

SECTION 050200

WELDING

1. DESCRIPTION

This specification shall govern for the field welding of structural steel and reinforcing steel.

Provisions are made herein for the welding of the types of steel listed in Table 1, using the manual shielded metal-arc process, semi-automatic (manual) gas metal-arc welding and flux cored arc welding processes. Other welding processes may be permitted with the specific approval of the Engineer and with qualification of the welding procedure.

2. STRUCTURAL STEEL GENERAL

Final welds including tack welds to be incorporated therein shall be by a certified welder; certified welder being previously certified by tests as prescribed in the "Code for Welding in Building Construction," ASW D1.0-69, of the American Welding Society, to perform the type of work required. Miscellaneous welds may be made by a qualified welder; qualified welder being an experienced welder who is capable of making good welds of sound quality, but does not have certification papers; miscellaneous welds being welds that have no load carrying capacity in the completed structure. Tack welds shall be cleaned and fused thoroughly with the final weld. Defective, cracked or broken tack welds shall be removed.

Welds shall be as required by the contract or erection drawings. The location or size shall not be changed without approval of the Engineer.

The welder shall place his identification mark with crayon or paint near the groove welds made by him.

No welding will be allowed 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 that will hamper good workmanship.

Any moisture present at the point of welding shall be driven off by heat before welding commences. Windbreaks shall be required for the protection of all welding operations.

There shall be no temporary welds for transportation, erection or other purpose on main members, except at locations more than one-sixth the depth of the web from the flanges of beams and girders, as approved by the Engineer.

On A514 steel, all groove welds in main members and in flanges of beams and girders subject to tensile stress or reversals of stress shall be finished smooth and flush on all surfaces, including edges, by grinding in the direction of applied stress, leaving the surfaces free from depressions. Chipping may be used provided it is followed by such grinding. Parts joined by groove welds connecting plates of unequal thickness or width shall have a smooth transition between offset surfaces at a slope not greater than one in four with the surface of either part. The surfaces shall be ground so that the radii at the points of transition will be four (4) inches minimum.

All groove welds, except when produced with the aid of backing, shall have the root of the initial weld gouged, chipped or otherwise removed to sound metal before welding is started from the second side, except that back gouging will not be required when welding steel piling or armor joints with E6010 electrodes. The back side shall be thoroughly cleaned before placing back-up pass.

When backing for welds is left in place to become a part of the structure, it shall be a single length insofar as possible. Where more than a single length is needed, they shall be joined by full penetration butt welds. The surfaces of this butt weld shall be ground flush as necessary to obtain proper fit-up in the weld joint.

Before welding over previously deposited metal, all slag shall be removed, and the weld and adjacent base metal shall be cleaned. This requirement shall apply equally to successive layers, successive beads and the crater area.

Arc strikes outside the area of permanent welds must be avoided on all steels. Where they do occur, resulting cracks and blemishes shall be ground out to a smooth contour and checked to insure soundness.

Stringer bead technique shall be used where possible for groove welds on all types of steel. Weaving will not be permitted for A514 steel except in welding vertically upward, when a weave not exceeding two electrode diameters is permissible for manual shielded metal-arc welding.

In all welding processes, the progression for all passes in vertical welding shall be upward using a back step sequence.

Groove welds shall begin and terminate at the ends of a joint on extension bars. Edge preparation and thickness of extension bars shall be the same as that of the member being welded and shall extend a minimum of three-quarter (3/4) inch beyond the joint. Extension bars shall be removed with a cutting torch upon completion and cooling of the weld, and the flange edges shall be ground smooth.

Any defects exposed by the grinding shall be cleaned, filled with weld metal, and reground to a uniform finish. All grinding shall be parallel to the flange. Excess grinding of the parent metal shall be avoided.

3. FILLER METAL

Electrodes for manual shielded metal-arc welding shall conform to the requirements of the latest edition of "Specifications for Mild Steel Covered Arc-Welding Electrodes", AWS A5.1, or to the requirements of the latest edition of "Specifications for Low Alloy Steel Covered Arc-Welding Electrodes," AWS A5.5.

