

AWS D1.1 (Structural Welding Code-Steel)

Quick Review on Essential Variables

1-Guide (Position)

AWS D1.1, Table 6.1 [Plate]/ Table 10.8 [Pipe],

WPS Qualification

CJP Groove Weld (Plate or Tubular), or
Fillet Weld (Plate or Tubular) Qualification Test:

Position Tested	Position Qualified*
1G, 1G (Rotated)	F
2G	F, H
3G	V
4G	OH
5G	F, V, OH
(2G+5G), 6G, 6GR	All
1F, 1F (Rotated)	F
2F, 2F (Rotated)	F, H
3F	V
4F (Plate)	OH
4F (Tubular)	F, H, OH
5F	All

* CJP Groove Qualify CJP, PJP and Fillet Welds

See AWS D1.1, Clause 6.12 for conditions that CJP groove weld qualification may also qualify PJP groove weld

* Fillet Qualify Fillet only (Clause 6.13, Table 6.4 and Figure 6.15 for Fillet Weld Test on Plate, [Clause 10.15 and Table 10.11 and Figure 10.16 for Tubular]

* Groove weld on plate qualifies pipes equal to or greater than 24 in [600 mm] nominal outer diameter.

* Vertical uphill to downhill or vice versa is essential variable

* Plug/Slot Welding Qualifies for Only the Positions Tested

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See AWS D1.1, Table 6.5: PQR Essential Variables (except ESW and EGW process), for Non-CVN Testing Applications

See AWS D1.1, Table 6.7: PQR Supplementary Essential Variables (including ESW and EGW process), for CVN Testing Applications

See AWS D1.1, Table 6.6: PQR Essential Variables for ESW and EGW process, for Non-CVN Testing Applications

2-Guide (Thickness/Diameter of Base Metal Range)

Test on Plate, CJP Groove Welds:

T: Thickness of Test Coupon Welded (Fig. 6.5, 6.6 or 6.7)
Qualified Plate, Pipe or Tube Thickness Range are as follow:
(See Note “b” below)

T from 1/8 in. (3 mm), but less than 1 in. (25 mm):
Qualified Thickness Range: 1/8 in. (3 mm) **Min.**, 2T **Max.**

T from 1 in. (25 mm) and over:
Qualified Thickness Range: 1/8 in. (3 mm) **Min.**, **Unlimited**

T test on ESW and EGW:
Qualified Plate Thickness Range: 0.5T **Min.**, 1.1T **Max.**

Note: Any CJP qualification shall also qualify any fillet weld size on any thickness.

Note “b” of AWS D1.1, Table 6.2: For square groove welds that are qualified without backgouging, the maximum thickness qualified shall be limited to the test thickness.

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Test on Plate (Pipe, Tube), PJP Groove Welds:

S: Test Groove Depth, Table 6.3 (Table 10.10)

T: Thickness of Test Plate (Pipe or Box Tube) used in the test assembly

S from 1/8 in. (3 mm), to 3/8 in. (10 mm), incl.:

Qualified Thickness Range:

1/8 in. (3 mm) **Min.**, 2T **Max.** (With S **Max.**)

S over 3/8 in. (10 mm) to 1 in. (25 mm), incl.:

Qualified Thickness Range:

1/8 in. (3 mm) **Min.**, **Unlimited** (With S **Max.**)

AWS D1.1, Clause 6.12 [Plate] and Note “d” of Table 10.10

[Pipe or Tube]: Any PJP qualification shall also qualify any fillet weld size on any thickness.

When qualifying a Flare-Groove Weld WPS:

Effective weld size qualified: The maximum weld size qualified is the minimum weld size of three cross sections from test specimens described in Note 1. The minimum radius qualified is that tested.

Note 1: If PJP WPS not using any Figure 5.2 joint detail, additional three macroetch test specimens are required to evaluate weld soundness and to verify that the required weld size is produced (weld parameters must be within those specified on CJP WPS) [See AWS D1.1 Clause 6.12.4, 6.10.4 and Figure 6.29 (Details B or C) for test plate with using any steel base metal]

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Fillet Weld WPS Qualification: Test shall be based on Max. single pass and Min. multiple pass fillet weld size to be used in construction: (A): Plate tested, (B): Pipe tested

Qualified Thickness Range:

(A): 1/8 in. (3 mm) Min., Unlimited Plate/Pipe thickness

(B): 1/8 in. (3 mm) Min., Unlimited Pipe thickness

Qualified Fillet Size: Max. tested single pass and smaller; Min. tested multiple pass and larger

(See AWS D1.1, Table 6.4 [Plate]/ Table 10.11 [Pipe])

(Clause 6.13, Table 6.4 and Figure 6.15 for Fillet Weld Test on Plate, [Clause 10.15, Table 10.11 and Figure 10.16 for Tubular])

3-Guide (Diameter of Base Metal Range)

Test on Pipe (Tube), CJP Groove Welds:

a) Job Size Test Pipes:

**Qualified Plate, Pipe or Tube Wall Thicknesses are as follow:
(See Note "c" and "e" below for more information)**

Diameter tested over or less than 24 in. (600 mm OD):

T from 1/8 in. (3 mm) to 3/8 in. (10 mm), incl.:

Qualified Thickness Range: 1/8 in. (3 mm) Min., 2T Max.

