with training and demonstration of ability to make satisfactory production welds.

Summary



Production Welding has to be in this area





QUESTIONS?