

Welding Inspection Tasks – The Role of the Inspector

In the first PAN in our welding series, we discussed standards, specifications, codes, and responsibilities of those involved in the welding process – the fabricator, engineer, Certified Weld Inspector (CWI), and welder. In our second PAN, we discussed welding discontinuities and defects. How can our industry reduce the occurrence of discontinuities and defects in the final work product? How does the entire process work together? How can you increase your chances of having a passing CWI report? **Detailed inspection tasks and quality inspection**

throughout is essential and gives the greatest chance of providing a finished welded product that complies with the *Structural Welding Code – Steel* AWS D1.1, the project specifications, and your customer's expectations. In this PAN, we are going to discuss more specifically the role of the CWI and the inspection tasks required to ensure a successful project and a passing CWI report.



The American Welding Society (AWS) *Structural Welding Code – Steel*, D1.1, is the code for fabricating and erecting welded steel structures. The code was specifically developed for welded steel structures that utilize carbon or low alloy steels that are 1/8 in or thicker with a minimum specified yield strength of 100 ksi or less. Per Section 6.9 of D1.1, the weld inspector is to visually inspect all of the welds and the welds shall be acceptable if the criteria of Table 6.1 are satisfied. **However, there is much that the CWI can do along the way to ensure compliance with AWS D1.1 Code and the overall success of the project.**



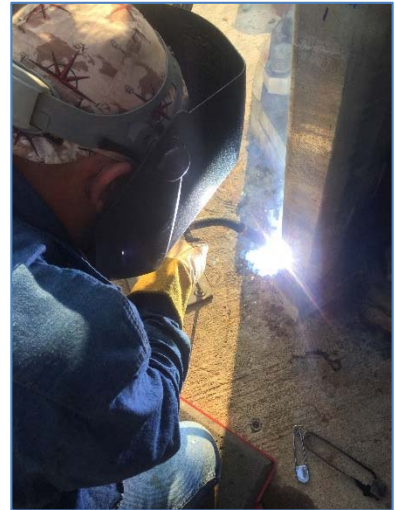
The American Institute of Steel Construction's (AISC) *Specification for Structural Steel Buildings*, ANSI/AISC 360-10, was developed as a consensus document to provide a uniform practice in the design of steel-framed buildings and other structures. As in towers, welding is a key activity to building construction. Chapter N of AISC 360 specifically provides minimum requirements for welding quality control, quality assurance, and nondestructive testing requirements. Tables C-N5.4-1 through C-N5.4-3 of the specification provide an excellent road-map for customers, engineers, welders, and CWIs of the required steps for inspection **prior** to welding, **during** welding, and **after** the welding process is completed. Each required inspection task is referenced back to the corresponding clause in AWS D1.1-2010 – a very helpful tool.

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Inspection Tasks Prior to Welding

Inspection tasks **PRIOR** to welding encompass review of welding procedures specifications, consumable certifications, material certifications, fit-up of weld joints, and checking weld equipment. This is outlined in Table C-N5.4-1 excerpted from AISC 360. The corresponding AWS D1.1 Code reference location is also identified in the Table.

A **welding procedure specification (WPS)** is a document providing the required welding variables for a specific application to assure repeatability by properly trained welders. Per AWS D1.1 Clauses 3 and 4, qualification with respect to welding must occur for the welding procedure itself and the welder performing the work. *The welding contractor is responsible for all welding procedure paperwork and for qualification of welding personnel.*



- ✓ A weld procedure precedes the welder qualification
- ✓ The weld procedure must proceed the welding activity
- ✓ A welding procedure is performed to show the compatibility of the following:
 - Base metal(s)
 - Weld filler metal(s)
 - Weld processes
 - Welding technique(s)

