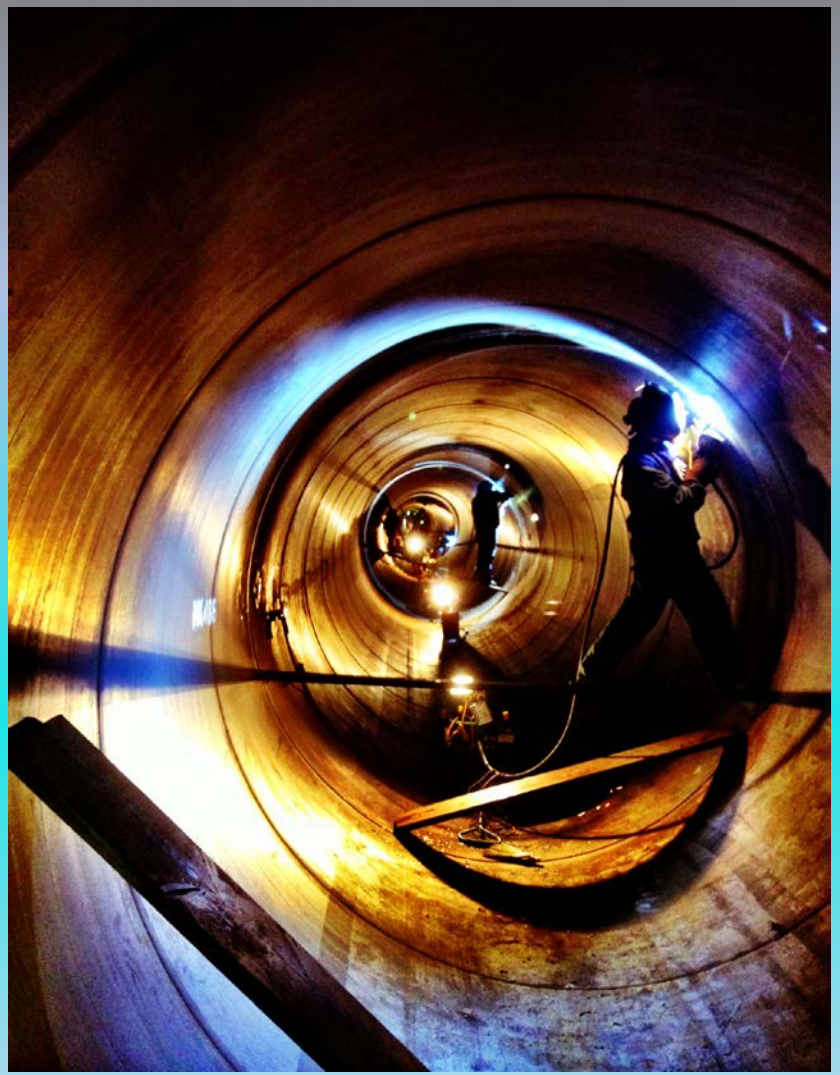
Welding of Large Diameter Pipelines: Design, Processes, Procedures Specifications for Welding Steel Water Pipe



