Welding In, On and Around Steel Joists

JULY 18, 2018

Presented by:

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Polling Question:

- New requirement to earn PDH credits
- Two questions will be asked during the duration of today's presentation
- The question will appear within the polling section of your GoToWebinar Control Panel to respond

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Learning Objectives:

- Understand some of the challenges and procedures related to welding in the manufacture of steel joists.
- Understand some of the challenges and procedures related to welding in the erection of steel joists.
- Understand the welding criteria published in the Steel Joist Institute SJI-100-2015 specification and how it relates to American Welding Society (AWS) specifications.

Background: Open Web Steel Joist Welding

- Manufactured in the United States since 1923
- Original was a Warren truss
  - Single continuous bent round bar web
  - Straight double round bars for both chords
  - Manual shielded metal arc welding (stick welding)

Background: Open Web Steel Joist Welding

- Steel Joist Institute (SJI) established in 1928 for the purpose of standardizing what had become a confusing industry
- First SJI load tables for Steel Joists published in 1929
- Various welding technologies have been used by different manufacturers, over the years

Background: Open Web Steel Joist Welding

- Resistance Welding – parts heated and fused without the use of filler metal.
- Semi-automatic gas-shielded welding introduced in 1950's.
  - Continuous feed of small diameter wire
  - No slag
  - Improved access and weld penetration for flare-bevel, flare-vee, and fillet welds common to joist manufacturing.

Background: Open Web Steel Joist Welding

- SJI member companies produce an estimated 900 million welds per year on steel joists and Joist Girders
- Huge number of welds produced in high speed production environment
- Very repetitive welds of similar size and type for a given production line
- Steel Joists have a proven track record with billions of in-service welds

Background: Open Web Steel Joist Welding

Single Joist Girder being Welded

Background: Open Web Steel Joist Welding

Multiple K-Series Joist being Welded

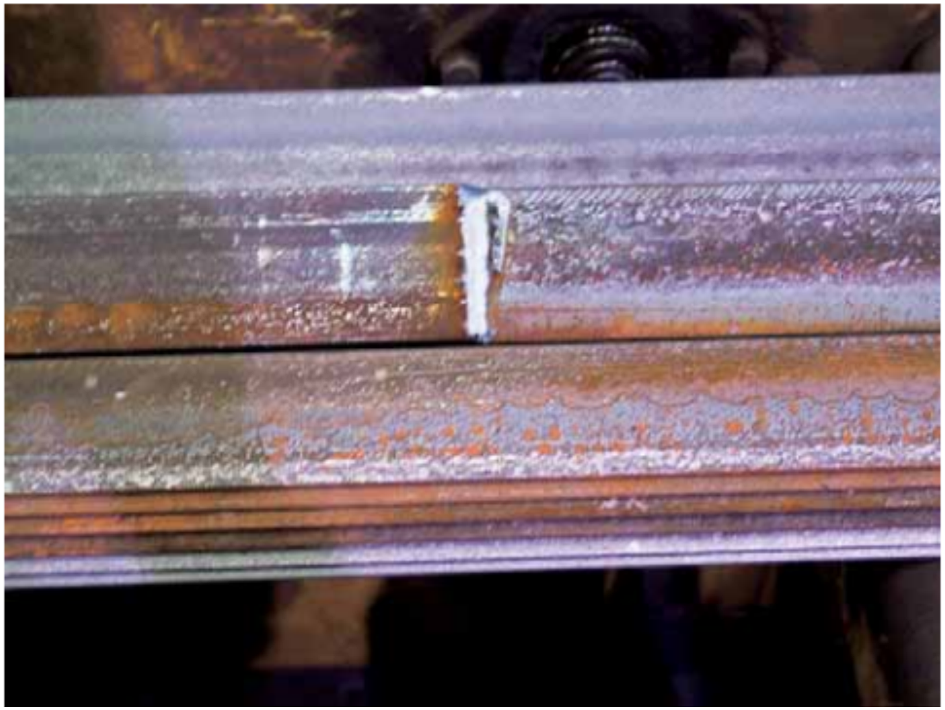
Background: Open Web Steel Joist Welding

