



Steel Penstocks, Second Edition



ASCE Manuals and Reports on
Engineering Practice No. 79

ASCE

ASCE MOP 79, Chapter 11 – Welding, Overview

Nash Williams-National Welding Corp.



“Welding of steel penstocks is critical to the success of hydroelectric projects.”



- **Welding requirements previously spread throughout 6 chapters**
- **Committee task was to compile into a single welding Chapter**
 - **Consolidated by removing redundancies and conflicts**
- **Welding design still based on ASME Section VIII, Division 1**



Variety of Penstock configurations Overview



Welding Procedures and Practices

Utilize both ASME Sect. VIII or AWS D1.1



NATIONAL WELDING CORPORATION
PROCEDURE QUALIFICATION RECORD (PQR) Revision 0

COMPANY NAME NATIONAL WELDING CORPORATION AUTHORIZED BY Nash Williams
 PROCEDURE QUALIFICATION RECORD NO. NWC-007 (GG) DATE 6/21/2005
 WELDING PROCEDURE SPECIFICATION NO. NWC-007 DATE 6/21/2005
 WELDING PROCESS(ES) FCAW, GMAW (Root Only) TYPE SEMI-AUTOMATIC

JOINT DESIGN USED POSITION
 Type Single V Groove Position of Groove 6G
 Single ☒ Double ☐ Progression Uphill
 Backing: Yes ☐ No ☒ Weld Metal NA Weld Other NA

ELECTRICAL CHARACTERISTICS
 Root Opening 0.125 Root Face Dimension NA Transfer Mode GMAW (Root Only), FCAW Spray
 Groove angle 45 Deg Radius (J-U) NA Short-Circuiting ☐ Globular ☒
 Back Gouging: Yes ☐ No ☒ Method Other Current: AC ☐ DCEP ☒ DCEN ☐ PULSED ☐
 Other NA

BASE METALS **TECHNIQUE**
 Material Specification ASTM A339 Stringer ☐ Weave ☒
 Type or Grade Grade C Multiple ☒ Single ☐
 Group No. II Single Electrode ☒ Multiple Electrode ☐
 Thickness of Test Coupon 5" Fillet 14" Electrode Spacing NA
 Diameter of Test Coupon 14" Longitudinal NA
 Other NA Lateral NA
 Angle 750"

FILLER METALS **POST WELD HEAT TREATMENT**
 AWS Specification No. SFA 5.2, SFA 5.18 (Root) No NA
 AWS Classification No. E71-T1, ER70S-6 (Fill) Mechanical-Power Bush NA
 Heat Input (kJ/in.) 60K29: 1X262/11.5=39.8 kJ/in

SHIELDING **PREHEAT**
 Flux NA Gas Argon/CO2 Temperature NA
 Composition 75%/25% Time NA
 Flow Rate 40 CTH Gas Cup Size 0.625
 Gas Cup Size 0.625 Preheat Temperature 50 Deg. F
 Electrode-Flux (Class) NA Interpass Temperature 500 Deg. F

Welding Procedure

WELD LAYER(S)	PROCESS	FILLER METAL		CURRENT				TRAVEL SPEED
		CLASS	DIAMETER	TYPE	POLARITY	AMP	VOLTS	
1	GMAW	ER70S-6	0.045	DC	EP	80	19	6.6 IPM
2-5	FCAW	E71-T1	.052"	DC	EP	262	29.1	11.5 IPM

PROCEDURE QUALIFICATION RECORD (PQR) # NWC-007 (GG)

TEST RESULTS

Specimen No.	Width	Thickness	Area	TENSILE TEST		Character of Failure and Location
				Ultimate Tensile Load, lb	PSI	
1	0.77	0.445	0.3427	27,300	79,370	BASE METAL
2	0.775	0.445	0.3449	27,700	80,313	BASE METAL

GUIDED BEND TEST

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

VISUAL INSPECTION
 Appearance SATISFACTORY
 Undercut NONE
 Piping Porosity NONE
 Convexity NONE
 Test Date 6/15/2005
 Witnessed By NASH WILLIAMS