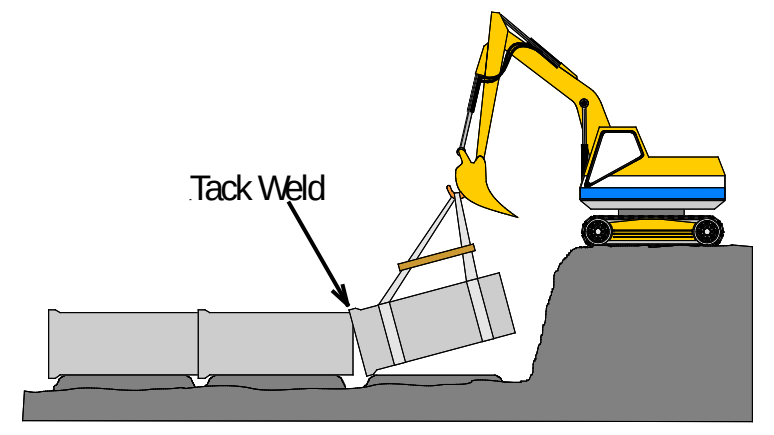
Field Welding of Steel Pipe Joints

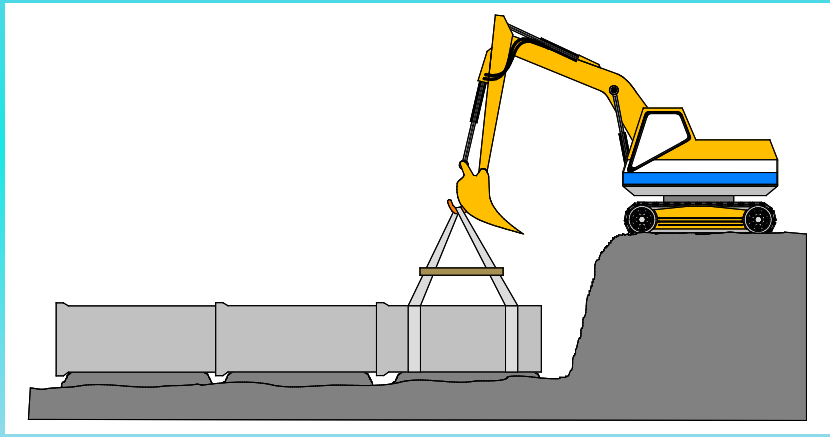
Nash Williams, Owner

National Welding Corporation

Steel Pipe Installation: Open Cut

- Stab depth should be marked generally 2”-3”
- Pipe is laid Bell onto Spigot
- Pipe is engaged at about a 10 degree angle.
- Tack weld made at Field Top which serves as hinge.
- Pipe lowered to proper grade and pulled into alignment. Stab is limited to 1” min. and no closer that 1” to bell tangent.





Graphics Courtesy AWWA

Steel Pipe Assembly

Fitting Tools for Stabbing Lap-welded Joints

Water Treatment Plant Installation

Stabbing Lap-Welded Joints

Field Connection to Existing Pipe

Butt Strap Installation & Welding

Most Common Welding Methods

Semi Automatic (FCAW)

Manual Welding (SMAW)

Manual Welding Process (Stick)

Shielded Metal Arc Welding (SMAW)

Welding Stinger

Welding Machine

Semi-Automatic Process

Flux Core Arc Welding (FCAW) – ‘Dual-Shield’

Wire Gun

Wire Feeder

Welding Procedure Submittals

Per AWS D.1.1 or ASME Section VIII

- Welding Procedure Qualification Record (PQR)
  - Welding Parameters followed during weld test (actual amperage voltage and travel speed)
- Welding Procedure Specification (WPS)
  - Developed from the PQR; factors in ranges allowed by code (AWS and ASME).
- Welder Qualification Record (WQR)
  - Uses WPS to verify welder performance

Procedure Qualification Record (PQR)

NATIONAL WELDING CORPORATION

PROCEDURE QUALIFICATION RECORD (PQR) Revision 0

COMPANY NAME NATIONAL WELDING CORPORATION
PROCEDURE QUALIFICATION RECORD NO. NWC-006A (6G)
WELDING PROCEDURE SPECIFICATION NO. NWC-006
WELDING PROCESS (ES) FCAW, GMAW (Root only)

AUTHORIZED BY Nash Williams
DATE 7-16-02
DATE 7-16-02
TYPE SEMI-AUTOMATIC

JOINTS DESIGN USED

Type Single V Groove
Single (X) Double ( )
Backing: Yes ( ) No (X)
Backing Material Weld Metal
Root Opening .125 Root Face Dimension NA
Groove Angle 45 Deg Radius (J-U) NA
Back Gouging: Yes ( ) No (x) Method
Other

POSITION:

Position of Groove 6G
Progression Downhill on root, Uphill on fill
Weld Other NA

ELECTRICAL CHARACTERISTICS

Transfer Mode (GMAW) Short-Circuiting ( )
Globular (X) Spray ( )
Current: AC ( ) DCEP (X) DCEN ( ) Pulsed ( )
Other

BASE METALS

Material Specification ASTM A 572
Type or Grade Grade 42
Group No. 2
Thickness of Test Coupon .500" Fillet NA
Diameter of Test Coupon 12"

TECHNIQUE

Stringer or Weave Weave
Multiple or Single Multiple
Single or Multiple Electrodes Single
Electrode Spacing Longitudinal NA
Lateral NA
Angle NA
Contact Tube to Work .750"
Peening No
Interpass Cleaning Mechanical-Power Brush
Heat Input(KJ/in) .60*26.2*242/13.5 = 28,180 KJ / in

FILLER METALS

AWS Specification No. SFA 5.20, SFA 5.18 (Root)
AWS Classification No. E71-T1, ER70S-6 (Root)

POSTWELD HEAT TREATMENT

Tempurature NA
Time NA

SHIELDING

Flux NA
Electrode - Flux (Class) NA
Gas Argon/CO2
Composition 75/25
Flow Rate 40 CFH
Gas Cup Size .625