T over 3/8 in. (10 mm), but less than 3/4 in. (20 mm):

Qualified Thickness Range: 0.5T Min., 2T Max.

T from 3/4 in. (20 mm) and over:

Qualified Thickness Range: 3/8 in. (10 mm) Min., Unlimited

Diameter tested is less than 24 in. (600 mm OD):

Qualified Nominal Diameter of Pipe (Tube) Size:

Test diameter and over

Diameter tested is over than 24 in. (600 mm OD):

Qualified Nominal Diameter of Pipe (Tube) Size:

(A) Test diameter and over, when thickness tested is less than or equal to 3/8 in (10 mm)

(B) 24 in. (600 mm OD) and over, when thickness tested is larger than 3/8 in (10 mm)

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b) Standard Test Pipes:

Qualified Plate, Pipe or Tube Wall Thicknesses are as follow:
(See Note “c” and “e” below for more information)

2 in. Sch. 80 (DN 50 mm OD x 5.5 mm WT) or

3 in. Sch. 40 (DN 80 mm OD x 5.5 mm WT)

Qualified Thickness Range:

1/8 in. (3 mm) **Min.**, 3/4 in. (20 mm) **Max.**

Qualified Nominal Diameter of Pipe (Tube) Size:

3/4 in. (20 mm OD) through 4 in. (100 mm OD)

6 in. Sch. 120 (DN 150 mm OD x 14.3 mm WT) or

8 in. Sch. 80 (DN 200 mm OD x 12.7 mm WT)

Qualified Thickness Range:

3/16 in. (5 mm) **Min.**, **Unlimited**

Qualified Nominal Diameter of Pipe (Tube) Size:

4 in. (100 mm OD) and over

Note “c” of AWS D1.1, Table 10.9 [Pipe]: For square groove welds that are qualified without backgouging, the maximum thickness qualified shall be limited to the test thickness.

Note “e” of AWS D1.1, Table 10.9 [Pipe]: Qualification with any pipe diameter shall qualify all box section widths, depths.

See AWS D1.1, Clause 6.12 for conditions that CJP groove weld qualification may also qualify PJP groove weld (See also Clause 6.10.4 for Macroetch tests requirement).

Note: PJP Groove welds WPS could be qualified based on CJP Groove WPS under one of the following conditions:

1) if PJP WPS using any Figure 5.2 joint detail, provided the essential variables for the qualified CJP WPS are within the limits listed in Tables 6.5 and 6.6 (when applicable).

2) if PJP WPS not using any Figure 5.2 joint detail, additional three macroetch test specimens are required to evaluate weld soundness and to verify that the required weld size is produced [See AWS D1.1 Clause 6.12.2, 6.10.4 and Figure 6.29 (Detail A) for test plate with using any steel base metal]

**AWS D1.1 (Structural Welding Code-Steel)
4-Guide (Base Metal Selection)**

AWS D1.1 Table 6.8:

Table 5.3, Table 6.9 and Unlisted Steels Qualified by PQR

PQR Base Metal:

WPS Base Metal Group Combinations Allowed by PQR

**Any Group I Steel to Any Group I Steel:
Any Group I Steel to Any Group I Steel**

**Any Group II Steel to Any Group II Steel:
Any Group II Steel to Any Group II Steel
Any Group II Steel to Any Group I Steel
Any Group I Steel to Any Group I Steel**

**Any Specific Group III Steel to Any Group I Steel:
The Specific PQR Group III Steel Tested to Any Group I**

**Any Specific Group III Steel to Any Group II Steel:
The Specific PQR Group III Steel Tested to Any Group I
or Group II Steel**

**Any Specific Table 6.9 Steel to Any Group I Steel:
The Specific PQR Table 6.9 Steel Tested to Any Group I**

**Any Specific Table 6.9 Steel to Any Group II Steel:
The Specific PQR Table 6.9 Steel Tested to Any Group I or
Group II Steel**

**Any Group III Steel to Any Group III Steel (or)
Any Group IV Steel to Any Group IV Steel (or)
Any Table 6.9 Steel to Any Table 6.9 Steel:
Steels shall be of the same material specification,
grade/type and minimum yield strength as the Steels
listed in the PQR**

**Any combination of Group III, IV, and Table 6.9 Steels:
Only the Specific Combination of Steels listed in the PQR**

**Any Unlisted Steel to Any Unlisted Steel or
Any Steel Listed in Table 5.3 or Table 6.9:
Only the Specific Combination of Steels listed in the PQR**

Note: Groups I through IV are found in Table 5.3

**AWS D1.1 (Structural Welding Code-Steel)
5-Guide (Preheat)**

The need for and the temperature of preheat are dependent upon a number of factors such as chemical analysis, degree of restraint of the parts being joined, elevated temperature, mechanical properties, and material thicknesses.