TABLE C-N5.4-1 Inspection Tasks Prior to Welding	
Inspection Tasks Prior to Welding	AWS D1.1/D1.1M References*
Welding procedure specifications (WPSs) available	6.3
Manufacturer certifications for welding consumables available	6.2
Material identification (type/grade)	6.2
Welder identification system	6.4 (welder qualification) (identification system not required by AWS D1.1/D1.1M)
Fit-up of groove welds (including joint geometry) <ul style="list-style-type: none"> • Joint preparation • Dimensions (alignment, root opening, root face, bevel) • Cleanliness (condition of steel surfaces) • Tacking (tack weld quality and location) • Backing type and fit (if applicable) 	6.5.2 5.22 5.15 5.18 5.10, 5.22.1.1
Configuration and finish of access holes	6.5.2, 5.17 (also see Section J1.6)
Fit-up of fillet welds <ul style="list-style-type: none"> • Dimensions (alignment, gaps at root) • Cleanliness (condition of steel surfaces) • Tacking (tack weld quality and location) 	5.22.1 5.15 5.18
Check welding equipment	6.2, 5.11
*AWS (2010)	

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There are three general approaches to welding procedure qualification per the AWS D.1 Code:

1. Prequalified procedures (Clause 3 of AWS D1.1)
2. Actual procedure qualification testing (Clause 4 of AWS D1.1 - not addressed in this article)
3. Mock-up tests for special applications (not addressed in this article)

Qualification of Procedures and Welder Steps



There are numerous welding procedure specifications which are prequalified. This means that a qualification test for the weld procedure is not required. AWS D1.1 Figures 3.3 and 3.4 provides prequalified procedures covering joints, processes, and positions:

Joints

Butt
Corner
Tee

Processes

Shielded metal arc welding (SMAW)
Flux cored arc welding (FCAW)
Other

Positions

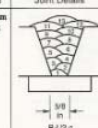
Flat, F
Horizontal, H
Vertical, V
Overhead, OH

Welds

Filletlets
Partial joint penetration (PJP)
Complete joint penetration (CJP)

A welding procedure specification should include the following at a minimum:

- ✓ Company Name
- ✓ Welding Process
- ✓ Supporting PQR's if applicable
- ✓ Identification No.
- ✓ Revision No.
- ✓ Date
- ✓ Authorizing Individual
- ✓ Joint Design
- ✓ Base Metals
- ✓ Filler Metals
- ✓ Shielding
- ✓ Preheat
- ✓ Position
- ✓ Electrical Characteristics
- ✓ Technique

WELDING PROCEDURE SPECIFICATION (WPS) Yes <input checked="" type="checkbox"/> PREQUALIFIED <input checked="" type="checkbox"/> QUALIFIED BY TESTING									
or PROCEDURE QUALIFICATION RECORDS (PQR) Yes <input type="checkbox"/>									
Company Name: LECO					Identification #: W2081				
Welding Process(es): SAW					Revision: 2 Date: 1-3-89 By: R. Jones				
Supporting PQR No. (s): Prequalified					Authorized by: C. W. Hayes Date: 1-3-89				
					Type: Manual <input type="checkbox"/> Machine <input checked="" type="checkbox"/> Semi-automatic <input type="checkbox"/> Automatic <input type="checkbox"/>				
JOINT DESIGN USED					POSITION				
Type: Butt					Position of Groove: F Fillet: --				
Single <input checked="" type="checkbox"/> Double Weld <input type="checkbox"/>					Vertical Progression: Up <input type="checkbox"/> Down <input type="checkbox"/>				
Backing: Yes <input checked="" type="checkbox"/> No <input type="checkbox"/>					ELECTRICAL CHARACTERISTICS				
Backing Material: ASTM A 36					Transfer Mode (GMAW): Short-Circuiting <input type="checkbox"/>				
Root Opening: 3/8" Root Face Dimension: --					Globular <input type="checkbox"/> Spray <input type="checkbox"/>				
Groove Angle: 30° Radius (J-U): --					Current: AC <input type="checkbox"/> DCEP <input checked="" type="checkbox"/> DCEN <input type="checkbox"/> Pulsed <input type="checkbox"/>				
Back Gouging: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> Method: --					Power Source: DC <input type="checkbox"/> CV <input type="checkbox"/>				
BASE METALS					Other: --				
Material Spec.: ASTM A 36					Tungsten Electrode (GTAW): --				
Type or Grade: --					Size: --				
Thickness: Groove 1" Fillet --					Type: --				
Diameter (Pipe): --					TECHNIQUE				
FILLER METALS					Stringer or Weave Bead: Stringer				
AWS Specification: A5.17					Multi-pass or Single Pass (per side): Multiple				
AWS Classification: EH12K					Number of Electrodes: 3				
SHIELDING					Electrode Spacing: Longitudinal --				
Flux: 880					Lateral --				
Gas: --					Angle: --				
Electrode-Flux (Class): --					Contact Tube to Work Distance: 1-3/4"				
Composition: --					Peening: None				
Electrode (Class): E70A2-EH12K					Interpass Cleaning: Slag Removed				
Flow Rate: --					POSTWELD HEAT TREATMENT				
Gas Cup Size: --					Temp: 8.A.				
PREHEAT					Time: --				
Preheat Temp., Min.: 150°F									
Interpass Temp., Min.: 150°F Max.: 350°F									
WELDING PROCEDURE									
Pass or Weld Layer(s)	Process	Class	Dim.	Type & Polarity	Current	Amperage or Wire Feed Speed	Volts	Travel Speed	Joint Details
1-a	SAW	EH12K	5/32"	DC+	45 ipm 550 Aavg ±10%	28 V ±7%	16 ipm ±15%		