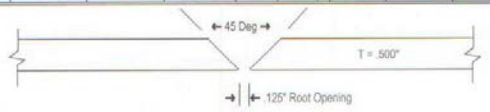
PREHEAT

Preheat Temperature 50 Deg. F
Interpass Temperature 500 Deg. F

Welding Procedure

FILLER METAL | CURRENT

WELD LAYER(S)	PROCESS	CLASS	DIA.	TYPE POLARITY	AMP	VOLTS	TRAVEL SPEED
1-Root	GMAW	ER70S-6	.045"	DCEP (Reverse)	122	21.4	6.6 IPM
2-4	FCAW	E71-T1	.052"	DCEP (Reverse)	242	26.2	13.5 IPM



NATIONAL WELDING CORPORATION

PROCEDURE QUALIFICATION RECORD (PQR) # NWC - 006A (6G)
TEST RESULTS

TENSILE TEST

Specimen No.	Width	Thickness	Area	Ultimate Tensile Load, lb	Ultimate Unit Stress, PSI	Character of Failure and Location
1	.760"	.495"	.3762"	30,700	81,606	WELD METAL
2	.768"	.495"	.3802"	32,000	84,166	BASE METAL
N/A						

GUIDED BEND TEST

Specimen No.	Type of Bend	Result	Remarks
3	SIDE	SATISFACTORY	
4	SIDE	SATISFACTORY	
5	SIDE	SATISFACTORY	
6	SIDE	SATISFACTORY	

VISUAL INSPECTION

Appearance Satisfactory
Undercut None
Piping Porosity None
Convexity None
Test Date 7/15/02
Witnessed By Nash Williams

Radiographic-Ultrasonic Examination
RT Report No.: 1026-04, Q321-02 Result Satisfactory
UT Report No.: N/A Result N/A

FILLET WELD TEST RESULTS
Minimum size of multiple pass Maximum size of single pass
Macroetch 1. N/A 3. 2.
Macroetch 1. N/A 3. 2.

Other Tests

All-weld-metal tension test

Tensile Strength, PSI N/A
Yield point/strength, PSI N/A
Elongation in 2 in., % N/A
Laboratory test no. N/A

Welder's Name Troy Wiltusen
Tests conducted by Quality Testing and Inspection

Clock No. RT-1 Stamp no. N/A
Laboratory
Test Number 1026-04, Q321-02
Per AWS D1.1

We, the undersigned, 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 4 of ANSI/AWS D1.1, Structural Welding Code-Steel and ASME Section VIII.

Signed
By B. Nash Williams
Title President-NWC
Date August 1, 2002

Welding Procedure Specification (WPS)

NATIONAL WELDING CORPORATION

WELDING PROCEDURE SPECIFICATION (WPS) Revision 0

COMPANY NAME: NATIONAL WELDING CORPORATION — BY: Nash Williams
WELDING PROCEDURE SPECIFICATION NO.: NWC-006- (Fillet) — DATE: 8-1-02
SUPPORTING PQR NO.: NWC-006A — DATE: 8-1-02
WELDING PROCESS (ES): FCAW — TYPE: SEMI-AUTOMATIC

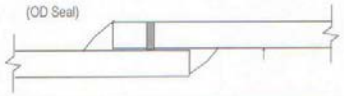
JOINTS (QW-402)

Details:

Joint design: Fillet
Backing (Yes or No): Yes
Backing Material: ASTM A 516 Gr 70

[X] Metal [ ] Nonfusing Metal [ ] Nonmetallic [ ] Other t=.250"-1.00"

AIRTEST HOLE ON DOUBLE FILLET ONLY



BASE METALS (QW-403) *

P-No. ____ Group No. 2 to P-No. ____ Group No. 2
or

Specification type and grade: ASTM A 516 Grade 70 to
Specification type and grade: ASTM A 516 Grade 70 or

Chemical Analysis and Mechanical Properties: N/A to
Chemical Analysis and Mechanical Properties:

Thickness Range:
Base Metal: Groove .250"-1.00" Fillet .250"-1.00"
Pipe Diameter Range: Groove OVER 12" Fillet OVER 12"
Other

Filler Metals (QW-404) *

Specification No. (SFA): SFA 5.20
AWS No. (Class): E71-T1
F-No.: 6
A-No.: 1
Size of Filler Metals: .052"
Weld Metal
Thickness Range:
Groove: 1/4" TO 1.0
Fillet: ALL
Electrode-Flux (Class): NA
Flux Trade Name: NA
Consumable Insert: NA
Other: NA

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

NATIONAL WELDING CORPORATION

QW-482 (Back)