When welding two different material groups, the minimum preheat temperature required shall be the higher temperature for the material to be welded. For prequalified procedures, preheat applicable to the higher strength group, as per Note 1 of Table 5.4-AWS D1.1. Also, thickness referred to for the prequalified minimum preheat and interpass temperature in Table 5.8-AWS D1.1, is the greater of the nominal thicknesses at the weld of the parts to be joined.

Preheat and Interpass for Non-Prequalified materials:

Table 6.9 of AWS D1.1 (**Non-Prequalified materials**): Code-Approved Base Metals and Filler Metals Requiring Qualification per Clause 6, includes Minimum Preheat and Interpass Temperature for materials in this Table.

Note: Maximum preheat and interpass temperature, as per note 3 of Table 6.9

AWS D1.1, Table 6.5: Decrease from preheat and interpass temperature above 25 °F (15 °C) [100 °F (55 °C) for GTAW] is essential variable.

Note: AWS D1.1, Table 6.5 PQR Essential Variables (**except** ESW and EGW process), for Non-CVN Testing Applications

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6-Guide (Joint)

AWS D1.1, Table 6.5: Essential Variables for Joints:

-A change in groove type (e.g., single-V to double-V), **except** qualification of any CJP groove weld qualifies for any groove detail conforming to the requirements of 5.4.2 (PJP-Figures 5.2) or 5.4.1 (CJP-Figures 5.1), 10.9 or 10.10 [Pipe].

-A decrease in the groove angle and root opening, an increase in the root face exceeding the tolerances (increase in the groove angle above 10 ° degree) for any groove detail conforming to the requirements of 5.4.2 (PJP-Figures 5.2) or 5.4.1 (CJP-Figures 5.1), 10.9 or 10.10, 7.21.4.1 or 10.10.2 and 10.23.2.1 (Tubular and Nontubular).

-The omission, but not inclusion, of backing or backgouging

-A change in the type of groove to a square groove and vice versa

Note: AWS D1.1, Table 6.5 PQR Essential Variables (**except** ESW and EGW process), for Non-CVN Testing Applications

7 (A)-Guide (Heat input)

AWS D1.1, 7.7 Heat Input Control for Quenched and Tempered Steels: When quenched and tempered steels are welded, the heat input shall be restricted in conjunction with the maximum preheat and interpass temperatures required. Such considerations shall include the additional heat input produced in simultaneous welding on the two sides of a common member. The preceding limitations shall be in conformance with the producer's recommendations. **The heat input limitations of this clause shall not apply to ASTM A913/A913M.**

The increase may be measured by the following:

Heat input [J /in. (J/mm)] =
(Voltage x Amperage x 60)/ Travel Speed [in./min
(mm/min)]

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7 (B)-Guide (Heat Treatment)

Clause 5.9 (C5.9)-Postweld Heat Treatment for prequalified condition, if/when it is required.

Clause 7.8 (C7.8)-Postweld Heat Treatment for both prequalified and Non-prequalified conditions:

Clause 7.8-Stress-Relief Heat Treatment (PWHT): Where required by the contract drawings or specifications, welded assemblies shall be stress relieved by heat treating.

AWS D1.1, 7.8.1, Requirements for stress-relief treatment

Table 7.2 (Minimum Holding Time),

Table 7.3 (Alternate Stress-Relief Heat Treatment)

Clauses 7.8.3 Steels Not Recommended for PWHT

8-Guide (Welding Process)

Essential Variables for SMAW, SAW, GMAW, FCAW, GTAW Process:

AWS D1.1, Table 6.5 PQR Essential Variables, for Non-CVN Testing Applications

AWS D1.1, Table 6.7 PQR Supplementary Essential Variables (including ESW and EGW process), for CVN Testing Applications

Essential Variables for ESW, EGW Process, for Non-CVN Testing Applications:

AWS D1.1, Table 6.6 PQR Essential Variable Changes Requiring WPS Re-qualification

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9-Guide (Type of Tests with References for PQR **)

Type of Tests	Clause/Figure(s) Reference	Acceptance Criteria
Visual Inspection	6.10.1	6.10.1
Radiographic Examination	6.10.2.1	6.10.2.2
Ultrasonic Testing	6.10.2.1	6.10.2.2
2 Transverse Root Bends	6.10.3.1/Fig. 6.8	6.10.3.3
2 Transverse Face Bends	6.10.3.1/Fig. 6.8	6.10.3.3
2 Longitudinal Root Bends	6.10.3.1/Fig. 6.8	6.10.3.3
2 Longitudinal Face Bends	6.10.3.1/Fig. 6.8	6.10.3.3
2 Side Bends	6.10.3.1/Fig. 6.9	6.10.3.3
4 Side Bends	6.10.3.1/Fig. 6.9	6.10.3.3
2 Tensile Tests	6.10.3.1/Fig. 6.10	6.10.3.5
All-Weld-Metal Tensions	6.10.3.1/Figs. 6.14 and 6.18	6.15.1.3(2)
3 Macroetch	6.10.4	6.10.4.1
4 Macroetch	6.10.4	6.10.4.1
CVN Tests	6 Part D/Fig. 6.28	6.30 and Table 6.15

****From Suggested Form J-1 (Sample PQR Form [Annex J of D1.1-2020](#))**