7. Stud Welding

7.1 Scope

Section 7 contains general requirements for welding steel studs to steel (see 7.2.7 and 1.2.2 for approved steels). In addition, it stipulates specific requirements for the following:

(1) Workmanship, preproduction testing, operator qualification, and application qualification testing, when required, all to be performed by the Contractor

(2) QC and QA inspection of stud welding during production

(3) Mechanical properties of steel studs, and requirements for qualification of stud bases, all tests and documentation to be furnished by the stud manufacturer

7.2 General Requirements

7.2.1 Studs shall be of suitable design for arc welding to steel members with the use of automatically timed stud welding equipment. The type and size of the stud shall be as specified by the drawings, specifications, or special provisions. For headed-type studs, see Figure 7.1.

7.2.2 An arc shield (ferrule) of heat-resistant ceramic or other suitable material shall be furnished with each stud.

7.2.3 A suitable deoxidizing and arc stabilizing flux for welding shall be furnished with each stud of 8 mm [5/16 in.] diameter or larger. Studs less than 8 mm [5/16 in.] in diameter may be furnished with or without flux.

7.2.4 Only studs with qualified stud bases shall be used. A stud base, to be qualified, shall have passed the test described in Annex VI. The arc shield used in production shall be the same as used in qualification tests or as recommended by the manufacturer. Qualification of stud bases in conformance with Annex VI shall be at the manufacturer's expense.

7.2.5 Finish shall be produced by heading, rolling, or machining. Finished studs shall be of uniform quality and condition, free of injurious laps, fins, seams, cracks, twists, bends, or other injurious discontinuities. Radial cracks or bursts in the head of a stud shall not be cause for rejection, provided that the cracks or bursts do not extend more than half the distance from the head periphery to the shank, as determined by visual inspection.

Note: Heads of shear connectors or anchor studs are subject to cracks or bursts, which are names for the same thing. Cracks or bursts designate an abrupt interruption of the periphery of the stud head by radial separation of the metal. Such interruptions do not adversely affect the structural strength, corrosion resistance, nor other functional requirements of headed studs.

7.2.6 Only bases qualified under Annex VI shall be used. When requested by the Engineer, the Contractor shall provide the following information:

(1) A description of the stud and arc shield

(2) Certification from the manufacturer that the stud base is qualified as described in 7.2.4

(3) Qualification test data

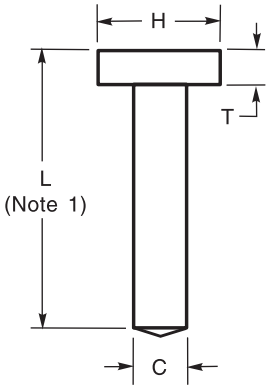
7.2.7 M270M (M270) Grades 690/690W (100/100W) (A 709M [A 709] Grades 690/690W [100/100W]) steels shall not be stud welded without approval of the Engineer.

7.3 Mechanical Requirements

7.3.1 Studs shall be made from cold-drawn bar stock conforming to the requirements of ASTM A 108, *Specification for Steel Bars, Carbon Cold Finished, Standard Quality Grades*, Grades G10100 through G10200, inclusive, either semi-killed or killed deoxidation.

7.3.1.1 Mechanical property requirements of studs other than outlined below shall be specified by the Engineer.

7.3.1.2 At the manufacturer's option, mechanical properties of studs shall be determined by testing either



Note:
1. L = manufactured length-length specified by Engineer plus upset distance.

Standard Dimensions, mm [in.]				
Shank Diameter (C)		Length Tolerance (L)	Head Diameter (H)	Minimum Head Height (T)
12.7 [1/2]	+0.00 -0.25 [-0.010]	±1.6 [±1/16]	25.4 ± 0.4 [1 ± 1/64]	7.1 [9/32]
15.9 [5/8]	+0.00 -0.25 [-0.010]	±1.6 [±1/16]	31.7 ± 0.4 [1-1/4 ± 1/64]	7.1 [9/32]
19.0 [3/4]	+0.00 -0.38 [-0.015]	±1.6 [±1/16]	31.7 ± 0.4 [1-1/4 ± 1/64]	9.5 [3/8]
22.1 [7/8]	+0.00 -0.38 [-0.015]	±1.6 [±1/16]	34.9 ± 0.4 [1-3/8 ± 1/64]	9.5 [3/8]
25.4 [1]	+0.00 -0.38 [-0.015]	±1.6 [±1/16]	41.3 ± 0.4 [1-5/8 ± 1/64]	12.7 [1/2]

Figure 7.1—Dimension and Tolerances of Standard-Type Shear Connectors (see 7.2.1)

(1) the steel after cold finishing, or (2) the full diameter finished studs. In either case, the studs shall conform to the requirements shown in Table 7.1.

