Weld Quality

Welding Qualification & Certification
Lecture Scope

- Need for welding qualification
- Codes & standards requirements
  - Welding procedure specifications
  - Welding procedure qualification
  - Welding operator qualification
- Company certification
Need For Weld Qualification

- Many variables influence weld quality, related to the parts to be joined, the welding process and welding operator skill

- The purpose of qualification is to demonstrate that welding procedures and personnel are adequately controlled and are capable of acceptable results

- Such tests cannot foretell performance in production. Quality of the production welds should be determined by inspection during and after the actual welding.
Codes & Standards

- Application codes & standards that specify qualification requirements for welding include:
  - ASME Boiler and Pressure Vessel Code
  - AWS D1.1 Structural Welding Code
  - ANSI B31 Power Piping Code
  - API 1104 Standard for Welding Pipelines and Related Facilities
  - CSA W59 Standard for Welded Steel Construction

- Standards for weld qualification
  - AWS B2.1 Welding Procedure and Performance Qualification
Codes & Standards Requirements

- A common approach to qualify welding procedures is by preparation and testing of standard test pieces. The qualification tests need not be repeated unless the welding procedure specification is changed.

- Some pressure vessel standards require test plates to be welded at the same time as the vessel seams and subsequently tested.

- Other standards accept certain welding procedures as "prequalified"
Welding Procedure Specification

- Standards normally require the contractor to prepare and qualify Welding Procedure Specifications (WPS)

- A WPS should define the welding variables in sufficient detail to ensure that the required quality is met

- Standards differ with respect to the generality or specificity of WPS
  - Some standards are very specific in defining the content of a WPS e.g. ASME Section IX. Other standards are more general
Welding Procedure Specifications

Typical WPS Contents

- Scope
- Base metal
  - to simplify qualifications, standards often group base metals by similar composition or strength levels
- Welding process
- Filler metal
- Type of current and range
- Arc voltage
- Travel speed
- Heat input

- Joint preparation
- Welding details
- Welding positions
- Preheat & interpass temperatures
- Post weld heat treatment and finishing
ASME Sample WPS
QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATIONS (WPS)
(See CW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

<table>
<thead>
<tr>
<th>JOINTS (QW-402)</th>
<th>V- GROOVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Design</td>
<td>V</td>
</tr>
<tr>
<td>Backing Type</td>
<td>X</td>
</tr>
<tr>
<td>Backing Material Type</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Sketch. Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of weld groove may be specified.

(At the option of the Mgr., sketches may be attached to illustrate joint design, weld layers and travel sequence, e.g. for notch toughness procedures, for multiple pass procedures, etc.)

**BASE METALS (QW-403)**

<table>
<thead>
<tr>
<th>F-No.</th>
<th>Group No. 1 to F-No.</th>
<th>Group No. 2</th>
</tr>
</thead>
</table>

Specification type and grade: SA 106 Cr B
Thickness Range:

**FILLER METALS (QW-404)**

<table>
<thead>
<tr>
<th>Spec. No. (SFA)</th>
<th>AWS No. (Class)</th>
<th>F-No.</th>
<th>A-No.</th>
<th>Size of Filler Metals</th>
</tr>
</thead>
</table>

Weld Metal

Thickness Range: Passe 1 to 2
Electrode-Flux (Class) N/A
Flux Trade Name N/A
Consumable Insert N/A

*Each base metal-filler metal combination should be recorded individually.*

This form (QW-0006) may be obtained from the Order Dept., ASME, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300
**POSTWELD HEAT TREATMENT (QW-407)**
- Temperature Range: None
- Time Range: N/A

**GAS (QW-408)**
- Percent Composition
  - Shielding: Argon
  - Flow Rate: 7 L/min
  - Trailing: N/A
  - Backing: Argon
- Flow Rate: 5 L/min

**ELECTRICAL CHARACTERISTICS (QW-409)**
- Current AC or DC: SEE BELOW
- Amperes (Range): 5-10A
- Volts (Range): 24-36V

- Tungsten Electrode Size and Type: EWTH-2 (ANS 5.12) 1/8" (Pure Tungsten, 2% Ceriated, etc.)
- Mode of Metal Transfer for GMAW: N/A
- (Spray arc, short circuiting arc, etc.)
- Electrode Wire feed speed range: N/A

**TECHNIQUE (QW-410)**
- String: STRING
- Wire Cup Size: #2
- Initial and Interpass Gouging (Brushing, Grinding, etc.): REMOVE RUST ETC TO 25 MM FROM WELD PREP BY WIRE BRUSH
- Method of Back Gouging: N/A
- Occlusion: NONE
- Contact Tube to Work Distance: MULTIPLE
- Multiple or Single Pass (per side): SINGLE
- Multiple or Single Electrodes: SINGLE 1-5 MM/S
- Travel Speed (Range): 1-5 MM/S
- Penetration: N/A
- Other: VISUALLY INSPECT EACH PASS FOR ACCEPTABLE PROFILE OR DEFECTS AFTER CLEANING