All electrodes and combination of electrode and shielding for gas metal-arc welding for producing weld metal with a minimum specified yield point not exceeding 60,000 psi shall conform to the requirements in the latest edition of, "Specification for Mild Steel Electrodes for Gas Metal-Arc Welding," AWS A5.18, or "Specification for Mild Steel Electrodes for Flux Cored Arc Welding," AWS A5.20, applicable for the classifications producing weld metal having a minimum impact strength of 20 ft.-lb., Charpy V-notch, at a temperature of 0° F or below.

For weld metal with a minimum specified yield strength exceeding 60,000 psi, the Contractor shall demonstrate that each electrode and flux or combination of electrode and shielding medium proposed for use will produce low alloy weld metal having the mechanical properties listed in Table A.

The mechanical properties shall be determined from a multiple pass weld made in accordance with the test requirements of the latest edition of AWS A5.18 or AWS A5.20, as applicable.

TABLE A
Required Mechanical Properties for GMAW and FCAW Electrodes

GMAW Grade	FCAW Grade	Tensile Strength psi - Min	Yield Strength psi - Min	Elongation, % in 2 inches Min	Impact Strength ft-lb @ 0°F- Min
E80S	E80T	80,000	65,000	18	20
E90S	E90T	90,000	78,000	17	20
E100S	E100T	100,000	90,000	16	20
E110S	E110T	110,000	98,000	15	20

The mechanical property tests for Grades E100S, E110S, E100T and E110T shall be made using ASTM A 514 base material.

Class of electrode required will be as shown in Table 1 (below). Electrodes shall be used with the type of current, the polarity and in the positions permitted by AWS A5.1 and A5.5 for manual shielded metal-arc welding. AWS A5.18 and A5.20 Specifications shall govern for gas metal-arc welding and flux cored arc welding.

TABLE 1
CLASSIFICATIONS OF ELECTRODES PERMITTED

<u>TYPE OF STEEL</u>	<u>MAIN MEMBERS</u>		<u>SECONDARY MEMBERS</u>		
	<u>Groove & Fillet Welds</u>		<u>Groove & Fillet Welds</u>		
Steel Piling,	E6010	E60T-8	E60XX	E60T-8	E70S-2
A53 Pipe,	E6011	E70S-1B	E70XX	E7XT-1	E70S-3
A500,	E7016	E70S-2	E70S-1B	E7XT-5	E70S-6
A501,	E7018	E70S-3	E70S-2	E7XT-6	E70S-7
Armor Joints		E70S-6	E70S-3	E7XT-8	
		E-70S-7	E70S-6		
			E70U-1		
A36,	E7016	E70S-2	E7016	E70S-2	
A441,	E7018	E70S-3	E7018	E70S-3	
A572-Grade 50	E7XT-1	E70S-6	E7XT-1	E70S-6	
A588,	E7XT-5	E70S-7	E7XT-5	E70S-7	
A242 Deck Plates	E7XT-6		E7XT-6		
API Pipe	E7XT-8		E7XT-8		
A514	E11018M	E110S	E11018M	E110S	
2½" Thick or Less	E110T		E110T		
A514	E10018M	E100S	E10018M	E100S	
Over 2½" Thick	E100T		E100T		
A588, A242,	E8018, C-3		E8018, C-3		
A618 Weathering	E80T ⁽³⁾	E80S ⁽³⁾	E80T ⁽³⁾		
Steel			E80S ⁽³⁾		
Reinforcing Steel	E7016	E7018			
A572 Grades	E8016	E80T			
60 and 65	E8018	E80S			
for Light Towers					

1. Use of the same type electrode with the next higher mechanical properties, in accordance with AWS A5.1 or A5.5, than those listed will be permitted.
2. In joints involving base metals of different yield points or strengths, low hydrogen electrodes applicable to the lower strength base metal may be used.

Before use, all electrodes with low hydrogen coverings conforming to AWS A5.1 shall be dried for not less than two hours between 450 and 500 degrees F and electrodes with low hydrogen coverings conforming to AWS A5.5 for not less than one hour at a temperature between 700 and 800 degrees F. Immediately after drying, electrodes shall be stored in ovens held at a temperature of at least 250 degrees F. E70 electrodes not used within four hours, E80 within two hours, and E110 within one-half hour after removal from the storage oven shall be redried before use. Electrodes with flux which has been wet, cracked or otherwise damaged, shall not be used. When used for welding A514 steel, electrodes shall be dried at least one hour at temperatures between 700 and 800 degrees F before being used. Electrodes may be redried only once.