WPS NO. NWC-006 5G REV. 0

POSITIONS (QW-405)

Positions of Groove: ALL
Welding Progression: UPHILL
Positions of Fillet: ALL

Tempurature Range: NA
Time Range: NA

PREHEAT (QW-409)

Preheat Temperature Minimum: 50 DEG F
Interpass Temperature Maximum: 500 DEG F
Preheat Maintenance: 50 DEG F

GAS (QW-409)

	Gas (es)	Percent Composition Mixture	Flow Rate
Shielding FCAW	AR/CO2	75/25	36-48 CFH
Trailing	NA		
Backing	NA		

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DC Polarity: EP
Amps Range FCAW: 218-266 Volts Range: 23.6- 28.0
Tungsten Electrode Size and Type: NA
Mode of Metal Transfer for GMAW: NA
Electrode Wire Feed Speed Range: FCAW 450-550

TECHNIQUE (QW-410)

String or Weave Bead: WEAVE
Orifice or Gas Cup Size: 5/8"
Initial and Interpass Cleaning: WIRE BRUSH OR GRIND
Method of Back Gouging: NA
Oscillation: NA
Contact Tube to Work Distance: NA
Multiple or Single Pass (per side): MULTIPLE
Multiple or Single Electrodes: SINGLE
Travel Speed Range: 10.1-16.8 IPM
Peening: NA
Other: NA

		FILLER METAL		CURRENT				
WELD LAYER (S)	PROCESS	CLASS	DIAMETER	TYPE POLARITY	AMPERAGE RANGE	VOLTAGE RANGE	TRAVEL SPEED RANGE	OTHER
1-4	FCAW	E71-T1	.052"	EP	218-266	24.4 - 28.0	10.1 - 16.8	NA

Welder Qualification Record (WQR)

NATIONAL WELDING CORPORATION

WELDER OR WELDING OPERATOR QUALIFICATION RECORD (WQR)

NAME DUSTIN BRIAN IDENTIFICATION NO. 167563222
WELDING PROCEDURE SPECIFICATION NO. NWC-003, NWC-005, NWC -006, NWC-007 REV. 0 DATE 2-12-08
TEST WITNESSED BY JEFF GREEN/TROY WITTUSEN

VARIABLES	RECORD ACTUAL VALUES USED IN QUALIFICATION	QUALIFICATION RANGE
PROCESS/TYPE	FCAW/SEMI-AUTOMATIC	FCAW/SEMI-AUTOMATIC
CURRENT/POLARITY	DCEP	DCEP
POSITION/WELD PROGRESS	3G UP AND 4G	ALL UP GROOVE ALL UP FILLET
BACKING (YES OR NO)	YES	WITH BACKING
MATERIAL/SPECIFICATION	A516 GRADE 70	A516 GRADE 70
BASE METAL: THICKNESS: PLATE	.500"	.125"-1.00"
PIPE/TUBE	NA	.125"-1.00"
DIAMETER: PIPE/TUBE	NA	24" AND OVER
FILLER METAL SPECIFICATION NUMBER	A5.20	A5.20
CLASSIFICATION	E71-T1	E71-T1
F-NUMBER	6	6
GAS/FLUX TYPE	75%ARGON, 25% CO2	75%ARGON, 25% CO2
OTHER	NA	NA

VISUAL INSPECTION: ACCEPTABLE X REJECTABLE
FILLET TEST RESULTS: APPEARANCE NA FILLET SIZE NA
FRACTURE TEST ROOT PENETRATION NA MACROETCH NA
DESCRIBE THE LOCATION, NATURE AND SIZE OF ANY CRACK OR TEARING OF THE SPECIMEN NA

GUIDED BEND TEST RESULTS:

TYPE	RESULTS	TYPE	RESULTS	TYPE	RESULTS	TYPE	RESULTS
NA							

RADIOGRAPHIC TEST RESULTS:

FILM ID NUMBER	RESULTS	REMARKS
Q122-08 DB 3G, Q123-08 DB 4G	ACCEPTABLE	

TESTED BY QUALITY TESTING AND INSPECTION TEST NUMBER 1026-WQ
DATE FEBRUARY 12, 2008 TECHNICIAN WAYNE BREWER, LEVEL II

We, the undersigned, certify the statements in this record are correct and the test welds were prepared, welded and tested in accordance with the requirements of Section 5, Part C or D of the ANSI/AWS D1.1 (2006 year) Structural Welding Code Steel and ASME Section IX.

MANUFACTURER OR CONTRACTOR NATIONAL WELDING CORPORATION
AUTHORIZED BY DATE 2/12/08

NATIONAL WELDING CORP.