RADIOGRAPHIC-ULTRASONIC EXAMINATION
 RT Report No. 2457-05 Result PASSED
 UT Report No. NA Result NA

ALL WELD METAL TENSION TEST
 Tensile Strength, PSI NA
 Yield Point/Strength, PSI NA
 Elongation in 2", % NA
 Laboratory Test No. NA
 Clock No. NA Stamp No. NA
 Laboratory Test No. NA Per NA

FILLET WELD TEST RESULTS
 Minimum size of multiple pass Maximum size of single pass:
 Macroetch 1 3 2 3

OTHER TESTS

Welders Name Troy Wittusen
 Tests Conducted By Quality Testing and Inspection Laboratory

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 AWS/AWS D1.1.(2010) Structural Welding Code-Steel and ASME Section VIII.

Signed Nash Williams
 By President - NWC
 Title 6/21/2005
 Date

Welding Procedures comprised of 3 key documents

- **Procedure Qualification Record (PQR)**
- **Welding Procedure Specification (WPS)**
- **Welder Performance Qualification (WPQ)**



NATIONAL WELDING CORPORATION
WELDING PROCEDURE SPECIFICATION (WPS) Revision 0

COMPANY NAME: NATIONAL WELDING CORPORATION AUTHORIZED BY: Nash Williams
WELDING PROCEDURE SPECIFICATION NO.: NWC-007 (Butt w/Backup) DATE: 6/21/2005
SUPPORTING PQR NO.: NWC-007 DATE: 6/21/2005
WELDING PROCESS(ES): FCAW TYPE: SEMI-AUTOMATIC

JOINTS (QW-402)

Joint Design: V-Groove
Backing: Yes ☒ No ☐
Backing Material: ASTM A 139 Grade C
Metal: ☒ Nonfusing Metal ☐ Nonmetallic ☐ Other ☐ T = .250" - 1.00"

45 DEG
+10 DEG/-0 DEG

T = .250" - 1.00"

.25" (+.25"/-1/16") ROOT OPENING

BASE METALS (QW-403)

P-No. _____ Group No. I or II _____ to P-No. _____ Group No. I or II _____
or _____
Specification Type and Grade: _____ ASTM A 139 Grade C _____ to _____
Specification Type and Grade: _____ ASTM A 139 Grade C _____ or _____
Chemical Analysis and Mechanical Properties: _____ NA _____ to _____
Chemical Analysis and Mechanical Properties: _____ NA _____ to _____

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 .250" - 1.00" _____
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
WELDING PROCEDURE SPECIFICATION NO. NWC-007 (Butt w/Backup)

POSITIONS (QW-409)

Positions of Groove: ALL Temperature Range: NA
Welding Progression: UPHILL Time Range: NA
Positions of Fillet: ALL

PREHEAT (QW-409) GAS QW-409

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

Shielding: AR/CO2
Trailing Backing: NA

Percent Composition
Gas(es) Mixture Flow Rate
75/25 36-48 CFH

ELECTRICAL CHARACTERISTICS (QW-409)

Current (AC or DC): DC Polarity: EP
Amps Range FCAW: 236-288 Volts Range FCAW: 27.1-31.1

Tungsten Electrode Size and Type: NA
Mode of Metal Transfer: NA
Electrode Wire Feed Speed Range: FCAW 450-550

