

SECTION 16448

STRUCTURAL FIELD WELDING

PART 1 DESCRIPTION

- A. Field-weld metal members using the shielded metal arc and flux-cored arc welding processes.

PART 2 MATERIALS

- A. Provide electrodes for shielded metal arc welding (SMAW) conforming to the requirements of the latest edition of ANSI/AWS A5.1, "Specifications for Mild Steel Covered Arc Welding Electrodes," or ANSI/AWS A5.5, "Specifications for Low-Alloy Steel Covered Arc Welding Electrodes."
- B. Provide electrodes for flux-cored arc welding (FCAW) conforming to the requirements of the latest edition of ANSI/AWS A5.20, "Specification for Carbon Steel Electrodes for Flux Cored Arc Welding," or ANSI/AWS A5.29, "Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding."
- C. Provide electrodes and flux-electrode combinations named on the approved list as discussed in Section 16000. To request that a product be added to this list or to renew an expired approval, the Contractor or the consumable manufacturer must submit certified reports of all tests required by the applicable AWS A5 specification according to the applicable welding code. For most structural steel construction, the applicable welding code is AASHTO/AWS D1.5, Bridge Welding Code, or ANSI/AWS D1.1, Structural Welding Code—Steel. For reinforcing steel, the applicable code is ANSI/AWS D1.4, Structural Welding Code—Reinforcing Steel. Tests must be conducted on electrodes of the same class, size, and brand and manufactured by the same process and with the same materials as the electrodes to be furnished. Resubmit electrodes or flux-electrode combinations every 12 months for renewal.
- D. Table 1 shows the classes of electrodes required. Use electrodes with the type of current, with the polarity, and in the positions permitted by AWS A5.1 and A5.5 for SMAW. AWS A5.20 and A5.29 specifications govern for FCAW. Obtain approval for electrode use on steel not listed in Table 1.

Table 1
Classification of Electrodes Permitted

Type of Steel (ASTM Standards)	Electrode Specification	Process	Filler Metal Requirements
Steel piling	AWS A5.1 or A5.5	SMAW	E60XX E70XX or E70XX-X
Armor joints A 500 A 501	AWS A5.20 or A5.29	FCAW	E6XTX-X E7XTX-X (except -2, -3, -10, -GS)
A 36 A 572 Gr. 50 A 588	AWS A5.1 or A5.5	SMAW	E7016 E7018 E7028
A 242 A 709 Gr. 36, 50, or 50S	AWS A5.20 or A5.29	FCAW	E7XT-1 E7XT-5 E7XT-6 E7XT-8
Weathering steel A 588 A 242 A 709 Gr. 50W	AWS A5.5	SMAW	E8018-W E8016-C3 E8018-C3 E8016-C1 E8018-C1 E8016-C2 E8018-C2
	AWS 5.29	FCAW	E8XT1-W E8XTX-Ni1 E8XTX-Ni2 E8XTX-Ni3
A 709 Gr. HPS 70W	AWS A5.5	SMAW	E9018-M-H8R
Reinforcing steel Grade 40	AWS A5.1 or A5.5	SMAW	E70XX
Reinforcing steel Grade 60	AWS A5.5	SMAW	E90XX
Permanent metal deck forms	AWS A5.1 or A5.5	SMAW	E6010 E6011 E6013 E7018

Note: Low-hydrogen electrodes applicable to the lower strength base metal may be used in joints involving base metals of different yield points or strengths.

- E. E7010 and E8010 electrodes may be used when welding the root passes of beam and girder splices if the requirements of Section 16448, Part 4, 4.03, E, 4, a, "High-Cellulose Electrodes for Root Passes," are met.
- F. When welding fracture-critical applications, use electrodes meeting the diffusible hydrogen requirements for fracture-critical welding in AASHTO/AWS D1.5.
- G. For FCAW, use gas or gas mixtures that are welding grade and have a dew point of -40°F or lower. Furnish certification to the Owner's Representative that the gas or

gas mixture is suitable for the intended application and will meet the dew point requirements.

PART 3 EQUIPMENT

- A. Provide electrode drying and storing ovens that can maintain the required temperatures specified in Section 16448, Part 4, 4.03, A, "Electrode Condition," along with thermometers for checking and controlling the oven temperatures. Provide preheating equipment that can maintain the entire joint at or above the specified temperature. Provide approved equipment for checking preheat and interpass temperatures at all times while welding is in progress. Provide welding equipment meeting the requirements of the approved welding procedure specification (WPS), if required, and capable of making consistent high-quality welds.

PART 4 CONSTRUCTION

4.01 PROCEDURE QUALIFICATION

- A. Use the proper classification and size of electrode, arc length, voltage, and amperage for the thickness of the material, type of groove, welding positions, and other circumstances of the work.
- B. Submit WPS's for FCAW, qualified in accordance with AASHTO/AWS D1.5, for approval before any field welding on a project.