Welders Continuity Log

Welder Name	Dustin Brian	**Stamp Number:**	DB
Foreman:	No	**Identification No.**	167563222
Welder Active	Yes	**Active Date**	2-12-08

PROCESS	ORIGINAL QUALIFICATION	MOST RECENT DATE WELDED	PROJECT	EXPIRATION DATE
FCAW-Semi-Auto	02-12-08	8-11-08	West Water Main, Charlotte, NC	2-11-09
FCAW-Semi-Auto	02-12-08	3-3-09	Spanish Fork Pipeline Reach 1	9-3-09
FCAW-Semi-Auto	02-12-08	10-26-09	Pioneer Crossing Pipeline, Lehi UT	4-26-10
FCAW-Semi-Auto	02-12-08	04-15-10	Palo Verde Generating Station, Phoenix AZ	10-15-10

Notes: Dustin has been welding continuously for National Welding since hiring on February 12, 2008

National Welding Corporation
Signature Title April 16, 2010 Date

National Welding Corporation
7025 S. Commerce Park Dr., Midvale, UT 84047 * PH (801) 255-5959 * FAX (801) 255-5919

Procedure Qualification Tests

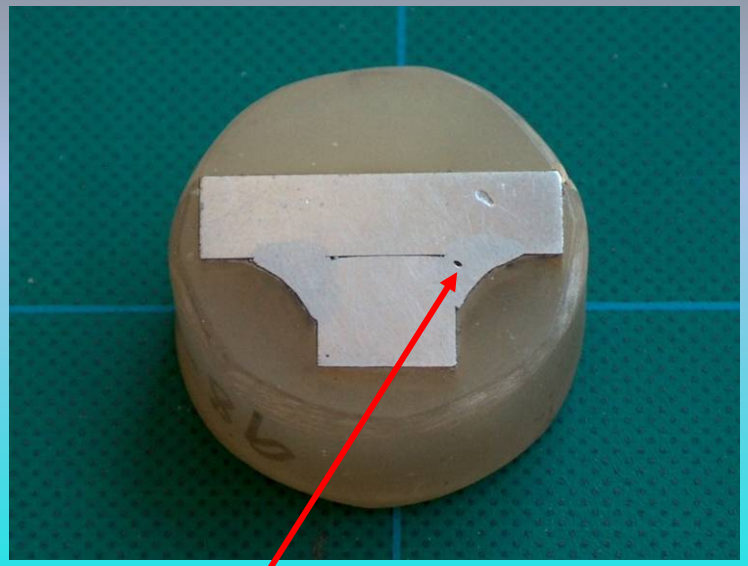
Guided Bend

Tensile

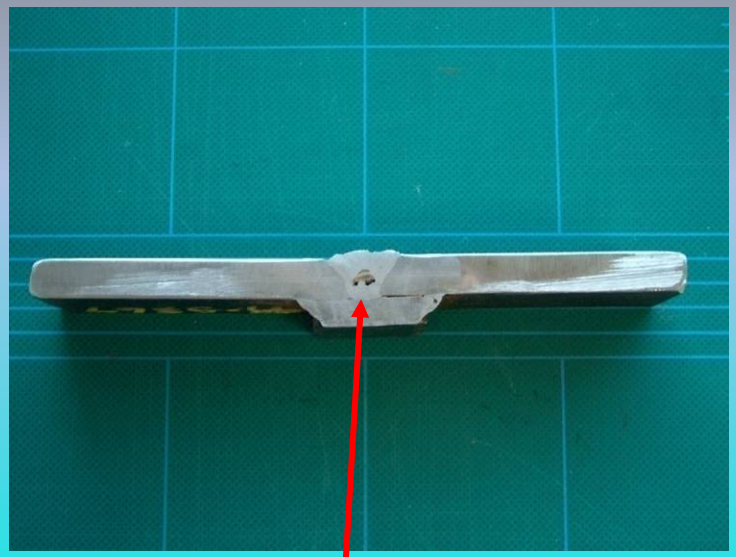
Procedure Qualification Tests

Charpy (Notch Tough) Test

Procedure Qualification Tests



Acceptable Indication



Unacceptable Indication
"Defect"