7.3.2 Mechanical properties shall be determined in conformance with the applicable sections of ASTM A 370, *Test Methods and Definitions for Mechanical Testing of Steel Products*. A typical test fixture is used, similar to that shown in Figure 7.2.

7.3.3 Upon request by the Engineer, the Contractor shall furnish the following:

7.3.3.1 The Contractor shall provide the stud manufacturer's certification that the studs, as delivered, conform to the applicable requirements of 7.2 and 7.3.

7.3.3.2 The Contractor shall provide certified copies of the stud manufacturer's test reports covering the last completed set of in-plant quality control mechanical tests, required by 7.3 for each stock size delivered. The quality control test shall have been made within the six month period before delivery of the studs.

Table 7.1
Mechanical Property Requirements for Studs (see 7.3.1.2)

	Type A[1]	Type B[2]
Tensile strength	380 MPa [55 ksi] min	415 MPa [60 ksi] min
Yield strength (0.2% offset)	—	345 MPa [50 ksi] min
Elongation (% in 50 mm [2 in.])	17% min	20% min
Reduction of area	50% min	50% min

Notes:
1. Type A studs shall be general purpose of any type and size used for purposes other than shear transfer in composite beam design and construction.
2. Type B studs shall be studs that are headed, bent, or of other configuration in 12 mm [1/2 in.] through 23 mm [7/8 in.] diameter that are used as an essential component in composite beam design and construction.

7.3.4 When quality control tests are not available, the Contractor shall furnish mechanical test reports conforming to the requirements of 7.3. The mechanical tests shall be on finished studs provided by the manufacturer of the studs. The number of tests to be performed shall be specified by the Engineer.

7.3.5 The Engineer may select studs of each type and size used under the contract as necessary for checking the requirements of 7.2 and 7.3. Furnishing these studs shall be at the Contractor's expense. Testing shall be at the Owner's expense.

7.4 Workmanship

7.4.1 At the time of welding, the studs shall be free from rust, rust pits, scale, oil, moisture, and other deleterious matter that would adversely affect the welding operation.

7.4.2 The stud base shall not be painted, galvanized, nor cadmium-plated prior to welding.

7.4.3 The areas to which the studs are to be welded shall be free of scale, rust, moisture, and other injurious mate-

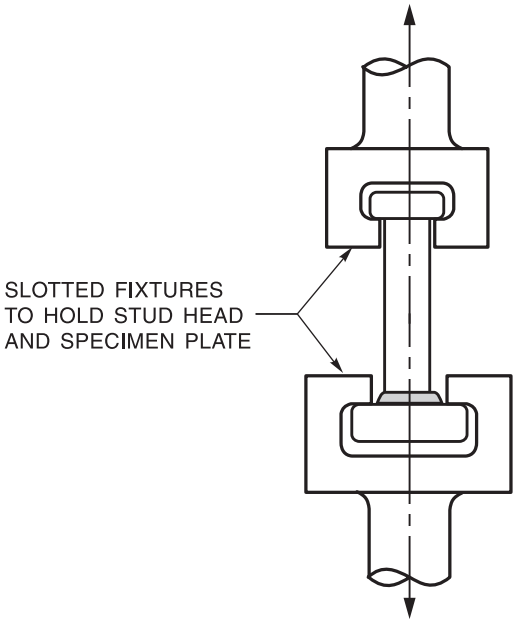


Figure 7.2—Typical Tension Test Fixture (see 7.3.2)

rial to the extent necessary to obtain satisfactory welds. These areas may be cleaned by wire brushing, scaling, prick-punching, or grinding. Extreme care should be exercised when welding through metal decking.

7.4.4 The arc shields or ferrules shall be kept dry. Any arc shields which show signs of surface moisture from dew or rain shall be oven dried at 120°C [250°F] for two hours before use.

7.4.5 Longitudinal and lateral spacings of stud shear connectors (type B) with respect to each other and to edges of beam or girder flanges may vary a maximum of 25 mm [1 in.] from the location shown in the drawings. The clear distance between studs shall not be less than 25 mm [1 in.] unless approved by the Engineer. The minimum distance from the edge of a stud base to the edge of a flange shall be the diameter of the stud plus 3 mm [1/8 in.] but preferably not less than 40 mm [1-1/2 in.].