4.02 WELDER QUALIFICATION

- A. Provide to the Owner's Representative certification papers for each welder for each welding process to be used before welding, except for miscellaneous welds described in Section 16448, Part 4, 4.02, A, 1, a, (1), "Miscellaneous Welding Applications." Certification is issued by the Owner's Representative as described in Section 16448, Part 4, 4.02, A, 2, "Certified Steel Structures Welder."

1. Miscellaneous Welding

- a. A qualified welder is an experienced welder who is capable of making welds of sound quality but does not have Owner's Representative certification papers. Before welding begins, the Owner's Representative will check the welder's ability by conducting a job-site test in accordance with Section 16448, Part 4, 4.02, A, 1, a, (2), "Miscellaneous Weld Qualification Test." Furnish all materials and equipment necessary for this test.

(1). Miscellaneous Welding Applications

- (a). A welder certified for structural or reinforcing steel or a qualified welder may make miscellaneous welds of the following types:
- 1) splicing reinforcing steel to extend bars in the bottom of a drilled shaft;
 - 2) attaching chairs to the reinforcing steel cage of a drilled shaft;
 - 3) armor joints and their supports;
 - 4) screed rail and form hanger supports where permitted on steel units;
 - 5) reinforcing steel to R bars for lateral stability between prestressed beams, spirals, or bands to reinforcing bars in drilled shaft cages;
 - 6) permanent metal deck forms;
 - 7) additional steel added in railing when slip-form construction is used; and
 - 8) other similar miscellaneous members that have no load-carrying capacity in the completed structure.

(2). Miscellaneous Weld Qualification Test

- (a). A qualified welder must pass a job-site Miscellaneous Weld Qualification Test before welding:
- 1) Make a single-pass fillet weld of 1/4 in. maximum size in the vertical position approximately 2 in. long on 1/2 in. plate in the location shown in Figure 1. Use the same electrode proposed for the work.
 - 2) The Owner's Representative will visually inspect the fillet weld for a reasonably uniform appearance and then rupture the weld as shown in Figure 2 with a force or by striking it with a hammer.
 - 3) The fractured surface of the weld will be inspected to ensure complete penetration into the root of the joint, complete fusion to the base metal, and no inclusion or porosity larger than 3/32 in. in its greatest dimension.

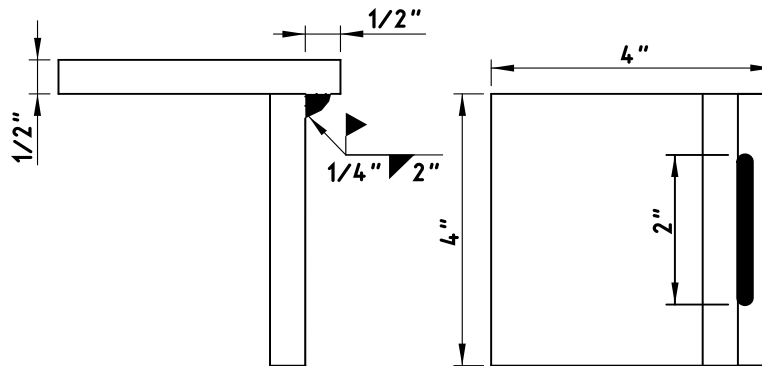


Figure 1
Miscellaneous qualification—fillet weld break specimen.

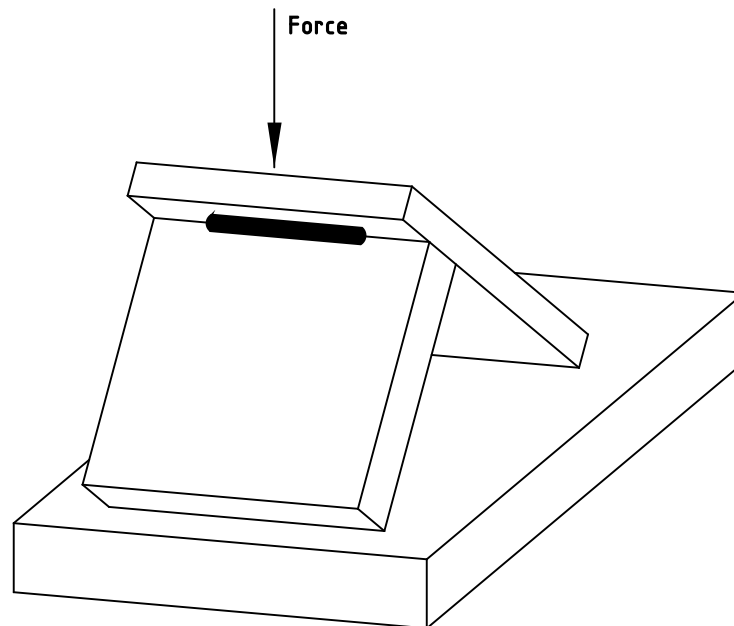


Figure 2
Miscellaneous qualification—method of rupturing specimen.