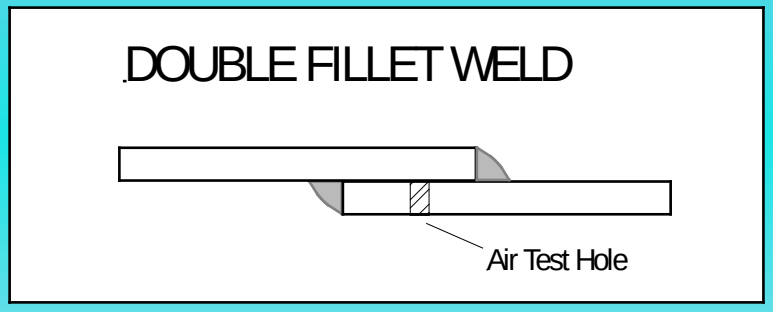
Macro Etch

Bell and Spigot Fillet Weld

Single Fillet Welding

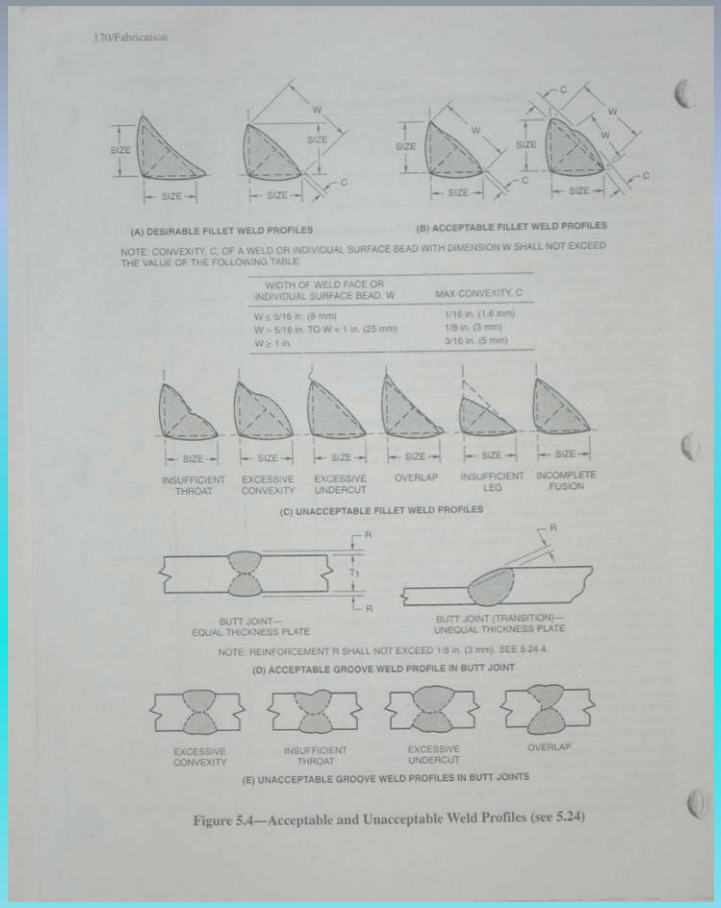
Fillet Weld Inspection Methods

- Visual (see AWS Table 6.1 handout)
- Magnetic Particle (MT)
- Air Test at 40 psi (for double fillet welds)
- Vacuum Box
- Dye Penetrant
- U.T. or R.T. not effective.



Fillet Weld Inspection

Visual Inspection (VT)

