Weld Presentation & Panel Discussion
AWS D1.1 Structural Welding Code: You Specify It- Do You Know What It Really Says?

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“All welding shall be done in conformance with AWS D1.1”

- a **minimum** mandatory welding requirement
- for welded structures made from **commonly used** carbon and low alloy constructional steels (i.e. typical structural buildings).

**IS THAT ENOUGH FOR THE HIGH PERFORMANCE, NON-REDUNDANT, FRACTURE CRITICAL WELDING, WE REQUIRE IN A TYPICAL TUBULAR STEEL TRANSMISSION POLE DESIGN?**
Poles you purchase should be fabricated to a standard that exceeds the MINIMUM AWS D1.1 requirements.
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Structural Welding Code - Steel

You have to read it to know what’s in it!

Consists of (540) Pages organized into:
• (8) “Clauses” (Chapters)
• (9) “Normative” Annexes
• (12) “Informative” Annexes
• Commentary
• Index
Let’s look at the Eight Chapters called “Clauses” of AWS D1.1:

**Clause 1:** General Requirements

- Basic Information on the scope and limitations of the code,
- Key definitions, and,
- Identifies the **major responsibilities of the parties involved** with steel fabrication.
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AWS D1.1: Paragraph 1.4 Responsibilities:

“The Engineer” (meaning the Owner or Owner’s Engineer) “shall specify” . . .:

- Code Requirements
- All NDT Requirements
- Any verification inspection required (other than fabricator’s inspection)
- Weld acceptance criteria (if different from clause 6 of the code)
- CVN toughness criteria for weld metal, base metal, and/or HAZ when required.
- Whether the structure is statically or cyclically loaded
- All additional requirements not specifically addressed in the code
- Responsibilities of the parties involved.
**Clause 2:** Design of Welded Connections

- Contains the requirements for the design of welded connections composed of **tubular, or nontubular**, product form members.
AWS D1.1: Paragraph 2.3.2 Notch Toughness Requirements

“The Engineer” (again meaning the Owner or Owner’s Engineer) shall specify that the Weld Procedure Specifications (WPS’s) be qualified with CVN tests.
**Clause 3:** Prequalification of WPS’s (Weld Procedure Specifications)

- Clause contains the requirements for exempting a WPS from the WPS qualification requirements of this code.
In my opinion, **we should not allow ANY exemptions** from the requirement to qualify a Weld Procedure Specification (WPS).

**Why?**

- Prequalified WPS’s do not reflect CVNL testing requirements in the weld metal, and HAZ (heat affected zone).

- Prequalified WPS’s do not reflect heat control during welding (maximum interpass temperature).
Clause 4: Qualification

- Contains the requirements for **Weld Procedure Specification** (WPS’s) including **Procedure Qualification Records** (PQR’s), and qualification tests for all welding personnel (**welders, welding operators, and tack welders**).
Clause 4: Qualification

Weld Procedure Specification (WPS’s)
A formal written document describing a specific welding procedure, which provides clear and unambiguous direction to the welder or welding operators performing the weld. Purpose is to achieve confidence in quality and repeatability.

Procedure Qualification Records (PQR’s)
The detailed record of a demonstration weld made by a specific procedure (WPS) can meet prescribed standards of weld performance.
WPS:
How you plan to weld this joint.
PQR: How you actually welded this joint.

Would include the test results required:

- Tensile tests
- Root Bend Test
- CVNL Tests (if required)
## Weld Procedure Specification (WPS) Qualification

**Table 4.2**  
WPS Qualification—CJP Groove Welds: Number and Type of Test Specimens and Range of Thickness and Diameter Qualified (see 4.5) (Dimensions in Inches)

<table>
<thead>
<tr>
<th>Nominal Plate Thickness (T) Tested, in</th>
<th>Reduced Section Tension (see Fig. 4.14)</th>
<th>Root Bend (see Fig. 4.12)</th>
<th>Face Bend (see Fig. 4.12)</th>
<th>Side Bend (see Fig. 4.13)</th>
<th>Nominal Plate, Pipe or Tube Thickness(^{c,d}) Qualified, in</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8 ≤ T ≤ 3/8</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>(Note i)</td>
<td>1/8</td>
<td>2T</td>
<td></td>
</tr>
<tr>
<td>3/8 &lt; T &lt; 1</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>4</td>
<td>1/8</td>
<td>2T</td>
<td></td>
</tr>
<tr>
<td>1 and over</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>4</td>
<td>1/8</td>
<td>Unlimited</td>
<td></td>
</tr>
</tbody>
</table>
Weld Procedure Specification (WPS) Qualification

Figure 4.3—Positions of Test Plates for Groove Welds (see 4.3.4)
Does welding two 1 inch thick plates together really simulate the issues we have with welding thin plates (pole or arm shafts) to thick plates (base plates to flanges):

- Restrained Joints,
- Heat Input Distortion,
- Differential Cooling Rates?