Suitable facilities for drying and storage of electrodes shall be furnished at the job site, along with thermometers for checking and controlling the oven temperature.

In humid atmospheres, the times allowed for use without redrying may be reduced.

When gas or gas mixture is used for gas metal-arc welding, it shall be of a welding grade having a dew point of -40° F or lower. The gas manufacturer shall furnish certification to the Engineer that the gas or gas mixture is suitable for the intended application and will meet the dew point requirements.

Welding wire coils removed from the original package shall be protected or stored to keep their characteristics or welding properties intact. Rusty coils, or portions of coils, that are rusty shall not be used.

Preheat

Preheat ahead of welding both groove and fillet welds (including tack welding) will be required as shown in Table 2. Any moisture present at the point of welding shall be driven off by preheating before welding begins. When the base metal is below the required temperature, it shall be preheated so the parts being welded are not less than the specified temperature within three inches (3") of the point of welding.

Preheat and interpass temperatures must be sufficient to prevent crack formation. The preheat temperatures shown in Table 2 are minimum and higher preheats may be necessary in highly restrained welds.

Preheating equipment shall be adequate to maintain the entire joint at or above the specified temperature. When possible, a joint shall be completely welded before it is allowed to cool below the specified temperature, but shall always be welded sufficiently to prevent cracking before cooling is permitted.

Usually preheat and interpass temperatures shall not exceed 400° F for thickness up to 1½ inches and 450° F for greater thickness. These temperatures shall never be exceeded on A514 steel.

The welder shall have and use approved equipment for checking preheat and interpass temperatures at all times while welding is in progress.

For all groove welds, preheat temperature shall be measured on the side opposite to which the heat is applied at points about three inches (3") away from the joint.

TABLE 2
MINIMUM PREHEAT AND INTERPASS TEMPERATURE FOR
MANUAL SHIELDED METAL-ARC WELDING, FLUX
CORED ARC WELDING OR GAS METAL-ARC WELDING

Thickness of Thickness Part at Point of Welding (Inches)	MANUAL OR SEMI-AUTOMATIC GAS METAL-ARC WELDING, FLUX CORED ARC WELDING OR MANUAL SHIELDED METAL-ARC WELDING	
	<u>With Low Hydrogen Electrodes</u>	
	ASTM A36; A242; A441 A572 Grades 42, 45 and 50; A588	ASTM A514
To 3/4, inclusive	50° F	50° F
Over 3/4 to 1½, inclusive	70° F	125° F
Over 1½ to 2½, inclusive	150° F	175° F
Over 2½	225° F	225° F

- (1) These temperatures are the minimum required for the thinner material shown for each increment, and higher preheat on a step basis will be required for the thicker material within each increment. Preheat and interpass temperatures must be sufficient to prevent crack formation and welding shall be carried continuously to completion or to a point that will assure freedom from cracking before the joint is allowed to cool below the minimum specified preheat and interpass temperature. Temperatures above those shown may be required for highly restrained welds.
- (2) When E7010 electrodes are permitted for tacking or temporary root pass, the material shall be preheated to 400° F.
- (3) When joining steels of different strengths or thickness with groove welds, the preheat and interpass temperatures for the higher strength steel and the average plate thickness shall be used. For fillet welds, the preheat shall be used for the higher strength steel and the thickest plate being welded.
- (4) When the base metal temperature is below 32° F, preheat to at least 70° F and maintain this minimum temperature during welding.
- (5) Heat input when welding A514 steel shall not exceed the steel producer's recommendations.
- (6) When moisture is present on the base metal, it shall be preheated to 200° F before welding is started.

4. QUALITY OF WELDS

Weld metal shall be sound throughout.

There shall be no cracks in any weld or weld pass.

There shall be complete fusion between the weld metal and the base metal and between successive passes throughout the joint.

Welds shall be free from overlap and the base metal free from undercut more than one one-hundredth inch (1/100") deep when its direction is transverse to the primary stress in the part that is undercut. Undercut shall not be more than one thirty-second inch (1/32") deep when its direction is parallel to the primary stress in the part that is undercut.

All craters shall be filled to the full cross section of the welds.

All welds on A514 steel shall be visually examined for longitudinal or transverse cracks not less than 48 hours after completion of the welding.