<table>
<thead>
<tr>
<th>Weld Layer(s)</th>
<th>Process</th>
<th>Class</th>
<th>Dia.</th>
<th>Type</th>
<th>Polarity</th>
<th>Amp. Range</th>
<th>Volt Range</th>
<th>Travel Speed Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>EWTH</td>
<td>ER70S2</td>
<td>2.4MM</td>
<td>DCEN</td>
<td>150-200</td>
<td>10-15</td>
<td>2.4 M/M/S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SMAW</td>
<td>ER7018</td>
<td>3-4MM</td>
<td>DCEP</td>
<td>120-180</td>
<td>22-25</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

**POSITIONS (QW-405)**
- Position(s) of Groove: 5G
- Welding Progression: Up
- Position(s) of Filler: X

**PREHEAT (QW-406)**
- Preheat Temp. Min.: 200°F
- Interpass Temp. Max.: 260°F
- Preheat Maintenance: PROPANE TORCH
- (Continuous or special heating where applicable should be recorded)
WPS Qualification

- The purpose of qualification is to show that welding in accordance with the WPS will produce sound welds with adequate properties.

- The WPS qualification requirements are specified by the applicable standard.

- Qualification may be achieved by:
  1. Use of prequalified welding procedures
  2. Qualification tests
  3. Mock-up tests
WPS Qualification

- Prequalified welding procedures
  - The concept of prequalification is based on the reliability of certain proven procedures as defined by the code or standard (e.g. CSA W59, AWS D1.1)
  - The contractor is nevertheless required to prepare WPS documents and to accept responsibility for their use.
  - Any deviation from the standard negates the prequalified status
WPS Qualification

- Prequalified welding procedures

- Qualification tests
  - Qualification tests are intended to demonstrate that the welding procedure results in sound welds with acceptable mechanical properties
  - Tests need not simulate the actual conditions for a given job. They usually consist of conventional butt joints on plates or pipes
  - Base and filler materials, welding variables and heat treatments must follow production plans within specified ranges.
  - However, other variables such as joint geometry or welding position might not be considered as qualification variables
WPS Qualification

- Prequalified welding procedures
- Qualification tests
- Mock-up tests
  - Mock-up tests are intended to simulate actual production or field conditions.
  - Codes and standards do not require preparation of welded mock-ups
  - However, mock-ups can help to anticipate or avoid problems in production. They are also useful when difficult access or other practical considerations may influence results in-situ, such as repair welding of nuclear plants.
Tests of Qualification Welds

- Specimens are removed from the sample welds for examination and testing.
- The type and number of tests depend on the requirements of the particular standard.
- Commonly specified tests include:
  - tensile tests
  - guided bend tests
  - Charpy notch toughness tests, or other fracture toughness tests such as drop weight tests
  - macro-etch tests
  - non-destructive examination
Mechanical Test Specimens

- Identical Dimensions
- Longitudinal Weld Specimen
- Transverse Specimen
- Charpy Specimen
- Miniature Round Specimens Depending on T

Gage Length
Face & Root Bend Tests

WELD JOINT

FACE BEND
ROOT BEND
SIDE BEND

ROOT BEND

FACE BEND

SIDE BEND
Guided Bend Test Jigs

(A) Guided Bend Test Jig

(B) Wrap-Around Bend Test Jig

T = SPECIMEN THICKNESS

PLUNGER

SHOULDERS OR ROLLERS

2A = 2(1"-1/16 in.)

(1.5 mm)

3/4 in. min

(19 mm)

CLAMP

ROLLER

T = SPECIMEN THICKNESS

1/16 in.

(1.6 mm)

3/4 in. min

(19 mm)
Charpy Impact Specimen

- 1.082 in. (27.5 mm)
- 2.165 in. (55 mm)
- 0.394 in. (10 mm)
- 0.079 in. (2 mm)
- R = 0.010 in. (0.254 mm)
- 45° ± 1°
Recording Test Results

- The welding conditions and the test results are entered on a Procedure Qualification Record (PQR)
- If the test results meet the requirements of the standard, the PQR is certified by the contractor and the third-party inspector
- The WPS may then be issued for production
QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORD (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure Vessel Code)

Record Actual Conditions Used to Weld Test Coupon.

Company Name: ABC INC
Procedure Qualification Record No: PQR 0123
WPS No: WPS 9/22
Welding Process(es): GTAW, SMAW
Types (Manual, Automatic, Semi-Auto): MANUAL

JOINTS (QW-402)

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal that should be requested for each filler metal or process used.)