- (b). A welder who fails the Miscellaneous Weld Qualification Test may take a retest under the following conditions:
- 1) The retest occurs immediately and consists of 2 test welds as described above with both test specimens meeting all of the requirements.
 - 2) The retest occurs after 30 days if the welder provides evidence of further training or practice. In this case the test consists of a single test weld.

- (c). Qualification by the Miscellaneous Weld Qualification Test is effective immediately upon satisfactory completion of the test and remains in effect for the duration of a project.
2. Certified Steel Structures Welder
 - a. Before making non-miscellaneous welds on structural steel, a welder must pass the AASHTO/AWS D1.5 qualification test for groove welds for plates of unlimited thickness in the vertical (3G) and overhead (4G) positions with the following additional requirements:
 - (1). Use metal for test plates that meets Section 16442, "Metal for Structures," with a minimum yield point of 50 ksi.
 - (2). Use approved electrodes meeting the required class in accordance with Table 1 and, in the case of FCAW, in accordance with the approved WPS.
 - (3). Have a radiographic inspection performed on the weld on each test plate. Any porosity or fusion-type discontinuity with greatest dimension larger than 1/16 in. found in the weld will result in failure of the test. Discontinuities with greatest dimension less than 1/16 in. are acceptable provided the sum of their greatest dimensions does not exceed 3/8 in. in any inch of weld.
 - (4). Have two side-bend specimens prepared, tested, and inspected for each test plate.
 - b. The test must be administered by an approved laboratory. Submit 2 copies of the certification issued by the laboratory, all accompanying test papers, and the radiographic films to the Owner's Representative for review. The Owner's Representative issues certification papers if the laboratory's certification is approved. A welder must also demonstrate to the Owner's Representative a thorough knowledge of the required welding procedures together with the ability and desire to follow them and make welds of sound quality and good appearance. The certification issued by an approved laboratory is accepted for 1 month from the time of certification, during which time the welder may work on City projects if the work is satisfactory. Certification papers issued by the Owner's Representative remain in effect as long as the welder performs acceptable work as determined by the Owner's Representative. The certification may be cancelled at any time if the welder's work is not acceptable.
 - c. For SMAW, a welder certified using EXX18 electrodes is qualified to weld with all approved SMAW electrodes up to E90XX to join metals with a maximum specified yield strength of 65 ksi.

4.03 WELDING STEEL STRUCTURES

A. Electrode Condition

1. SMAW

- a. For electrodes with low-hydrogen coverings conforming to AWS A5.1, dry in conformance with the manufacturer's written drying instructions or dry for at least 2 hours between 450°F and 500°F. For electrodes with low-hydrogen coverings conforming to AWS A5.5, dry for at least 1 hour between 700°F and 800°F or as specified by the electrode manufacturer. If using electrodes from a newly opened undamaged hermetically sealed container, drying is not required. Immediately after drying or removal from hermetically sealed container, store electrodes in ovens held at a temperature of at least 250°F. Elapsed time permitted between removal of an electrode from the storage oven or hermetically sealed container and use of the electrode is given in Table 2.

Table 2
SMAW Electrode Exposure Limits

Electrode Type	Exposure Time (hours)
E70	4
E80	2
E90	1

- b. If electrodes are placed back in the holding oven before the times given in Table 2 have lapsed, leave them in for at least 4 hours at 250°F before reusing. The Owner's Representative may reduce times allowed for use without redrying in humid atmospheres. Do not redry electrodes more than once. Do not use electrodes with flux that has been wet, cracked, or otherwise damaged.

2. FCAW

- a. Protect or store welding wire coils removed from the original package to keep their characteristics or welding properties intact. Do not use coils or portions of coils that are rusty.

3. Special Applications

- a. For fracture-critical applications or when welding steel not shown in Table 1, dry electrodes in accordance with the manufacturer's specifications and AASHTO/AWS D1.5.

B. Environmental Conditions

1. Do not weld when the air temperature is lower than 20°F; when surfaces are wet or exposed to rain, snow, or wind; or when operators are exposed to inclement conditions. Provide wind breaks to protect welding operations from winds greater than 5 MPH.