The Bridge Welding Code is far more stringent in this area.
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Welder/Operator/Tack Welder Performance Qualification Record (WPQR):

[Diagram of structural weld test specimen]
Clause 5: Fabrication

- General fabrication and erection requirements applicable to welded structures governed by this code, including
  - base metals
  - welding consumables
  - welding technique
  - welded details
  - material preparation and assembly
  - workmanship
  - weld repair
  - and other requirements
Heat Input:

(Values are from the WPS/PQR):
Preheat and interpass temperatures shall be maintained for a distance of “not less than 3 inches in all directions from the point of welding”.
Clause 6: Inspection

- Contains the criteria for the qualifications and responsibilities of inspectors,
- Acceptance criteria for production welds,
- Standard procedures for performing visual inspections and NDT (nondestructive testing)

AWS D1.1 has very liberal visual inspection acceptance criteria!
Clause 7: Stud Welding

- Requirements for welding studs to structural steel

Clause 8: Strengthening and Repairing Existing Structures

- Basic information pertinent to welded modification or repair of existing structures.
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1941: Revised and renamed D1.0

1972: Combined with D2.0 (Highway & Railway Bridges) and renamed D1.1: Structural Welding Code.

1988: Bridges separated out into D1.5 Bridge Welding Code (In response to a need to accommodate specific AASHTO bridge welding requirements into the AWS Codes)

2005: D1.5 the Seismic Supplement to AWS D1.1 was introduced (In response to the 1994 Northridge earthquake in California).
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AWS D1.8 Structural Welding Code - Seismic Supplement
Introduced in 2005

AWS D1.5 Bridge Welding Code
Introduced in 1988
AWS D1.1 2010
Structural Welding Code - Steel
“All welding shall be done in conformance with AWS D1.1”.

It is certainly better than no requirement, but don’t let this statement give you great comfort!

AWS D1.1 alone does not insure worry free welds in our poles!
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Thank you!
Weld Inspection of Transmission Tubular Steel Structures

Ed Jacobs, Director of Quality, R&D, Solid Modeling
Al Clare, NDT Manager
Paul Cameron, Quality Manager & AWS-CWI
Objectives

• Framework and shortcomings of AWS D1.1
• Repeatable UT inspection
• NDE metallurgical examinations & validations
• Recommend a standard
History of AWS & D1.1

- 1928- Published First Edition
  - Code for Fusion Welding and Gas Cutting in Building Construction, Code 1 Part A
- 1930, 1937 & 1941 - Revised
  - Given AWS-D1.0 designation
- 1936- Published First Edition of Bridge D2.0
- 1972- D1.0 & D2.0 combined to form AWS D1.1
  - Section 8: Buildings, Section 9: Bridges, Section 10 Tubular
History of AWS & D1.1 cont.

• 1988- Bridges group separated
  – Formed AASHTO/AWS D1.5 – Bridge Welding Code

• 1990’s- Section 10 Tubular removed
  – All inspection condensed into Section 6
    • Now Clause 6
    • Change was significant to Pole Structures industry

• Currently- AWS D1.1/D1.1M:2010
  – 5 year rev. cycle
Framework of AWS D1.1

- Known throughout the industry
  - “All Welding per AWS D1.1”
- Qualifies process and people
  - Clause 3 & 4
- Discusses alternative means of UT inspection
  - Annex S
- Inspector Qualification
  - AWS QC1 & ASNT SNT-TC-1A
- Calibration of UT equipment
  - Clause 6 Part F
  - Based on CRT technology
Shortcomings of AWS D1.1

• Very broad; not specific to our industry
  – Pre-Qualified Joints not geared to Pole Industry

• No UT acceptance criteria for CJP’s under 5/16”

• Clause 6.8 offers alternative acceptance with very little info on how to document that

• No mention of Galvanizing (& UT)
  – UT is common and necessary on galvanized structures

• Doesn’t account for modern technology
Shortcomings of AWS D1.1 cont.

• Evaluation from 1 face (UT)
  – Corner or T-Joint ≤ 1.5 inch

• Needs more consideration
  – CVN

• Identifies all defects
  – Finite Element Analysis (FEA)
  – Should concentrate on critical defects

• Frequency of CJP UT inspection
  – 10% vs. 100%
A Proper Inspection Program

• A good program starts with good VT
• Welding variables defined
  – WPS, Work Instruction, Print
• Inspection before, during, and after
• Inspector qualification
  – AWS, ASNT, CWB, ACCP
A Proper Inspection Program cont.

