## Weld Quality

# Welding Qualification & Certification

# Lecture Scope

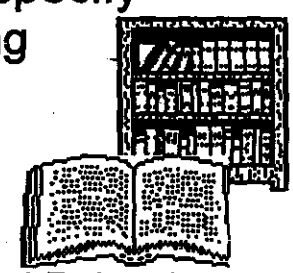
- Need for welding qualification
- Codes & standards requirements
  - Welding procedure specifications
  - Welding procedure qualification
  - Welding operator qualification
- Company certification

# 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 QW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name AISC INC. By: T.M. GRANT
Welding Procedure Specification No. WPS 0123 Date 97.10.31 Supporting PQR No.(s) PQR 0123
Revision No. 0 Date
Welding Process(es) GTAW, SMAW Type(s) MANUAL (Automatic, Manual, Machine, or Semi-Auto.)

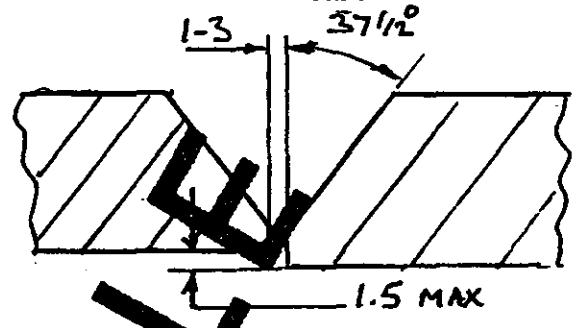
JOINTS (QW-402) V-GROOVE
Joint Design
Backing (Yes) (No) X
Backing Material (Type) NIL
(Refer to both backing and retainers.)

☐ Metal ☐ Nonfusing Metal
☐ Nonmetallic ☐ Other

Sketches, 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 Mfgr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc.)

Details




*BASE METALS (QW-403)
P-No. 1 Group No. 1 to P-No. 1 Group No. 1
OR
Specification type and grade SA 106 Gr B
to Specification type and grade SA 106 Gr B
OR
Chem. Analysis and Mech. Prop.
to Chem. Analysis and Mech. Prop.
Thickness Range:
Base Metal: Groove 4.7 mm - 19 mm Fillet
Pipe Dia. Range: Groove ALL Fillet
Other

| *FILLER METALS (QW-404) | | | |
|---|---|---|---|
| Spec. No. (SFA) | SFA 5.28 | SFA 5.1 | |
| AWS No. (Class) | ER 70S-2 | E7018 | |
| F-No. | 4 | 4 | |
| A-No. | 1 | 1 | |
| Size of Filler Metals | 2.4 mm | 3-4 mm | |
| Weld Metal Thickness Range: Groove | PASSES 1 & 2 | REMAINDER. | |
| Fillet | | | |
| Electrode-Flux (Class) | N/A | | |
| Flux Trade Name | N/A | | |
| Consumable Insert | N/A | | |
| Other | | | |

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

This form (E00006) may be obtained from the Order Dept., ASME, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

## QW-482 (Back)

WPS No. 0123 Rev. 97.10.31

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

**POSTWELD HEAT TREATMENT (QW-407)**
Temperature Range NONE
Time Range N/A

**PREHEAT (QW-406)**
Preheat Temp. Min. 20°C
Interpass Temp. Max. 260°C
Preheat Maintenance PROPANE TORCH
(Continuous or special heating where applicable should be recorded)

**GAS (QW-408)**

| | Gas(es) | Percent Composition (Mixture) | Flow Rate |
|---|---|---|---|
| Shielding | ARGON | | 7 L/min |
| Trailing | N/A | | |
| Backing | ARGON | | 5 L/MIN |

**ELECTRICAL CHARACTERISTICS (QW-409)**
Current AC or DC SEE BELOW Polarity
Amps (Range) 6 Volts (Range)
(Amps and volts range should be recorded for each electrode size, position, and thickness, etc. This information may be listed in a tabular form similar to that shown below.)
Tungsten Electrode Size and Type EWTH-2 (AWS 5.12) 1/8" DIA. (Pure Tungsten, 2% Thoriated, 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 or Weave Bead STRING
Orifice or Gas Cup Size #2
Initial and Interpass Cleaning (Brushing, Grinding, etc.) REMOVE RUST ETC TO 25 MM FROM WELD PREP BY WIRE BRUSH
Method of Back Gouging N/A
Oscillation NONE
Contact Tube to Work Distance —
Multiple or Single Pass (per side) MULTIPLE
Multiple or Single Electrodes SINGLE
Travel Speed (Range) 1-5 MM/S
Peening NONE
Other VISUALLY INSPECT EACH PASS FOR ACCEPTABLE PROFILE & DEFECTS AFTER CLEANING