5. CORRECTIONS

When welding is unsatisfactory or indicates inferior workmanship, the following corrective measures will be required by the Engineer whose specific approval shall be obtained for making each correction.

When requirements prescribe the removal of part of the weld or a portion of the base metal, removal shall be by oxygen gouging or arc-air gouging.

Oxygen gouging shall not be used on A514 steel or A588 weathering steel. All surfaces shall be ground after arc-air gouging.

Backgouging of splices in beams and girders or cutouts of defective welds shall be done by a welder qualified to make beam and girder splices.

Where corrections require the deposition of additional weld metal, the sides of the area to be welded shall have sufficient slope to permit depositing new metal.

Defective or unsound welds shall be corrected either by removing and replacing the entire weld, or as follows:

Excessive convexity. Reduce to size by grinding off the excess weld metal.

Shrinkage cracks. Cracks in base metal, craters and excessive porosity. Remove defective portions of base and weld metal down to sound metal and replace with additional sound weld metal.

Undercutting, undersize and excessive concavity. Clean and deposit additional weld metal.

Overlapping and incomplete fusion. Remove and replace the defective portion of weld.

Slag inclusions. Remove the parts of the weld containing slag and replace with sound weld metal.

Removal of adjacent base metal during welding. Clean and form full size by depositing additional weld metal.

Where corrections require the deposition of additional weld metal, the electrode used shall be smaller than that used for making the original weld. Surfaces shall be cleaned thoroughly before re-welding.

A cracked weld shall be removed throughout its length, unless the extent of the crack can be ascertained to be limited, in which case the weld metal shall be removed 2 inches (2") beyond each end of the crack and repairs made.

Where work performed after the making of a deficient weld has made the weld inaccessible or has caused new conditions making the correction of the deficiency dangerous or ineffectual, the original conditions shall be restored by removal of welds or members, or both, before making the necessary corrections, or else the deficiency shall be compensated by additional work according to a revised design approved by the Engineer.

Improperly fitted and misaligned parts shall be cut apart and re-welded.

Members distorted by the heat of welding shall be straightened by mechanical means or by the carefully supervised application of a limited amount of localized heat. Heated areas shall not exceed 1200° F as measured by Tempil-sticks or other approved methods for steel up to 65,000 psi yield strength. Parts to be heat straightened shall be substantially free of stress from external forces, except when mechanical means are used in conjunction with the application of heat.

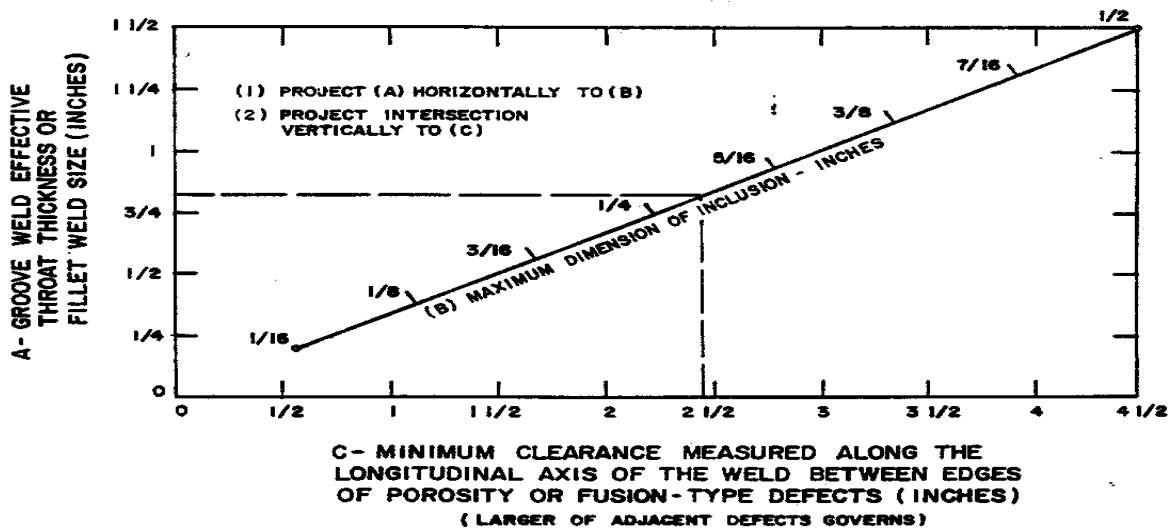
Heat straightening of A514 steel shall be done only under rigidly controlled procedures, subject to the approval of the Engineer. In no case shall the maximum temperature of the steel exceed 1100° F. Sharp kinks and bends shall be cause for rejection of the material.