• If more than VT required
  – VT then UT

• Minimize variation between inspectors (VT & UT)
T&B Destructive Testing Results and Validation of NDE

Figure 1.
A single indication was reported by UT. It was characterized as 2.0"L x 0.12"D. The section containing the defect was sent for metallurgical analysis.
Figure 2.
Examination of the cut slices revealed a defect.
T&B Destructive Testing Results and Validation of NDE cont.

Figure 3.
Under 20X Magnification, the indication exhibited a small slag defect in the center of the weld at the base of the weldment. Actual flaw was less than 0.5"L X 0.1" D.
Results

- Indication rejectable by UT (AWS D1.1)
- Major reduction in size and geometry reported (UT 2.0”L x 0.12”D vs. Actual 0.5”L x 0.1”D)
- No effect on structural integrity of pole
T&B Enhancements to AWS D1.1 for Full Penetration Welds cont.

**T&B Enhanced Method**

- Calibrate to IIW Block
  - 0.060 Side Drilled Hole to 80% FSH
  - Add 7db
    - Previously add 6db
  - Evaluate at this level

**AWS D1.1 Method**

- Calibrate to IIW Block
  - 0.060 Side Drilled Hole between 50% to 75% FSH
  - Evaluate at 5-7db’s
T&B Enhancements to AWS D1.1 for Full Penetration Welds cont.

**T&B Enhanced Method**
- Evaluate from Scan Level
  - 80% FSH for 0.060 Hole plus 7db
- 80% FSH - Reject Regardless of Length
- 40% - <80% FSH – Reject after 1 inch of Length
- 20% - <40% FSH – Reject after 2 inches of length

**AWS D1.1 Method**
- Indication level (a) – Reference Level (b) – Attenuation Factor (c) = Indication Rating
- Compare Rating to Table 6.2
  - Determine Acceptance
T&B Enhanced Method

- Add 2db per inch after 2 Inch of Sound Path
  - Was “Add 2db per inch after 5 Inch of Sound Path”
  - Added “Skip Charts” to Standard for easy reference.

AWS D1.1 Method

- Calculated using Sound Path

\[
\theta_R = \text{Reflected Angle} \\
T = \text{Material Thickness} \\
\text{Skip Distance} = 2T \times \tan \theta_R \\
\text{Leg} = \frac{T}{\cos \theta_R} \\
\text{V-Path} = \frac{2T}{\cos \theta_R}
\]
T&B Enhancements to AWS D1.1 for Full Penetration Welds cont.

**T&B Enhanced Method**
- Length Evaluation
  - Measured from Center of Transducer
- From Max Indication:
  - Scan Left and Right until indication drops below 10%

**AWS D1.1 Method**
- Length Evaluation
  - Measured from Center of Transducer
- From Max Indication:
  - Scan Left and Right until indication drops by 50% (6db)
  - This could still be 37.5% FSH
  - This would not be less than 25% FSH
T&B Enhancements to AWS D1.1 for Full Penetration Welds cont.

**T&B Advantage**
- Meets
  - AWS Requirements
- Exceeds
  - More Critical on Longer Indications
  - Allows Evaluations after 2\textsuperscript{nd} Leg
  - Allows Evaluation with Both a 70° and 45° Transducer

**D1.1 Disadvantage**
- No Acceptance Criteria for Material Under 5/16 inch
- No Criteria for Coated Material
  - Galvanized
- Evaluation in the 1\textsuperscript{st} and 2\textsuperscript{nd} Legs Only
  - On thinner material the 2\textsuperscript{nd} Leg may not be out from under the transducer
Considerations for a New Standard

**API 2X**
- Off-Shore Structures
- Same idea as Annex S
- DAC curve; includes Coatings
- Recognize
  - FEA/Fracture Mechanics
  - Certain flaws better left

**D1.8 Seismic Supplement**
- Designed for strain
- Adequate strength
- Certain defects more critical
- Repairs may result in more harm than good (Example: Figure 1-3)
Conclusions

- The long-term approach for the industry is to work within our industry committees to collectively develop, as AWS D1.1 recommends, a standard suitable specifically for tubular steel transmission structures.
- Refer to Paper, “Baseplate and Flange Weld Inspection of Tubular Steel Transmission Structures”
Panel Discussion
Panelists

- Wes Oliphant, Owner (ReliaPOLE)
- Ed Jacobs, Director of Quality (T&B)
- Al Clare, NDT Manager (T&B)
- Paul Cameron, Plant Quality Manager (T&B)