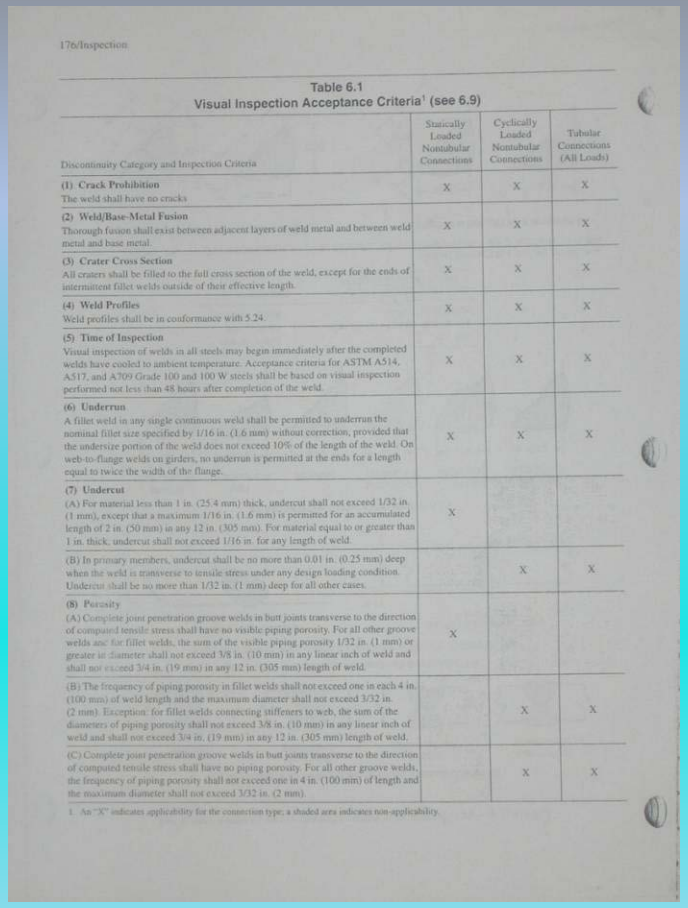


170/Fabrication

NOTE: CONVEXITY, C, OF A WELD OR INDIVIDUAL SURFACE BEAD WITH DIMENSION W SHALL NOT EXCEED THE VALUE OF THE FOLLOWING TABLE:

WIDTH OF WELD FACE OR INDIVIDUAL SURFACE BEAD, W	MAX CONVEXITY, C
W ≤ 5/16 in. (8 mm)	1/16 in. (1.6 mm)
W > 5/16 in. TO W < 1 in. (25 mm)	1/8 in. (3 mm)
W ≥ 1 in.	3/16 in. (5 mm)

Figure 5.4—Acceptable and Unacceptable Weld Profiles (see 5.24)



176/Inspection

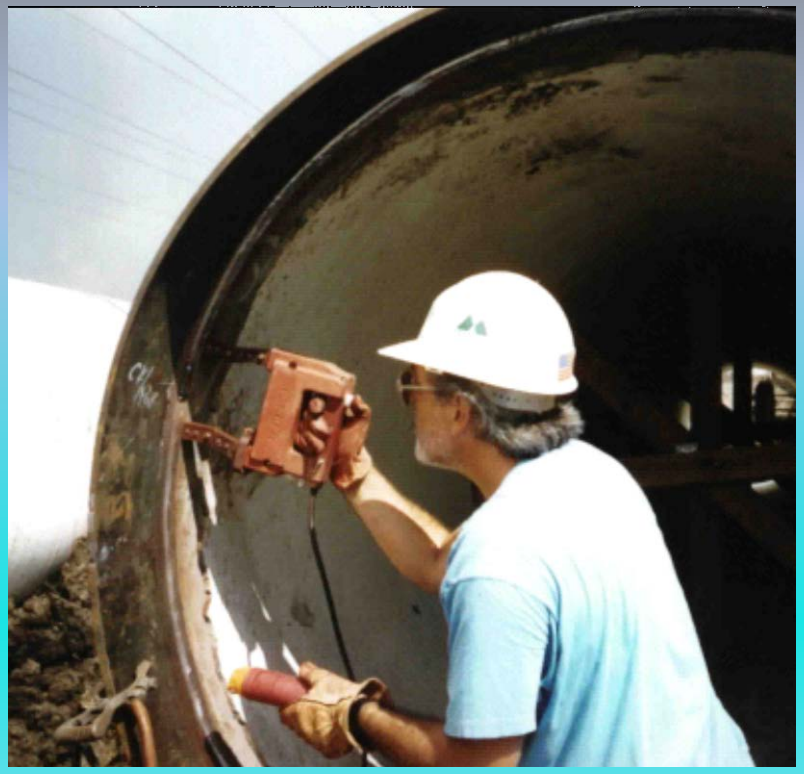
Table 6.1
Visual Inspection Acceptance Criteria[1] (see 6.9)

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
(1) Crack Prohibition The weld shall have no cracks	X	X	X
(2) Weld/Base-Metal Fusion Thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X
(3) Crater Cross Section All craters shall be filled to the full cross section of the weld, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X
(4) Weld Profiles Weld profiles shall be in conformance with 5.24.	X	X	X
(5) Time of Inspection Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A514, A517, and A709 Grade 100 and 100 W steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X	X
(6) Underrun A fillet weld in any single continuous weld shall be permitted to underrun the nominal fillet size specified by 1/16 in. (1.6 mm) without correction, provided that the undersize portion of the weld does not exceed 10% of the length of the weld. On web-to-flange welds on girders, no underrun is permitted at the ends for a length equal to twice the width of the flange.	X	X	X
(7) Undercut (A) For material less than 1 in. (25.4 mm) thick, undercut shall not exceed 1/32 in. (1 mm), except that a maximum 1/16 in. (1.6 mm) is permitted for an accumulated length of 2 in. (50 mm) in any 12 in. (305 mm). For material equal to or greater than 1 in. thick, undercut shall not exceed 1/16 in. for any length of weld.	X		
(B) In primary members, undercut shall be no more than 0.01 in. (0.25 mm) deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 1/32 in. (1 mm) deep for all other cases.		X	X
(8) Porosity (A) Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping porosity 1/32 in. (1 mm) or greater in diameter shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (19 mm) in any 12 in. (305 mm) length of weld.	X		
(B) The frequency of piping porosity in fillet welds shall not exceed one in each 4 in. (100 mm) of weld length and the maximum diameter shall not exceed 3/32 in. (2 mm). Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (19 mm) in any 12 in. (305 mm) length of weld.		X	X
(C) Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 4 in. (100 mm) of length and the maximum diameter shall not exceed 3/32 in. (2 mm).		X	X