7.4.6 After welding, arc shields shall be broken free from studs to be embedded in concrete, and, where practical, from all other studs.

7.4.7 The studs, after welding, shall be free of any discontinuities or substances that would interfere with their intended function. However, nonfusion on the legs of the flash and small shrink fissures are acceptable.

Note: The fillet weld profiles shown in Figure 3.3 do not apply to the flash of automatically timed stud welds. The expelled metal around the base of the stud shall be designated as flash in conformance with Annex V of this code. It shall not be defined as a fillet weld such as those formed by conventional arc welding. The expelled metal, which is excess to the weld required for strength, is not detrimental but, on the contrary, is essential to provide a good weld. The containment of this excess molten metal around a welded stud by the ferrule (arc shield) assists in securing sound fusion of the entire cross section of the stud base. The stud weld flash may have nonfusion in its vertical leg and overlap on its horizontal leg, and it may contain occasional small shrink fissures or other discontinuities that usually form at the top of the weld flash with essentially radial or longitudinal orientation, or both, to the axis of the stud. Such nonfusion, on the vertical leg of the flash, and small shrink fissures shall be acceptable.

7.5 Technique

7.5.1 Studs shall be welded with automatically timed stud welding equipment connected to a suitable source of direct current electrode negative (DCEN) power. Welding voltage, current, time, and gun settings for lift and plunge should be set at optimum settings, based on past practice, recommendations of stud and equipment manufacturer, or both. AWS C5.4, *Recommended Practices for Stud Welding*, should also be used for technique guidance.

7.5.2 If two or more stud welding guns are to be operated from the same power source, they shall be interlocked so that only one gun can operate at a time, and so that the power source has fully recovered from making one weld before another weld is started.

7.5.3 While in operation, the welding gun shall be held in position without movement until the weld metal has solidified.

7.5.4 Welding shall not be done when the base metal temperature is below –20°C [0°F] or when the surface is wet or exposed to falling rain or snow.

7.5.4.1 When the temperature of the base metal is below 0°C [32°F], one additional stud in each 100 studs welded shall be tested by methods described in 7.7.1.3 and 7.7.1.4, except that the angle of testing shall be approximately 15°. This is in addition to the first two studs tested for each start of a new production period or change in set-up.

7.5.4.2 Set-up includes stud gun, power source, stud diameter, gun lift and plunge, total welding lead length, or changes greater than ±5% in current (amperage) and time.

7.5.5 At the option of the Contractor, studs may be fillet welded by the SMAW, provided the following requirements shall be met:

7.5.5.1 The minimum fillet size to be used shall be the larger of those required in Table 2.1 or Table 7.2.

7.5.5.2 Welding shall be done with low-hydrogen electrodes 4.0 mm [5/32 in.] or 4.8 mm [3/16 in.] in diameter except that a smaller diameter electrode may be used on studs 10 mm [3/8 in.] or less in diameter or for out-of-position welds.

7.5.5.3 The stud base shall be prepared so that the base of the stud fits against the base metal.

7.5.5.4 All rust and mill scale at the location of the stud shall be removed from the base metal by grinding. The end of the stud shall also be clean.

7.5.5.5 The base metal to which studs are welded shall be preheated in conformance with the requirements of Table 4.4.

7.5.5.6 Fillet welded stud bases shall be visually inspected per 6.5.

7.6 Stud Application Qualification Requirements

7.6.1 Prequalification. Studs which are shop or field applied in the flat (down-hand) position to a planar and horizontal surface shall be deemed prequalified by virtue of the manufacturer's stud-base qualification tests (Annex VI), and no further application testing is required. The limit of flat position is defined as 0–15° slope on the surface to which the stud is applied.

The following are some non-prequalified stud applications that require tests of this section:

(1) Studs which are applied on nonplanar surfaces or to a planar surface in the vertical or overhead positions.

Table 7.2
Minimum Fillet Weld Size for Small Diameter Studs (see 7.5.5.1)

Stud Diameter, ϕ, mm [in.]	Minimum Fillet Weld Size, mm [in.]
$\phi \leq 10$ [3/8]	6 [1/4]
10 [3/8] $< \phi \leq 25$ [1]	8 [5/16]
$\phi > 25$ [1]	10 [3/8]

(2) Studs which are welded through decking. The tests should be with material representative of the condition to be used in construction.

(3) Studs welded to steels other than those described in 1.2.2.

7.6.2 Responsibilities for Tests. The Contractor or stud applicator shall be responsible for the performance of these tests. Tests may be performed by the Contractor or stud applicator, the stud manufacturer, or by another testing agency satisfactory to all parties involved.