BASE METALS (QW-403)
Material Spec: SA 106
Type or Grade: E.R. B
P-No. 1 to P-No. 1
Thickness of Test Coupon: 0.148 in
Diameter of Test Coupon: 6 NPS pipe

POST-WELD HEAT TREATMENT (QW-407)
NONE

AS (QW-408)
Percent Composition
Shading
Argon
Topping
Ar-Gon

ELECTRICAL CHARACTERISTICS (QW-409)
Current: DCEP (GTAW) DEEP (SMAW)
Polarity: DCEN (GTAW)
Amps: Volts
Tungsten Electrode Size: E6TH-2.5 MM

FILLER METALS (QW-404)
AWS Classification: ER710S2
Filler Metal F-No.: 4
Weld Metal Analysis A-No.: 4
Size of Filler Metal: 3.4 MM
Weld Metal Thickness: PASS6S1/02 REMAINDER

POSITION (QW-405)
Position of Groove: 6
Weld Progression (Uphill, Downhill): UP

PREHEAT (QW-406)
Preheat Temp: 200°C
Interpass Temp: 260°C MAX

TECHNIQUE (QW-410)
Travel Speed: 1 - 3 MM/S
String or Weave Bead: STRONG
Oscillation: NONE
Multiple or Single Pass (per side): MULTIPLE
Single or Multiple Electodes: SINGLE

This form (EOI 007) may be obtained from the Order Dept., ASME, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300
### Tensile Test (QW-150)

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Width</th>
<th>Thickness</th>
<th>Area</th>
<th>Ultimate Total Load N ( \times 10^4 )</th>
<th>Ultimate Unit Stress ( \text{psi} )</th>
<th>Type of Failure &amp; Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.3</td>
<td>6.5</td>
<td>162.4</td>
<td>86.5</td>
<td>5.6</td>
<td>B.M. Ductile</td>
</tr>
<tr>
<td>2</td>
<td>15.4</td>
<td>6.7</td>
<td>162.2</td>
<td>85.8</td>
<td>5.7</td>
<td>B.M. Ductile</td>
</tr>
<tr>
<td>3</td>
<td>15.8</td>
<td>8.4</td>
<td>158.7</td>
<td>81.3</td>
<td>5.1</td>
<td>B.M. Ductile</td>
</tr>
<tr>
<td>4</td>
<td>17.2</td>
<td>8.3</td>
<td>154.3</td>
<td>81.4</td>
<td>5.0</td>
<td>B.M. Ductile</td>
</tr>
</tbody>
</table>

### Guided-Bend Tests (QW-160)

<table>
<thead>
<tr>
<th>Type and Figure No.</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACE</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>ROOT</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>FACE</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>ROOT</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

### Toughness Tests (QW-170)

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Notch Location</th>
<th>Notch Type</th>
<th>Test Temp.</th>
<th>Impact Values</th>
<th>Lateral Exp.</th>
<th>Drop Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Net-Weld Test (QW-180)

- **Result**: Satisfactory; Yes N/A No
- **Penetration into Parent Metal**: Yes
- **Macro-Results**: 

### Other Tests

- **Type of Test**: N/A
- **Deposit Analysis**:  
- **Other**: 

**Welder's Name**: A. WELDER  
**Clock No.**:  
**Stamp No.**: HL-3  
**Laboratory Test No.**: 789  
**Tests conducted by**: B. TECH.  
**We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.**  
**Manufacturer**: RESPONSIBLE MANAGER  
**Date**: 9/10/31  
**By**:  

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)
Changes in a qualified WPS

- If a WPS is to be revised or modified beyond the qualified ranges of the "essential variables" it is necessary to do additional qualification tests.
- If the changes are within the qualified ranges of essential variables, then a revised WPS can be issued without requalification.
- A PQR may support several WPS.
- Since the PQR is a certified record of a qualification test, it should not be revised.
Welder Performance Qualification

- Welder or welding operator qualification tests are performed to determine the ability of the persons tested to produce acceptable welds.
Performance Qualification Req'ts

- Most standards require each welder or welding operator to make one or more test welds in plate or pipe

- Variables that affect the ability of welders to make sound welds are considered qualification variables. These include:
  - welding process
  - filler metal
  - welding position
  - joint detail
  - plate thickness
  - welding technique
Standard Welding Positions - Plates

Test Position 1G

Test Position 2G

Test Position 3G

Test Position 4G
Welding Positions-Pipes

Test Position 1G

Test Position 2G

Test Position 5G

Test Position 6G
Performance Qualification Tests

- Test specimens may be groove welds or fillet welds
  - groove weld qualification usually qualifies the operator to weld both groove and fillet welds
  - fillet weld qualification limits the welder to fillet welds in only the position qualified or less difficult positions

- Tests consist of either bend tests, macro-etch tests or radiography

- The welder who prepares a test plate for a procedure qualification is usually qualified within the variables in the WPS.
Performance Qualification Records

- Responsibility for performance qualification records lies with the employer.

- After successful qualification of a welder the employer and third party inspector certify the performance qualification record.

- Most codes limit the duration of qualification to three to six months inactivity.

- For most codes qualification may be extended indefinitely provided the welder performs satisfactory work within the stated period.
Company Certification

- Some standards extend qualification to the company's organisational practices
  - ASME Boiler and Pressure Vessel Code
    - requires audit by ASME of a company's quality control program before issuing a code symbol stamp for construction of components
    - Section III for nuclear components requires a quality assurance program
  - CSA W59 / W47.1
    - requires employment of designated welding engineers and welding supervisors, and preparation of welding standards and WPS audited by Canadian Welding Bureau
  - ISO 9000
    - generalized quality assurance program