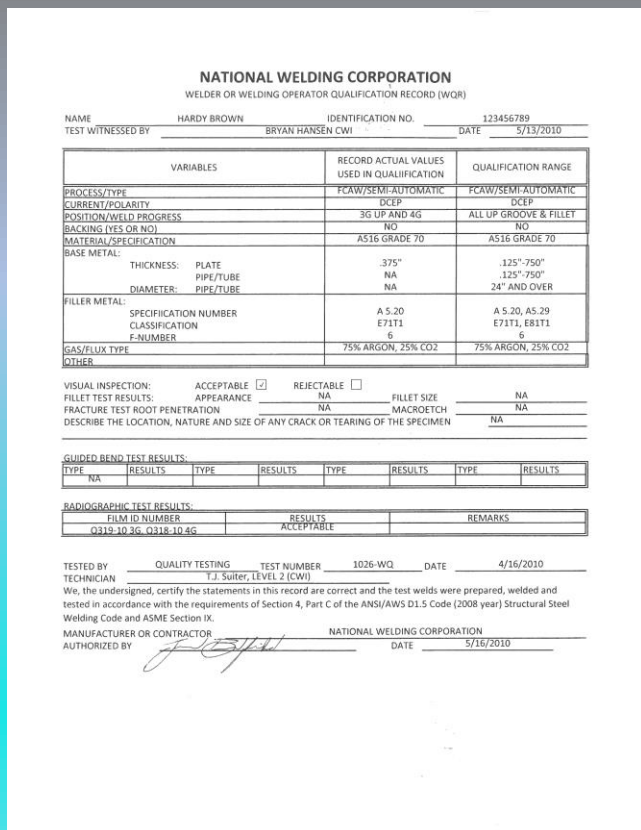
TECHNIQUE (QW-410)

Stringer 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: 75"
Multiple or Single Pass (Per Side): MULTIPLE
Multiple or Single Electrodes: SINGLE
Travel Speed Range: 9.7-13.3 IPM
Peening: NA
Other: NA

WELD LAYER(S)	PROCESS	FILLER METAL		CURRENT		VOLTAGE RANGE	TRAVEL SPEED RANGE	OTHER
		CLASS	DIAMETER	POLARITY TYPE	AMPERAGE RANGE			
1-8	FCAW	E71-T1	.052"	DCEP	236-288	27.1-31.1	9.7-13.3 IPM	NA

Welding Procedure Specification

Provides parameter ranges



Documents a welders ability to deposit sound welds

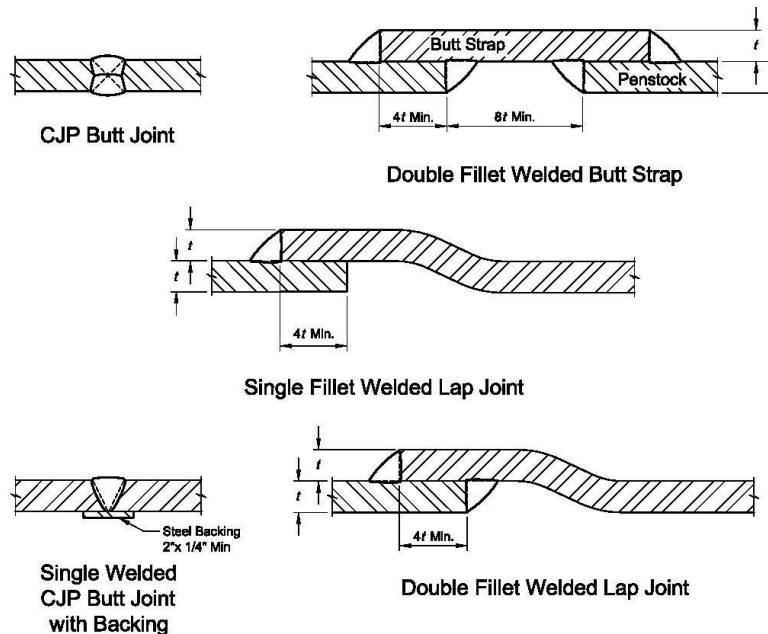
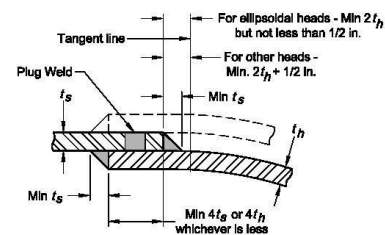
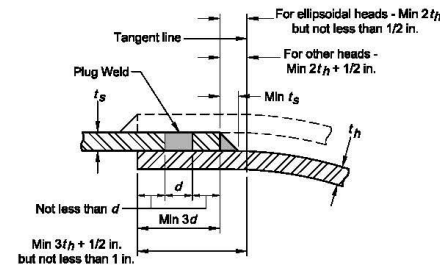