Sample WPS

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If your welding procedure specification is prequalified, you do **NOT** need a qualification test for the procedure. However, a written WPS is still required to be on file. The CWI is required to confirm that you have procedures for each welding process (stick or wire welding) and joint being utilized. Just having your original test procedures will most likely NOT cover you depending on the project requirements. Your WPS documents should be on site and readily available for the CWI to review upon request.



FCAW E81T1 Wire

A **welding consumable** typically refers to the electrode providing the filler material for the welded joint. Typical stick electrodes (shielded metal arc welding – SMAW) are E7018 or E8018. Typical wire electrodes (flux-cored arc welding – FCAW) are E71T or E81T. The basic difference is the strength of the stick electrode or wire. While the choice of SMAW versus FCAW is entirely up to the welder, the CWI will confirm what filler metal strength is being used against the project requirements and what is required by the Code.

The **material identification** identifies the type and grade (strength) of the material. The CWI will ask for the material certifications which are provided by the material supplier. The certification should identify the American Society of Testing and Materials (ASTM) designation for the material and the type and grade. AWS D1.1 Table 3.1 identifies prequalified base metal – filler metal combinations for matching strength. The base metal/filler metal strength is specified by the design engineer and is critical to ensuring the performance of the final welded component. It is the CWI's job to ensure that the welder is using the correct filler metal for the materials that are being joined.

AWS defines **fit-up** as the as-fit joint geometry of the members being welding together. Joint geometry is critical to the integrity of the final welded connection and to remaining within the D1.1 Code's prequalified joint parameters. In other words, if the root gap between parts is too large, then it will be outside what is permitted by the code for a prequalified joint and a qualification will be required for the weld. Poor fit-up almost always causes weld quality issues and discontinuities as previously discussed.



Root Gap to Base Plate Below Anchor Rod Bracket

Areas of concern for the CWI related to fit-up:

- ✓ Joint preparation
- ✓ Dimensions (alignment, root opening, bevel, etc.)
- ✓ Cleanliness
- ✓ Tacking
- ✓ Backing type and fit

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Weld fit-up is critical for all types of welds – both groove welds and fillet welds alike. If the CWI can identify a fit-up issue prior to welding, then you will improve your chances for a sound weld and no discontinuities and/or defects requiring repair.

Inspection Tasks During Welding

Inspection tasks **DURING** welding encompass qualification of welders, control and handling of welding consumables, environmental conditions, adherence to WPS, and welding techniques. This is outlined in Table C-N5.4-2 excerpted from AISC 360 with corresponding AWS D1.1 Code reference.

Welder Performance Qualification Record or welder certification as typically used is a written verification that a welder has produced welds meeting a prescribed standard of welder performance. This is often called the welder's certification paperwork.