6. RADIOGRAPHIC INSPECTION

All groove welds designed to carry primary stresses shall be subject to radiographic inspection. When subjected to such inspections, the presence of any of the following defects in excess of the limits indicated will result in rejection of the defective weld until corrected.

1. Sections of welds shown to have any cracking, regardless of length or location, incomplete fusion, overlapping, or inadequate penetration shall be judged unacceptable.
2. Inclusions less than one-sixteenth inch (1/16") in greatest dimension including slag, porosity and other deleterious material, shall be permitted if well dispersed so that the sum of the greatest dimensions of the inclusions in any linear inch of welded joint shall not exceed three-eighth inch (3/8").
3. Inclusions one-sixteenth inch (1/16") or larger in greatest dimension shall be permitted provided such defects do not exceed the limits shown on Figure 1 or in subparagraph (2) above.
4. There shall be no inclusion greater than one-sixteenth inch (1/16") within one inch of the edge of part or member at the joint or point of restraint.

FIGURE 1
STANDARDS FOR ALLOWABLE INCLUSIONS



NOTES:

- (1) The distance from the edge of an inclusion to the edge of a plate or to any intersecting weld shall be equal to or greater than the clearance between inclusions.
- (2) Inclusions with any dimension greater than 1/2 inch are not acceptable.
- (3) For joint thickness greater than 1½ inches, the minimum allowable dimension and spacing of inclusions shall be the same as for 1½-inch joints.
- (4) Values of (B) obtained by projecting horizontally from (A) are maximum values. Any value of (B) smaller than the maximum is satisfactory.
- (5) Values of (C) obtained by projecting vertically from (B) are minimum values. Any value of (C) larger than the minimum is satisfactory.

Radiographic inspection shall be made of A514 steel not less than 48 hours following the completion of the welding. For other steels, nondestructive inspection may begin immediately after welding and cleaning or grinding is completed.

Definitions:

Porosity signifies gas pockets or any similar generally globular type voids.

Fusion-type defect signifies slag inclusions and similar elongated defects.

7. REINFORCING STEEL - GENERAL

Provisions are made herein for the welding of reinforcing steel by the manual shielded metal-arc process. Other processes may be permitted with the specific approval of the Engineer or may be specified on the plans.

Splicing of reinforcing steel by welding shall be done only at locations approved by the Engineer.

8. BASE METAL

Reinforcing steel to be welded shall be new billet steel conforming to ASTM Designation: A615, and shall also conform to the following chemical composition:

Maximum Carbon	0.40 Percent
Maximum Manganese	1.30 Percent

9. FILLER METAL

Low hydrogen electrodes as specified in Table A will be required for all welding of reinforcing steel. Drying of electrodes shall be as specified in Article 3, "Filler Metal" for Structural Steel.

10. PREHEAT AND INTERPASS TEMPERATURE

Minimum preheat and interpass temperatures for reinforcing steel shall be as shown in Table 3.

TABLE 3
PREHEAT AND INTERPASS TEMPERATURE FOR REINFORCING STEEL

<u>CARBON RANGE</u>	<u>NO. 7 & SMALLER</u>	<u>NO. 8 & LARGER</u>
Up to and including 0.30	None	100
0.31 to 0.35 inclusive	None	150
0.36 to 0.40 inclusive	100	250
Unknown	250	400

For widening projects, use carbon content and bar size of new steel to determine preheat required.

11. JOINT TYPES

For all bars No. 8 and larger, butt splices shall be required. For No. 7 bars and smaller, lap splices shall be required.