C. Assembly and Fitup

1. Verify that ends of members to be welded are prepared in accordance with the welded joint detail specified. For girder splices, see Figures 3, 4, and 5 for proper end preparation and weld details.
2. Bring the parts to be joined by fillet welds into as close contact as possible, not separated more than 3/16 in. If the separation is 1/16 in. or more, increase the leg of the fillet weld by the amount of the separation. Keep the separation between faying surfaces of lap joints and of butt joints landing on backing strips to no more than 1/16 in.
3. Make suitable allowance for shrinkage, and never restrain the joint on both sides in any welding process.
4. Use the following fitup procedure for groove welds for butt joints:
 - a. Align splices of beams and girders joined by groove welds with the center of gravity of both cross sections coinciding or each flange vertically offset equally. Fit beams and girders with offset webs with the webs aligned and the flanges offset laterally. When flanges are offset or abutting parts differ in thickness or width by more than 1/8 in., make the joint with a smooth transition between offset surfaces and with a slope of no more than 1:4.
 - b. Space members to provide a 3/16 in. root opening at the nearest point. At other points of the joint when the spacing provides up to a 7/16 in. opening, correction may be made by buildup up to 1/8 in. on each bevel nose. Rebevel openings exceeding 7/16 in. and move the parts to be joined closer together to bring the joint within the maximum buildup limits. Allow buildups to cool to the maximum preheat and interpass temperatures before welding the joint.
 - c. Bring all members into correct alignment and hold them in position by acceptable clamps while welding.
5. Complete all butt splices before welding diaphragms or sway bracing in a particular section of a unit. Diaphragms and sway bracing may be welded in a unit behind the splice welding to provide stability except where such welding interferes with butt splice adjustments, such as at a drop-in segment of a

continuous unit. Complete all splices before welding beams or girders to shoes.

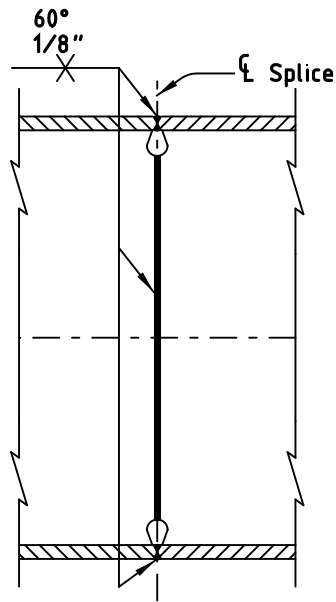


Figure 3
Girder splice details.

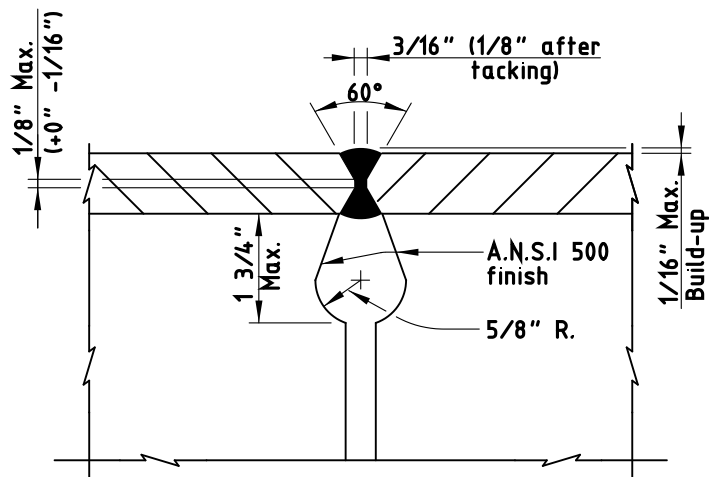


Figure 4
Girder splice details (flange).

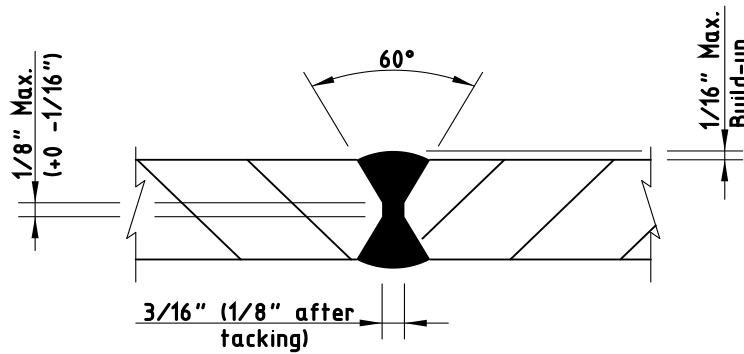


Figure 5
Girder splice details (web).

D. Preheat

1. Preheat ahead of welding both groove and fillet welds (including tack welding) to the temperatures shown in Table 3. Keep preheat and interpass temperatures high enough to prevent cracks. The preheat temperatures shown in Table 3 are minimums, and higher preheats may be necessary in highly restrained welds. When the base metal is below the required temperature, preheat it so that parts being welded are not cooler than the specified temperature within 3 in. of the point of welding.
2. Measure preheat temperature on the side opposite to which the heat is applied at points approximately 3 in. away from the joint.
3. When possible, completely weld a joint before allowing it to cool below the specified temperature. Always deposit enough weld to prevent cracking before allowing a joint to cool. Do not allow preheat and interpass temperatures to exceed 400°F for thickness up to 1 1/2 in. and 450°F for greater thicknesses.