| Weld Layer(s) | Process | Filler Metal Class | Filler Metal Dia. | Current Type Polar. | Current Amp. Range | Volt Range | Travel Speed Range | Other (e.g., Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, Etc.) |
|---|---|---|---|---|---|---|---|---|
| 1-2 | GTAW | ER70S2 | 2.4 MM | DCEN | 150-200 | 10-15 | 2-4 MM/S | |
| REMAINDER | SMAW | E7018 | 3-4 MM | DCEP | 120/180 | 22-25 | — | |

SAMPLE

# 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

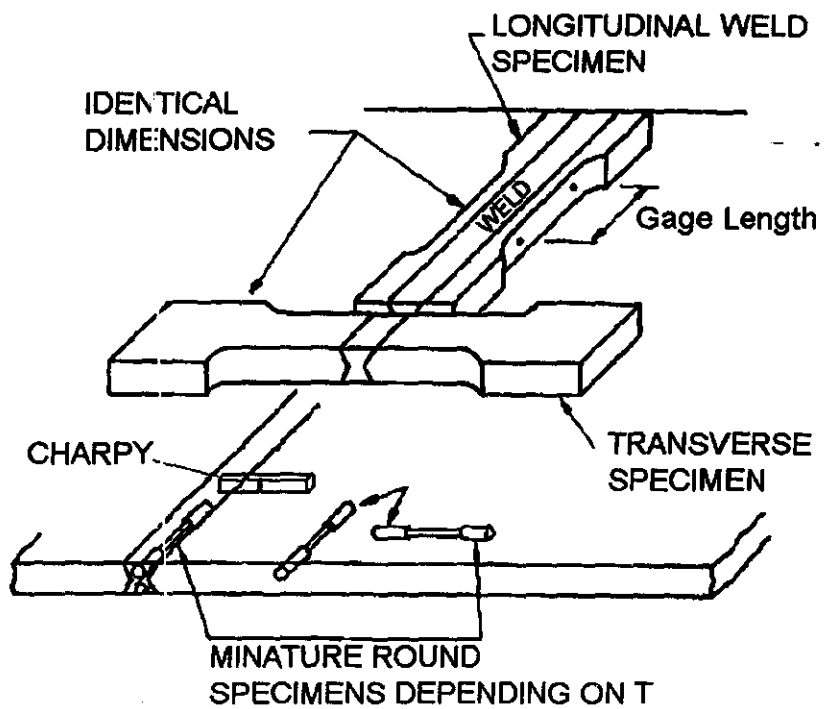
# WPS Qualification

- 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.