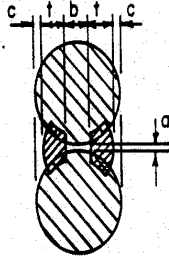
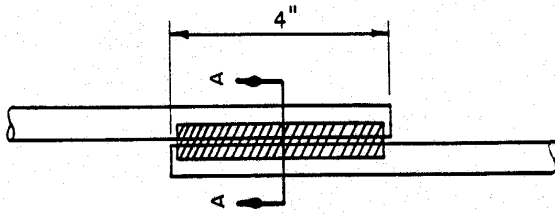
Fillet welds in lap splices shall be a minimum of 4 inches in length and shall be welded on each side of the lap joint. For bars No. 5 and smaller, welding from one side of the lap will be permitted by the Engineer when it is impractical to weld from both sides of the joint, and the weld shall be a minimum of 6 inches in length.

Lap welds shall meet the requirements specified in Table 4.

Where possible, all butt splices shall be made in the flat position. All butt splices, except horizontal, shall be as shown in Figure 2 with the back-up strip required. Horizontal splices shall be as shown in Figure 3.

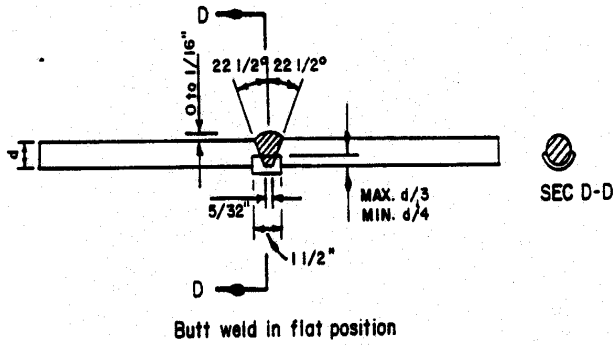
TABLE 4
REQUIRED DIMENSIONS FOR LAP SPLICES

<u>BAR SIZE</u>	<u>"a"</u>	<u>"b"</u> (Max.)	<u>"t"</u> (Min.)	<u>"c"</u> (Max.)	<u>ELECTRODE</u> <u>SIZE</u>
No. 4	0.04 in.	1/8 in.	1/8 in.	1/16 in.	1/8 in.
No. 5	0.05 in.	1/8 in.	3/16 in.	1/16 in.	5/32 in.
No. 6	0.06 in.	1/8 in.	1/4 in.	1/16 in.	5/32 in.
No. 7	0.07 in.	3/16 in.	5/16 in.	1/16 in.	5/32 in.



SEC. A-A (ENLARGED)

TABLE 4
Required Dimensions for Lap Splices



Butt weld in flat position



BUTT WELD WITH BAR IN HORIZONTAL POSITION

FIGURE 2

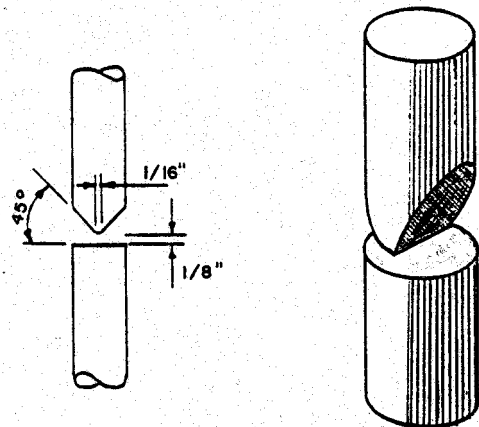


FIGURE 3

12. WIDENING PROJECTS

In general, the new reinforcing steel shall be either lap or butt spliced directly to the bar to be extended. When the reinforcement in the old portion of a structure is found to be of the wrong spacing, dowel bars long enough to develop the welded lap or butt splice and also develop the bar in bond, as required in City Standard Specification Section 032020 "Reinforcing Steel", shall be welded to the old steel, and the new reinforcement placed at the correct spacing without welding to the old steel. No measurement or payment will be made for the dowels but will be subsidiary to the other items in the contract.

Both old and new reinforcement shall be cleaned thoroughly prior to the preparation of the joint.

13. RADIOGRAPHIC INSPECTION

When so designated on the plans, welded butt splices shall be radiographed. Weld quality shall be as follows: There shall be no cracks and the sum of the greatest dimensions of porosity and fusion-type defects shall not exceed one-tenth of the nominal bar diameter in inches.

14. MEASUREMENT AND PAYMENT

Unless otherwise specified on the Bid Form, welding will not be measured for pay, but will be considered subsidiary to the various other bid items in the Bid Form.