7.6.3 Preparation of Specimens

7.6.3.1 Test specimens shall be prepared by welding the studs being qualified to specimen plates of M270M (M270) Grade 250 (36) (A 709M [A 709] Grade 250 [36]) steel or any base metal described in 1.2.2.

7.6.3.2 Weld position, nature of base metal and stud surfaces, current, and time shall be recorded.

7.6.4 Number of Specimens. Ten (10) specimens shall be welded consecutively using recommended WPSs and settings for each diameter, position, and surface geometry.

7.6.5 Tests Required. The ten (10) specimens shall be tested using one or more of the following test methods: bending, torquing, or tensioning.

7.6.6 Test Methods

7.6.6.1 Bend Test. Studs shall be bend tested by being bent 90° from their original axis. A stud application shall be considered qualified if the studs are bent 90° and fracture occurs in the plate or shape material or in the shank of the stud and not in the weld.

7.6.6.2 Torque Test. Studs shall be torque tested using a torque-test arrangement that is substantially in conformance with Figure 7.3. A stud application shall be considered qualified if all test specimens are torqued to destruction without failure in the weld.

7.6.6.3 Tension Test. Studs shall be tension tested to destruction using any machine capable of supplying the required force. A stud application shall be considered qualified if the test specimens do not fail in the weld.

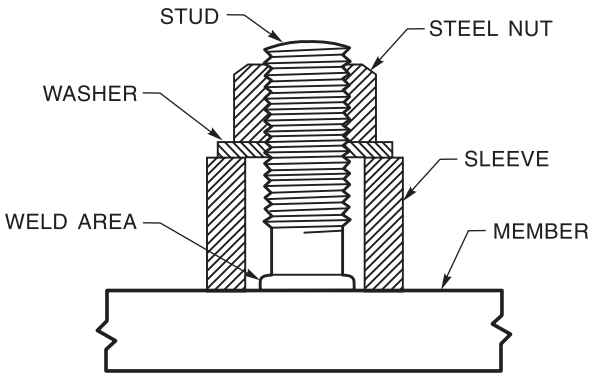
7.6.7 Application Qualification Test Data shall include the following:

(1) Drawings that show shapes and dimensions of studs and arc shields

(2) A complete description of stud and base materials and a description (part number) of the arc shield

(3) Welding position and settings (current, time)

(4) A record which shall be made for each qualification and that record shall be available for each contract



General Note: The dimensions shall be appropriate to the size of the stud. The threads of the stud shall be clean and free of lubricant other than the residue of cutting oil.

Required Torque for Testing Threaded Studs	
Nominal Diameter and Thread Pitch (mm)	Testing Torque (J)
M 6 × 1	6
M 8 × 1.25	12
M 10 × 1.5	20
M 12 × 1.75	50
M 14 × 2	73
M 16 × 2	100
M 20 × 2.5	180
M 22 × 2.5	285
M 24 × 3	430

Required Torque for Testing Threaded Studs		
Nominal Diameter of Studs (in.)	Threads per inch and Series Designated	Testing Torque (ft-lb)
1/4	28 UNF	5.0
1/4	20 UNC	4.2
5/16	24 UNF	9.5
5/16	18 UNC	8.6
3/8	24 UNF	17.0
3/8	16 UNC	15.0
7/16	20 UNF	27.0
7/16	14 UNC	24.0
1/2	20 UNF	42.0
1/2	13 UNC	37.0
9/16	18 UNF	60.0
9/16	12 UNC	54.0
5/8	18 UNF	84.0
5/8	11 UNC	74.0
3/4	16 UNF	147.0
3/4	10 UNC	132.0
7/8	14 UNF	234.0
7/8	9 UNC	212.0
1.0	12 UNF	348.0
1.0	8 UNC	318.0

Figure 7.3—Torque Testing Arrangement and Table of Testing Torques (see 7.6.6.2)

7.7 Production Control

7.7.1 Preproduction Testing

7.7.1.1 Before production welding with a particular set-up (see 7.5.4.2) and with a given size and type of stud, and at the beginning of each day's or shift's production, testing shall be performed on the first two studs that are welded. The stud technique may be developed on a piece of material similar to the production member in thickness and properties. If actual production thickness is not available, the thickness may vary plus or minus 25 percent. All test studs shall be welded in the same general position as required on the production member (flat, vertical, or overhead).

7.7.1.2 Instead of being welded to separate material, the test studs may be welded on the production member, except when separate plates are required by 7.7.1.5.