Table 3
Minimum Preheat and Interpass Temperature
for Welding with Low-Hydrogen Electrodes

Thickest Part at Point of Welding	Temperature
Up to 3/4 in., inclusive	50°F
More than 3/4 in. up to 1-1/2 in., inclusive	70°F
More than 1-1/2 in. up to 2-1/2 in., inclusive	150°F
More than 2-1/2 in.	225°F

4. When E7010 or E8010 electrodes are used for tacking or temporary root pass, preheat the material in accordance with Table 4.

Table 4
Minimum Preheat Temperature for Welding
with E7010 or E8010 Electrodes

Thickest Part at Point of Welding	Temperature
1/2 in. and less	150°F
9/16 in. through 3/4 in.	200°F
13/16 in. through 1-1/2 in.	300°F
More than 1-1/2 in.	400°F

5. Use preheat and interpass temperatures for the thicker plate thickness when joining steels of different thickness.
6. When the base metal temperature is below 32°F, preheat to at least 70°F and maintain this minimum temperature during welding. If the base metal is moist, preheat it to 200°F before starting to weld.

E. Welding Practice

1. Use an approved procedure to control shrinkage and distortion. For FCAW, weld in accordance with an approved WPS. Weld as required by the Contract or erection drawings. Do not change the location or size of welds without approval. Do not make temporary welds for transportation, erection, or other purposes on main members except as shown on the plans or approved. Use a crayon, paint, or other approved method to mark each groove weld to identify the welder who performed the work.
2. Use the stringer-bead technique where possible for groove welds. In vertical welding passes, progress upward using a back-step sequence.
3. Begin and terminate groove welds at the ends of a joint on extension bars. Make edge preparation and thickness of extension bars the same as that of the member being welded but extending at least 2 in. beyond the joint. After the weld is completed and cooled, remove extension bars with a cutting torch or arc-air gouging, and grind the flange edges smooth. If any defects are exposed by the grinding, clean them, fill them with weld metal, and regrind them to a uniform finish. Grind so that grind marks are parallel to the flange, and avoid excess grinding of the parent metal. Clean and fuse tack welds thoroughly with the final weld. Remove defective, cracked, or broken tack welds.
4. Gouge, chip, or otherwise remove the root of the initial weld to sound metal for all groove welds, except those produced with the aid of backing or those on steel piling or armor joints, before welding is started on the second side. Thoroughly clean the back side before placing the backup pass. For groove welds made with steel backing, thoroughly fuse the weld metal with the backing, and use backing that is continuous for the full length of the weld. Make a continuous length of backing by welding shorter sections together only under the following conditions:

- All splices in the backing are complete joint penetration (CJP) groove welds made with the same controls as similar CJP groove welds in the structure.
 - The welds are radiographed and examined as described in Section 16448, Part 4, 4.03, G, “Radiographic Inspection,” to ensure weld soundness.
 - All welding and testing of the backing is complete before the backing is used to make the structural weld.
- a. High-Cellulose Electrodes for Root Passes
- (1). E7010 and E8010 electrodes may be used when welding the root passes of beam and girder splices if the work is preheated in accordance with Table 4. After the root passes are backed up, completely remove the E7010 or E8010 electrode pass by arc-air gouging, and replace it using a low-hydrogen electrode.
- b. Welding Sequence
- (1). Make beam and girder splices using the sequences shown in Figure 6. (Some members will require fewer or more passes than Figure 6 shows.) Alternate welds from flat to overhead to prevent heat buildup along bevel edge. Arrange the passes between the top and bottom flange to maintain balance and symmetry.
 - (2). For both rolled I beams and built-up girders, place passes 1, 2, and 3 in the top flange, followed by passes 4, 5, and 6 in the bottom flange (see Figure 6). Gouge out and replace passes 1 and 4, which always are placed in the overhead position. Next, place passes 7, 8, and 9 in the top flange, followed by passes 10, 11, and 12 in the bottom flange. Continue with placing passes 13–17 in the top flange, followed by passes 18–22 in the bottom flange. Continue to alternate welding between top and bottom flange with a maximum of 5 passes per flange until the flange splices are complete. Tack weld web after aligning girder webs with short tacks as required to obtain proper alignment. Place pass 23 and pass 24 on the web. Gouge out and replace pass 23. Finish web splice with pass 25.
 - (3). For each layer, each bead, and the crater area, remove all slag and clean the weld and adjacent base metal before welding over previously deposited metal. Avoid arc strikes, and if they

occur, grind resulting cracks and blemishes out to a smooth contour and check them visually to ensure soundness.