A welder certification should include the following items:

- ✓ Company name
- ✓ Welding procedure no.
- ✓ Identification no.
- ✓ Revision no.
- ✓ Date
- ✓ Authorizing individual & date
- ✓ Variables
- ✓ Visual inspection results
- ✓ Fillet test results
- ✓ Radiographic test results
- ✓ Inspector name, organization, signature

TABLE C-N5.4-2 Inspection Tasks During Welding	
Inspection Tasks During Welding	AWS D1.1/D1.1M References*
Use of qualified welders	6.4
Control and handling of welding consumables <ul style="list-style-type: none">• Packaging• Exposure control	6.2 5.3.1 5.3.2 (for SMAW), 5.3.3 (for SAW)
No welding over cracked tack welds	5.18
Environmental conditions <ul style="list-style-type: none">• Wind speed within limits• Precipitation and temperature	5.12.1 5.12.2
WPS followed <ul style="list-style-type: none">• Settings on welding equipment• Travel speed• Selected welding materials• Shielding gas type/flow rate• Preheat applied• Interpass temperature maintained (min/max.)• Proper position (F, V, H, OH)	6.3.3, 6.5.2, 5.5, 5.21 5.6, 5.7
Welding techniques <ul style="list-style-type: none">• Interpass and final cleaning• Each pass within profile limitations• Each pass meets quality requirements	6.5.2, 6.5.3, 5.24 5.30.1
*AWS (2010)	

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A CWI will check the welder's documentation and make sure that the welder is qualified to perform the welds with the process being utilized and in the position and progression required.

Control and handling of welding consumables is critical to the integrity of the final welded product. Welding electrodes must be properly stored prior to arriving at site and while on site. SMAW electrodes with low hydrogen coatings, such as E8018 must be kept very dry since hydrogen induced cracking can easily occur when moisture is absorbed. After electrode cans are opened, electrodes that will not be immediately used should be placed in a rod oven. Electrodes should be removed in quantities that can be consumed within time limits that are dependent on the electrode. When the hermetic seal is broken, (either deliberately such as when a can is opened, or accidentally as when a can is punctured) a can of low hydrogen SMAW electrodes must be re-dried. If you are using SMAW electrodes, the CWI will confirm you are using a rod oven, the oven is at the appropriate temperature, or you are using low quantity boxes of electrodes and using an entire box at a time. FCAW welding wire must be protected from exposure to the atmosphere in order to maintain hydrogen levels as low as possible, prevent rusting of the product, and prevent porosity during welding.

Welding in less than ideal **environmental conditions** will almost always cause quality issues and discontinuities. AWS D1.1 5.12 specifies a maximum wind velocity of 5 mph in the vicinity of the weld for wire-related welding processes unless the weld is protected with a shelter. Also per D1.1 5.12, welding shall not be performed if the area of the weld is less than 0 degrees Fahrenheit or when the surfaces are wet or exposed to rain, snow, high wind velocities, or when the welder is exposed to inclement conditions.



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Although a WPS may exist, the WPS does no good if the document is not present in the field or being followed. A crucial component to the CWI's field tasks is ensuring the **WPS is being followed** in the field.

Are the settings correct on the welding equipment?

- ✓ Is the travel speed correct?
- ✓ Do the selected welding materials match those being used?
- ✓ Does the shielding gas type/flow rate match?
- ✓ Is preheat being performed?
- ✓ Are interpass temperatures being maintained?
- ✓ Is the proper welding position being used (F, V, H, OH)?



Checking Preheat

A critical component of the CWI's job is to check preheat during the welding process. Preheat is critical to the integrity of a good weld by slowing the **rate of cooling** after welding which improves ductility and helps to prevent the development of cracks. Preheating should always be done regardless of ambient temperature. AWS D1.1 Table 3.2 identifies minimum preheat temperatures based on steel specification, welding process, and thickness of the parts being joined. The CWI checks this process with a laser or temp sticks. Simple but often overlooked, preheating per the Code helps ensure a quality final product.

Proper **welding techniques** will ensure a sound product and passing CWI report. Interpass and final cleaning, proper weld profile, and attention to each pass will ensure a sound weld. The CWI will witness the welder's technique, cleaning, and each pass.



Root Pass



Interpass Cleaning

Inspection Tasks After Welding

Inspection tasks **AFTER** welding encompass weld cleaning, checking size, length, and location of the welds, visual acceptance, arc strikes, repair activities, and reporting. These steps are outlined in Table C-N5.4-3 excerpted from AISC 360. As before, the corresponding AWS D1.1 Code section is also identified for reference.