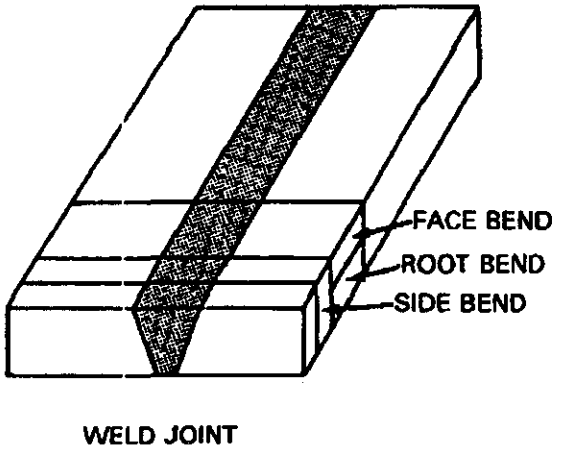
# Tests of Qualification Welds

- 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

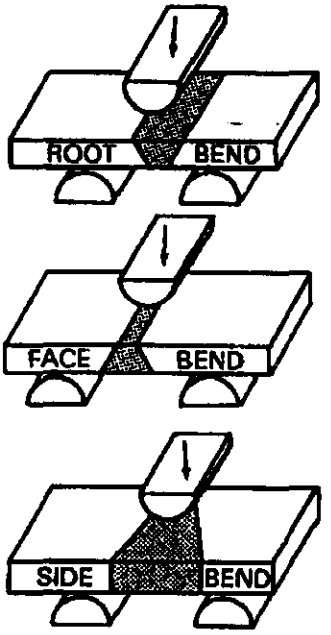
# Mechanical Test Specimens



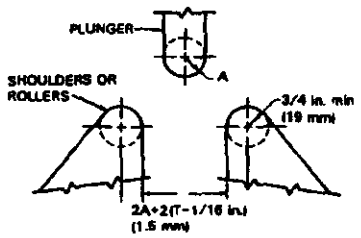
# Face & Root Bend Tests




WELD JOINT

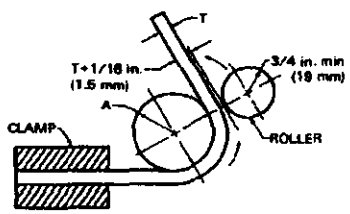


# Guided Bend Test Jigs




T = SPECIMEN THICKNESS

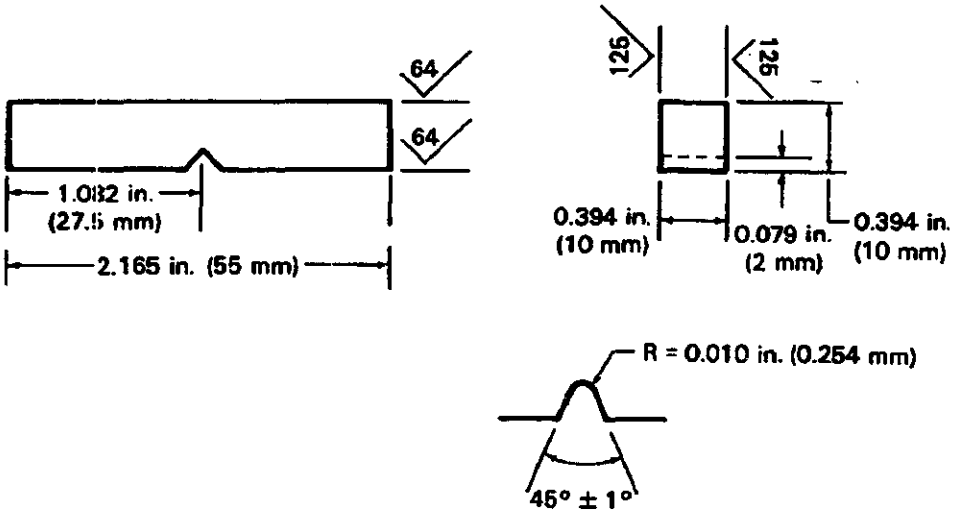
(A) Guided Bend Test Jig




T = SPECIMEN THICKNESS

(B) Wrap-Around Bend Test Jig

# Charpy Impact Specimen



# Recording Test Results

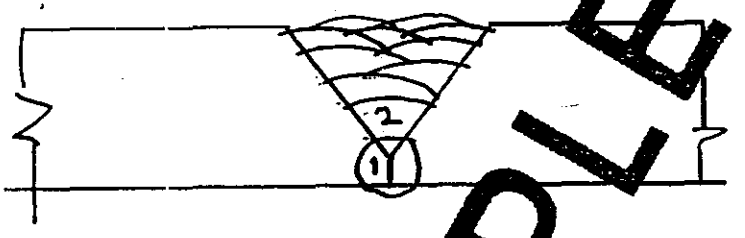
- The welding conditions and the test results are entered on a Procedure Qualification Record (PQR)
- If the test results meet the requirements of the standard, the PQR is certified by the contractor and the third-party inspector
- The WPS may then be issued for production

# ASME Sample PQR

## 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 Date: 97.10.31
WPS No.: WPS 0123
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 thickness shall be recorded for each filler metal or process used.)