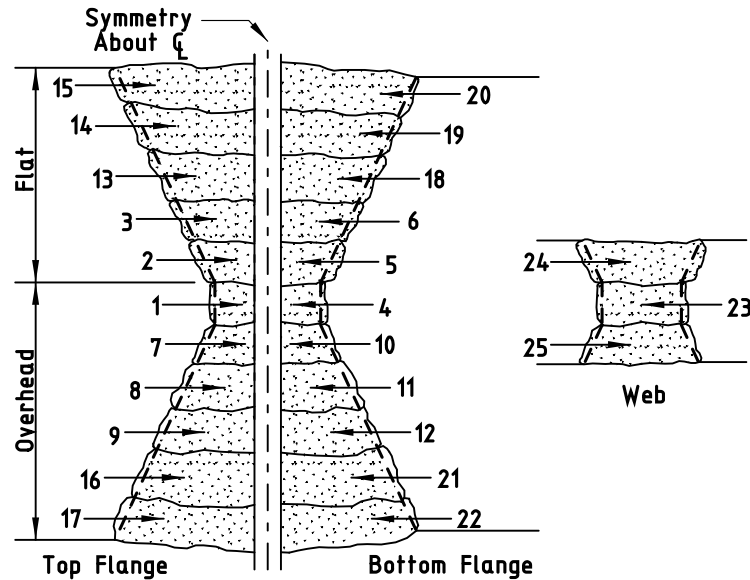


Figure 6

Welding sequence for splices for material up to 50,000-psi yield strength.

- (4). Deviation from the above sequence of weld passes requires approval. Obtain approval from the Bridge Division for welding procedures and sequences for special connections.
- c. Electrode Size and Weld Layer Thickness
 - (1). SMAW
 - (a). Electrode Size
 - 1) Use electrodes with the following maximum size:
 - a) 1/4 in. for all welds made in the flat position except root passes,
 - b) 1/4 in. for horizontal fillet welds,
 - c) 1/4 in. for root passes of fillet welds made in the flat position and of groove welds made in the flat position with backing and with a root opening of 1/4 in. or more,
 - d) 5/32 in. for welds made with low hydrogen electrodes in the vertical and overhead positions, and
 - e) 3/16 in. for all other welds.
 - (b). Weld Size and Layer Thickness

- 1) Make the root pass large enough to prevent cracking. Make layers subsequent to the root pass in fillet welds and all layers in groove welds of the following maximum thickness:
 - a) 1/4 in. for root passes of groove welds;
 - b) 1/8 in. for subsequent layers of welds made in the flat position; and
 - c) 3/16 in. for subsequent layers of welds made in the vertical, overhead, and horizontal positions.
 - 2) Make fillet welds passes no larger than:
 - a) 3/8 in. in the flat position,
 - b) 5/16 in. in the horizontal or overhead positions, and
 - c) 1/2 in. in the vertical position.
- (2). FCAW
- (a). Electrode Size
 - 1) Use electrodes with the following maximum size:
 - a) 5/32 in. for the flat and horizontal positions,
 - b) 3/32 in. for the vertical position, and
 - c) 5/64 in. for the overhead position.
 - (b). Weld Size and Layer Thickness
 - 1) Make weld layers, except root and surface layers, no thicker than 1/4 in. When the root opening of a groove weld is 1/2 in. or wider, use a multiple-pass split-layer technique. Use the split-layer technique to make all multiple-pass welds when the width of the layer exceeds 5/8 in.
 - 2) Ensure that each pass has complete fusion with adjacent base metal and weld metal and that there is no overlap, excessive porosity, or undercutting.
 - 3) Do not use FCAW with external gas shielding in a draft or wind. Furnish an approved shelter of material and shape to reduce wind velocity near the welding to a maximum of 5 MPH.

- 4) Make fillet weld passes no larger than:
 - a) 1/2 in. in the flat position,
 - b) 3/8 in. in the horizontal or overhead positions, and
 - c) 5/16 in. in the vertical position.

F. Weld Quality

1. Provide welds that are sound throughout with no cracks in the weld metal or weld pass. Completely fuse the weld metal and the base metal and each subsequent pass. Keep welds free from overlap, and keep the base metal free from undercut more than 1/100 in. deep when the direction of undercut is transverse to the primary stress in the part that is undercut. Fill all craters to the full cross section of the welds.

G. Radiographic Inspection

1. Conduct radiographic testing (RT) as required in the field at the expense of the Contractor by an agency or individual registered and licensed to perform industrial radiography. Follow all applicable rules and regulations for radiographic operations. Testing includes furnishing all materials, equipment, tools, labor, and incidentals necessary to perform the required testing. The Owner's Representative may require further tests and may perform additional testing, including other methods of inspection.
2. Perform RT in accordance with AASHTO/AWS D1.5. The Owner's Representative will examine and interpret the resulting radiographs in accordance with AASHTO/AWS D1.5. All radiographs become the property of the Owner's Representative and remain with the Owner's Representative.
3. For field welds of splices in beams or girders, radiographically inspect the full flange width of all flange splices and the top and bottom 1/6 of the web at each splice. Radiographically retest repaired welds. Make necessary repairs before any further work is done. Additional RT required because of unacceptable welding or poor radiograph quality is at the Contractor's expense. RT of particular welds required by the plans is in addition to the RT required by this Section.