While all inspection tasks are equally crucial, most people are familiar with this phase of inspection. When the CWI performs the 'after' or final phase of his inspections, they will be looking for the following:

- ✓ Are the welds clean of slag, oil, grease?
- ✓ Do the weld sizes, lengths, and locations match the drawings?
- ✓ Are there deviations from the drawings? If so, is there engineering approval?
- ✓ Do the welds meet the visual acceptance criteria outlined in AWS D1.1 Table 6.1? Remember, we discussed discontinuities and defects in our last PAN.
- ✓ Are any repair activities required? If so, are they acceptable?
- ✓ Reporting - document acceptance or rejection with photos



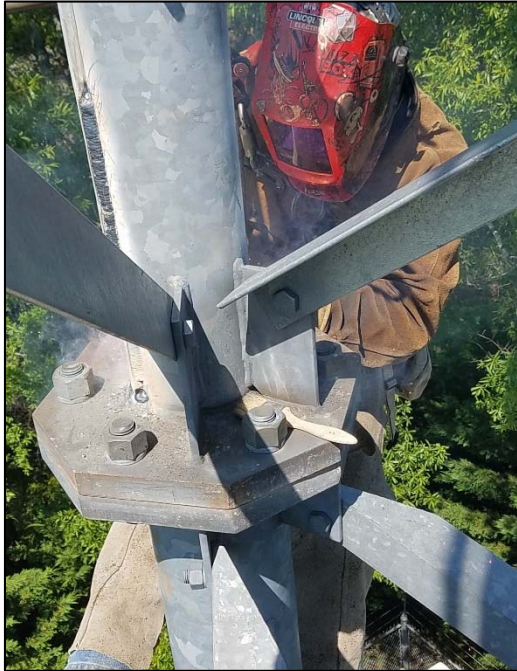
TABLE C-N5.4-3
Inspection Tasks After Welding

Inspection Tasks After Welding	AWS D1.1/D1.1M References**
Welds cleaned	5.30.1
Size, length and location of welds	6.5.1
Welds meet visual acceptance criteria <ul style="list-style-type: none"> • Crack prohibition • Weld/base-metal fusion • Crater cross section • Weld profiles • Weld size • Undercut • Porosity 	6.5.3 Table 6.1(1) Table 6.1(2) Table 6.1(3) Table 6.1(4), 5.24 Table 6.1(6) Table 6.1(7) Table 6.1(8)
Arc strikes	5.29
k-area*	not addressed in AWS
Backing removed and weld tabs removed (if required)	5.10, 5.31
Repair activities	6.5.3, 5.26
Document acceptance or rejection of welded joint or member	6.5.4, 6.5.5

* k-area issues were identified in AISC (1997b). See Commentary Section A3.1c and Section J10.8.
** AWS (2010)

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Summary and Conclusion



Detailed inspection tasks and quality inspection throughout your project is essential and gives you the greatest chance of providing a finished welded product that complies with the AWS Code D1.1, the project specifications, and your customer's expectations. Inspection **prior** to welding, **during** welding, and **after** the welding process is completed is required. AISC 360-10 contains helpful weld inspection activity tables for each phase of the inspection process. Each required inspection task is referenced back to the corresponding clause in AWS D1.1-2010 – a very helpful tool for everyone involved in the project. Following these recommendations and steps will greatly increase your chances of receiving a passing CWI report at the conclusion of your project.

References

1. American National Standards Institute/American Institute of Steel Construction (ANSI/AISC). (2010). ANSI/AISC 360-10 Specification for Structural Steel Buildings, Chicago, IL.
2. American Welding Society (AWS). (2010). AWS A3.0M/A3.0: 2010 Standard Welding Terms and Definitions, Miami, FL.
3. American Welding Society (AWS). (2010). AWS D1.1/D1.1M: 2010 Structural Welding Code – Steel, Miami, FL.
4. American Welding Society (AWS) Education Department. (2008). Welding Inspection Technology (WIT), 5th Edition, Miami, FL.