**BASE METALS (QW-403)**
Material Spec.: SA 106
Type or Grade: GR. B
P-No.: 1 to P-No.: 1
Thickness of Test Coupon: 0.43 IN
Diameter of Test Coupon: 6 NPS PIPE
Other:

**POST-WELD HEAT TREATMENT (QW-407)**
Temperature: NONE
Time:
Other:

**GAS (QW-408)**

| | Gas(es) | Percent Composition (Mixture) | Flow Rate |
|---|---|---|---|
| Shielding | ARGON | — | 7 L/MIN |
| Trailing | | | |
| Backing | ARGON | — | 5 L/MIN |

**FILLER METALS (QW-404)**

| | | |
|---|---|---|
| SFA Specification | | |
| AWS Classification | ER70S2 | E7018 |
| Filler Metal F-No. | 4 | 4 |
| Weld Metal Analysis A-No. | 1 | 1 |
| Size of Filler Metal | 2.4 MM | 3-4 MM |
| Other | | |
| Weld Metal Thickness | PASSES 1&2 | REMAINDER |

**ELECTRICAL CHARACTERISTICS (QW-409)**
Current: DCEN (GTAW) DCEP (SMAW)
Polarity:
Amps. Volts:
Tungsten Electrode Size: EWTH-2 3 MM
Other:

**POSITION (QW-405)**
Position of Groove: 5G
Weld Progression (Uphill, Downhill): UP
Other:

**TECHNIQUE (QW-410)**
Travel Speed: 1-3 MM/S
String or Weave Bead: STRING
Oscillation: NONE
Multipass or Single Pass (per side): MULTIPLE
Single or Multiple Electrodes: SINGLE
Other:

**PREHEAT (QW-406)**
Preheat Temp.: 20°C
Interpass Temp.: 260°C MAX
Other:

This form (E00007) may be obtained from the Order Dept., ASME, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

## QW-483 (Back)

PQR No. _____

### Tensile Test (QW-150)

| Specimen No. | Width | Thickness | Area | Ultimate Total Load N lb $\times 10^3$ | Ultimate Unit Stress psi MPa | Type of Failure & Location |
|---|---|---|---|---|---|---|
| 1 | 19.3 | 8.5 | 163.9 | 84.5 | 517 | BM DUCTILE |
| 2 | 18.9 | 8.7 | 165.2 | 85.8 | 519 | BM DUCTILE |
| 3 | 19.9 | 8.4 | 158.7 | 81.8 | 514 | BM DUCTILE |
| 4 | 19.2 | 8.3 | 159.3 | 81.4 | 509 | BM DUCTILE |

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

| Type and Figure No. | Result |
|---|---|
| FACE | SATISFACTORY |
| ROOT | SATISFACTORY |
| FACE | SATISFACTORY |
| ROOT | SATISFACTORY |

### Toughness Tests (QW-170)

| Specimen No. | Notch Location | Notch Type | Test Temp. | Impact Values | Lateral Exp. % Shear | Lateral Exp. Mils | Drop Weight Break | Drop Weight No Break |
|---|---|---|---|---|---|---|---|---|
| NONE | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

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

Result — Satisfactory: Yes N/A No _____ Penetration into Parent Metal: Yes _____ No _____

Macro—Results _____

### Other Tests

Type of Test N/A

Deposit Analysis _____

Other _____

Welder's Name A. WELDER Clock No. _____ Stamp No. HL-3

Tests conducted by: B. TECH. Laboratory Test No. 789

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 97.10.31. 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.

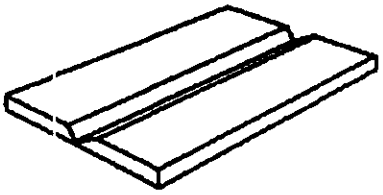
# Welder Performance Qualification

- Welder or welding operator qualification tests are performed to determine the ability of the persons tested to produce acceptable welds

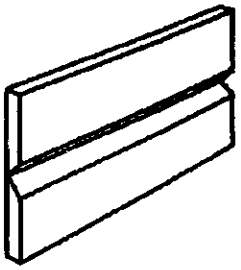
# Performance Qualification Req'ts

- 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

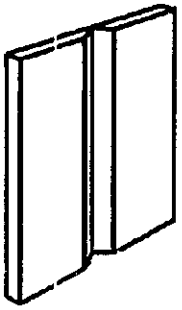
# Standard Welding Positions - Plates



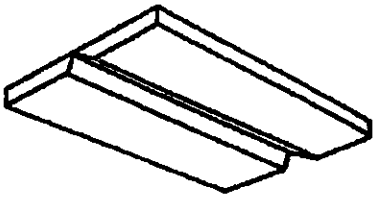
Test Position 1G



Test Position 2G



Test Position 3G



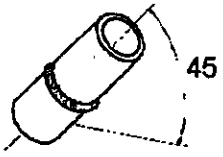
Test Position 4G

# 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