H. Corrections

1. When welding is unsatisfactory or indicates inferior workmanship, the Owner's Representative will require corrective measures and approve the subsequent corrections.
2. Use oxygen gouging or arc-air gouging when required to remove part of the weld or base metal. Do not use oxygen gouging on weathering steel.

- Backgouge splices in beams and girders or cut out defective welds using arc-air gouging by a welder qualified to make beam and girder splices.
3. Where corrections require depositing additional weld metal, slope the sides of the area to be welded enough to permit depositing new metal.
 4. Where corrections require depositing additional weld metal, use a smaller electrode than that used for the original weld. Clean surfaces thoroughly before rewelding.
 5. Remove cracked welds completely and repair. If crack length is less than half the length of the weld, remove the weld metal for the length of the crack plus 2 in. beyond each end of the crack, and repair.
 6. Where work performed after making a deficient weld has made the weld inaccessible or has caused new conditions making the correction of the deficiency dangerous or ineffectual, restore the original conditions by removing welds, members, or both before making the necessary corrections; otherwise, compensate for the deficiency by performing additional work according to a revised and approved design.
 7. Cut apart and reweld improperly fitted or misaligned parts.
 8. Straighten members distorted by the heat of welding using mechanical means or the carefully supervised application of a limited amount of localized heat. Do not let heated areas exceed 1,200°F as measured by temperature-indicating crayons or other approved methods for steel up to 65,000 psi yield strength. Do not let heated areas exceed 1,100°F for higher-strength steels. Keep parts to be heat-straightened substantially free of stress from external forces except when mechanical means are used with the application of heat. Before straightening, submit a straightening procedure to the Owner's Representative for approval.
 9. Correct defective or unsound welds either by removing and replacing the entire weld or as follows.
 - a. Excessive Convexity
 - (1). Reduce to size by grinding off the excess weld metal, leaving a smooth profile.
 - b. Shrinkage Cracks, Cracks in Base Metal, Craters, and Excessive Porosity
 - (1). Remove defective portions of base and weld metal down to sound metal, and replace with additional sound weld metal.
 - c. Undercut, Undersize, and Excessive Concavity
 - (1). Clean and deposit additional weld metal.
 - d. Overlap and Incomplete Fusion
 - (1). Remove and replace the defective portion of weld.
 - e. Slag Inclusions

- (1). Remove the parts of the weld containing slag, and replace them with sound weld metal.
- f. Removal of Base Metal during Welding
 - (1). Clean and form full size by depositing additional weld metal using stringer beads.

4.04 WELDING REINFORCING STEEL

- A. Splice reinforcing steel by welding only at locations shown on the plans.
 1. Base Metal
 - a. Provide weldable reinforcing steel in conformance with Section 16440, "Reinforcing Steel."
 2. Preheat and Interpass Temperature
 - a. Minimum preheat and interpass temperatures are shown in Table 5. When reinforcing steel is below the listed temperature for the size and carbon equivalency range of the bar being welded, preheat it so that the cross section of the bar is above the minimum temperature for at least 6 in. on each side of the joint. After welding is complete, allow bars to cool naturally to ambient temperature. Do not accelerate cooling.

Table 5
Minimum Preheat and Interpass Temperature for Reinforcing Steel

Carbon Equivalent Range (%)	Size of Reinforcing Bar (no.)	Temperature (°F)
Up to and including 0.40	Up to 11 inclusive	None
	14 and 18	50
0.41 through 0.45 inclusive	Up to 11 inclusive	None
	14 and 18	100
0.46 through 0.55 inclusive	Up to 6 inclusive	None
	7 to 11 inclusive	50
	14 and 18	200
Unknown	Up to 18 inclusive	500

- b. For widening projects, base the preheat and interpass temperatures on the existing reinforcing steel and the requirements of Table 5.
3. Joint Types
 - a. Use butt splices for all No. 7 and larger bars. Use lap splices for No. 6 and smaller bars.
 - b. Make groove welds in lap splices at least 4 in. long, and weld them on each side of the lap joint as shown in Figure 7. For No. 5 and smaller bars, weld from one side of the lap when it is impractical to weld from

both sides of the joint if approved by the Owner's Representative, but in this case make the weld at least 6 in. long.