1. An "X" indicates applicability for the connection type; a shaded area indicates non-applicability.

Fillet Weld Inspection

Magnetic Particle (MT) and Air Leak Test



Fillet Weld Inspection

Vacuum Box Inspection and Dye Penetrant

Illustration from AWWA C-206

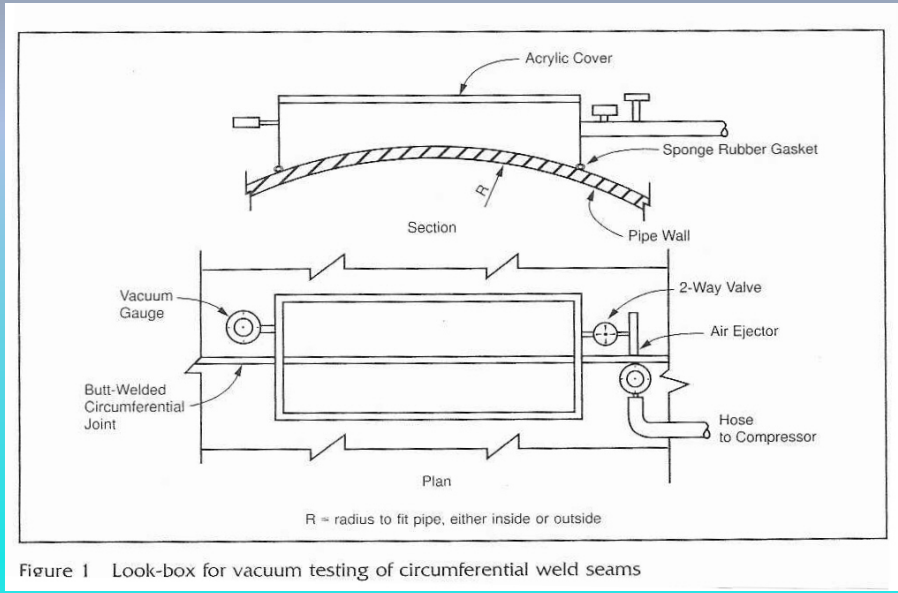


Figure 1 Look-box for vacuum testing of circumferential weld seams

Note: Dye Penetrant is used to find surface cracks. Dye Penetrant is no longer recommended by AWWA C-206 for field weld inspection due to the process introducing contaminates which could adversely effect linings and coatings.

Butt Weld Inspection Methods

Magnetic Particle (MT) or Ultrasonic Testing (UT)

- Magnetic Particle (MT)
  - Also utilized for fillet weld inspection

- Ultrasonic Testing (UT)
  - Can be performed immediately after the joint has cooled from welding.
  - Only requires access to one side of the joint.
  - Radiographic Testing (RT) is not addressed in AWWA C206

Weld After Backfill

Typical Joint Coatings

- Weld After Backfill is a sequence used to improve overall installation rate for steel pipe.
- Pipe is laid and welded outside (if required).
- Joint coating is applied, usually a shrink sleeve or mortar diaper.
- Pipe is backfilled.
- The inside weld is made later.

Shrink Sleeve

Mortar Diaper

Inside Welding Access

Inside 30” pipe

Inside 48” pipe

Top Issues of Concern

- Issue: Welding subcontractor or welders are inexperienced with production welding of steel pipe.

  Remedy: Specifications should require the welding subcontractor to be qualified for the project, such as requiring a minimum experience of three separate projects exceeding 60” dia. x 5000’ long and must provide a statement of qualification acceptable to the Owner/Engineer.

- Issue: Welding Subcontractor may compensate individual welders by piece work which can severely impact quality.

  Remedy: Make sure a reputable company is performing the welding and/or disallow piece work compensation for individual welders.

- Issue: Inadequate or no inspection

  Remedy: Welded steel joints should be inspected by a qualified inspector in accordance with AWWA C206 to verify conformance to the Specification and Specification should dictate the method of inspection


QUESTIONS?