Figure 11-1. Common Field-Welded Joints

Longitudinal joints are generally full penetration butt joints (CJP)
Circumferential joints can be a butt weld or fillet weld (designer discretion)



(a) Double Fillet Lap Weld with Plug Weld



(b) Single Fillet Lap Weld With Plug Weld

Notes:

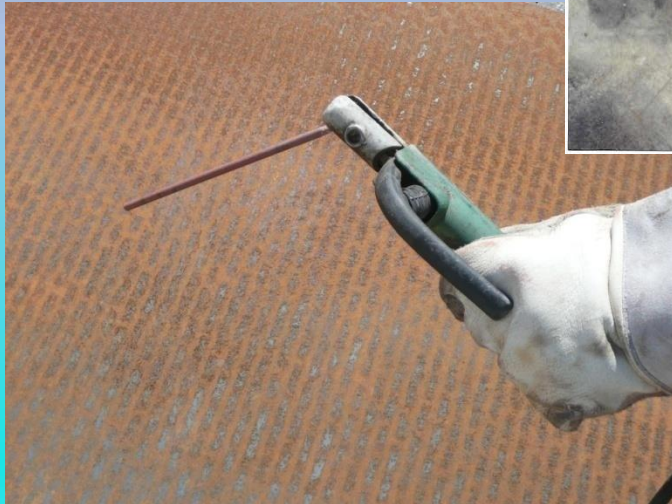
1. Plug weld holes should have a diameter not less than $t + 1/4$ in. and not more than $2t + 1/4$ in. where t is the thickness in in. of the plate or attached part in which the hole is made.
2. Plug weld holes should be completely filled with weld metal when the thickness of the plate, or attached part, in which the weld is made is $5/16$ in. or less; for thicker plates or attached parts the holes should be filled to a depth of at least half the plate thickness or $5/16$ in. of the hole diameter, whichever is larger, but in no case less than $5/16$ in.
3. Additional design information may be found in ASME BPVC Section VIII, Division 1, ASME (2010a).

Figure 11-3. Plug Welds

Plug Welds have been added to this manual
Less common joint type but often found beneficial to designers
intending to increase joint strength



Flux Cored Arc Welding
Gas Metal Arc Welding



Shielded Metal Arc Welding
Stick-Manual



Submerged Arc Welding

Welding Processes

- FCAW (Flux Cored Arc Welding)
- GMAW (Gas Metal Arc Welding)
- SMAW (Shielded Metal Arc Welding)
- SAW (Submerged Arc Welding)



Assembly and Thermal Affects



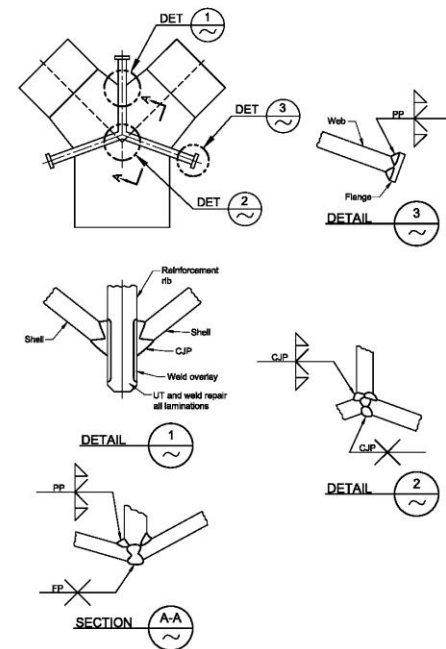


Figure 11-4. Welded Joints - Bifurcations

Bifurcations and Joint Designs



Importance of Inspection

See Chapter 14

Question & Answer