7.7.1.3 The test studs shall be visually examined. They shall exhibit full 360° flash.

7.7.1.4 In addition to visual examination, the test shall consist of bending the studs after they are allowed to cool, to an angle of approximately 30° from their original axes by either striking the studs on the head with a hammer or placing a pipe or other suitable hollow device over the stud and manually or mechanically bending the stud. At temperatures below 10°C [50°F], bending shall preferably be done by continuous slow application of load. For threaded studs, the torque test of Figure 7.3 shall be substituted for the bend test.

7.7.1.5 If on visual examination the test studs do not exhibit 360° flash, or if on testing, failure occurs in the weld zone of either stud, the WPS shall be corrected, and two more studs shall be welded to separate material or on the production member and tested in conformance with the provisions of 7.7.1.3 and 7.7.1.4. If either of the second two studs fails, additional welding shall be continued on separate plates until two consecutive studs are tested and found to be satisfactory before any more production studs are welded to the member.

7.7.2 Production Welding. Once production welding has begun, any changes made to the welding set-up (see 7.5.4.2) as determined in 7.7.1 shall require that the testing in 7.7.1.3 and 7.7.1.4 be performed prior to resuming production welding.

7.7.3 In production, studs on which a full 360° flash is not obtained may, at the option of the Contractor, be repaired by adding the minimum fillet weld as required by 7.5.5 in place of the missing flash. The repair weld shall extend at least 10 mm [3/8 in.] beyond each end of the discontinuity being repaired.

7.7.4 Operator Qualification

7.7.4.1 The preproduction test required by 7.7.1, if successful, shall also serve to qualify the stud welding operator.

7.7.4.2 Before any production studs are welded by an operator not involved in the preproduction set-up of 7.7.1, the first two studs welded by the operator shall be tested in conformance with 7.7.1.3 and 7.7.1.4. When two consecutively welded studs have been tested and found satisfactory, the operator may then weld production studs.

7.7.5 If an unacceptable stud has been removed from a component subjected to tensile stresses, the area from which the stud was removed shall be made smooth and flush.

7.7.5.1 Where in such areas the base metal has been pulled out in the course of stud removal, SMAW with low-hydrogen electrodes in conformance with the requirements of this code shall be used to fill the pockets, and the weld surface shall be ground flush.

7.7.5.2 In compression areas of members, if stud failures are confined to shanks or fusion zones of studs, a new stud may be welded adjacent to each unacceptable area in lieu of repair and replacement on the existing weld area (see 7.4.3). If base metal is pulled out during stud removal, the repair provisions shall be the same as for tension areas, except that when the depth of discontinuity is the lesser of 3 mm [1/8 in.] or 7 percent of the base-metal thickness, the discontinuity may be faired by grinding in lieu of filling with weld metal.

7.7.5.3 Where a replacement stud is to be provided, the base-metal repair shall be made prior to welding the replacement stud.

7.7.5.4 Replacement studs (other than threaded type which should be torque tested) shall be tested by bending to an angle of approximately 15° from their original axis.

7.7.5.5 The areas of components exposed to view in completed structures shall be made smooth and flush where a stud has been removed.

7.8 Inspection Requirements

7.8.1 If visual inspection reveals any stud that does not show a full 360 degree flash or any stud that has been repaired by welding, such stud shall be bent to an angle of approximately 15 degrees from its original axis.

7.8.2 The method of bending shall be in conformance with 7.7.1.4. The direction of bending for studs with less than a 360 degree flash shall be opposite to the missing portion of the flash.

7.8.3 Threaded studs shall be torque tested. Torque testing shall be in conformance with Figure 7.3.

7.8.4 The inspector, where conditions warrant, may select a reasonable number of additional studs to be subjected to the tests described in 7.8.1.

7.8.5 The bent stud shear connectors (Type B) and other studs to be embedded in concrete (Type A) that show no sign of failure shall be acceptable for use and left in the bent position. All bending and straightening when required shall be done without heating, before completion of the production stud welding operation, except as otherwise provided in the contract.

7.8.6 If, in the judgment of the Engineer, studs welded during the progress of the work are not in conformance with code provisions, as indicated by inspection and testing, corrective action shall be required of the Contractor at the Contractor's expense. The Contractor shall make the set-up changes necessary to insure that studs subsequently welded will meet code requirements.

7.8.7 At the option and the expense of the Owner, the Contractor may be required, at any time, to submit studs of the types used under the contract for a qualification check in conformance with the procedures of Annex VI.