- c. Where possible, make all butt splices in the flat position. Make all welds for butt splices, except horizontal welds on vertical bars, as shown in Figures 8 and 9. The back-up strip is required when access to the splice is from the top only. When bars can be rotated or access to the splice is available from two sides, the double bevel splice may be used, and this type weld requires gouging out the root pass similar to a flange splice on structural steel. The root pass may be made using E7010 or E8010 electrodes for all double beveled splices. If using E7010 or E8010 electrodes, preheat the steel to 400°F and then completely remove the root pass before welding the opposite side. Make horizontal splices on vertical bars as shown in Figure 10. Provide alignment strips as shown in Figures 9 and 10 to hold bars during welding operation. Trim alignment strips after welding is complete.

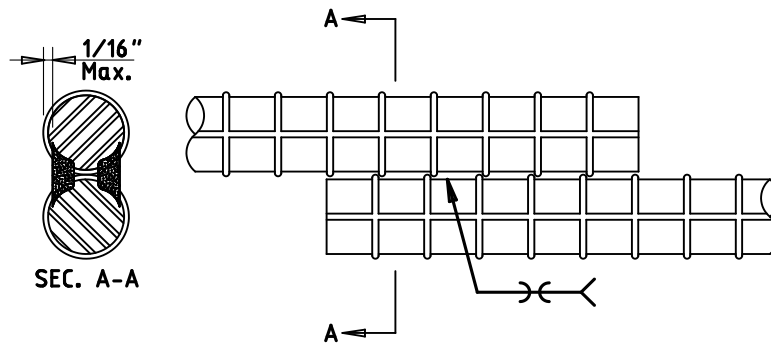


Figure 7
Direct lap joint with bars in contact.

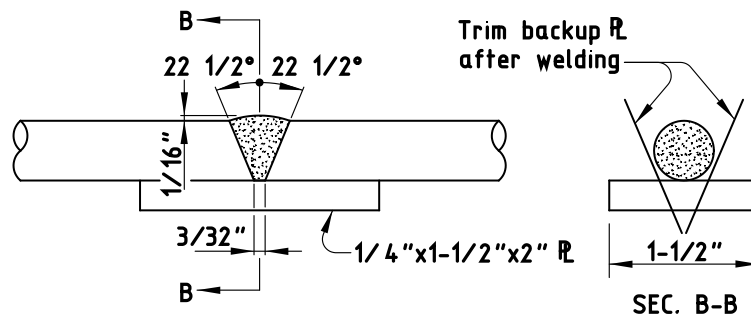


Figure 8
Single bevel V-groove weld in horizontal position.

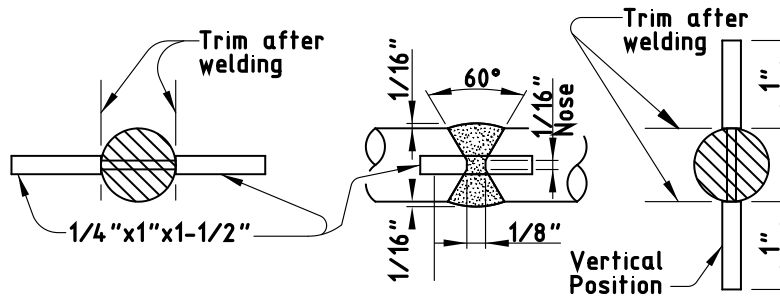


Figure 9
Double bevel V-groove weld in horizontal position.

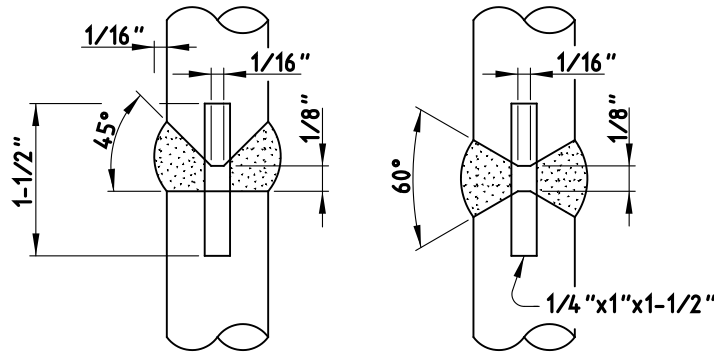


Figure 10
Double bevel V-groove weld in vertical position.

4. Radiographic Inspection
 - a. Radiograph welded butt splices at the expense of the Contractor when designated on the plans. Follow all applicable rules and regulations for radiographic operations. Ensure that welds have no cracks and that the sum of the greatest dimensions of porosity and fusion-type defects do not exceed 1/10 of the nominal bar diameter.
 - b. The Owner's Representative examines and interprets the resulting radiographs, which become the property of and remain with the Owner's Representative.

PART 5 MEASUREMENT AND PAYMENT

- A. The work performed, materials furnished, equipment, labor, tools, and incidentals will not be measured or paid for directly but will be subsidiary to pertinent Sections.

END OF SECTION