- Quality Control for welds may include:
  - Visual Inspection
  - Proof testing by non-destructive pry loading
  - Proof testing by loading of a complete joist
  - Test complete joist to destruction
  - Destructive test of sample welded joints
  - Cross-section and etch of sample welded joints

Common Welded Joints in Steel Joists:

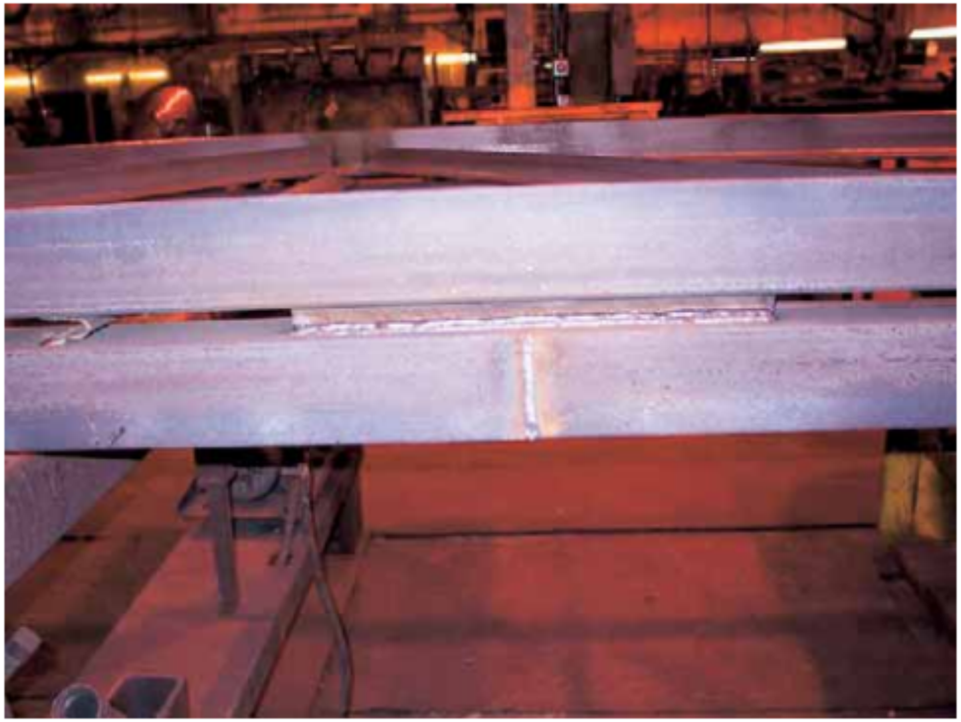
- Chord Splices:
- Usually angle sections cut and/or butt spliced to obtain appropriate length
- Continuous feed for efficient material use results in splices even in chords of length less than standard inventory length
- Angle sizes range from 1” x 1” x 7/64” to 6” x 6” x ¾” and higher.
- Some manufacturers use cold-formed angle chords which are fed off a coil and spliced while flat, prior to cold-forming.

Common Welded Joints in Steel Joists:



Typical Chord Angle Butt Splice

Common Welded Joints in Steel Joists:



Typical Reinforced Chord Angle Butt Splice

Common Welded Joints in Steel Joists:

- Temporary Welds:
- Joists must be held together at the ‘rigging table’ (jig) prior to being moved to the welding area.
- Clamps are sometimes used where feasible.
- Where clamps are not feasible, tack welds are used to hold the joist together until fully welded.
- Tack welds may (or may not) be later incorporated into the final design weld.
- If incorporated into design weld must meet all design weld requirements.

Common Welded Joints in Steel Joists:

- Finish/Joint Welds:
- Web to Chord Joint welds
- Minimum size and length of weld is dictated by a combination of manufacturer standards and design requirements specified on the manufacturing shop order.
- Three primary types of web members:
  - Round Bar
  - Single Member
  - Double Member

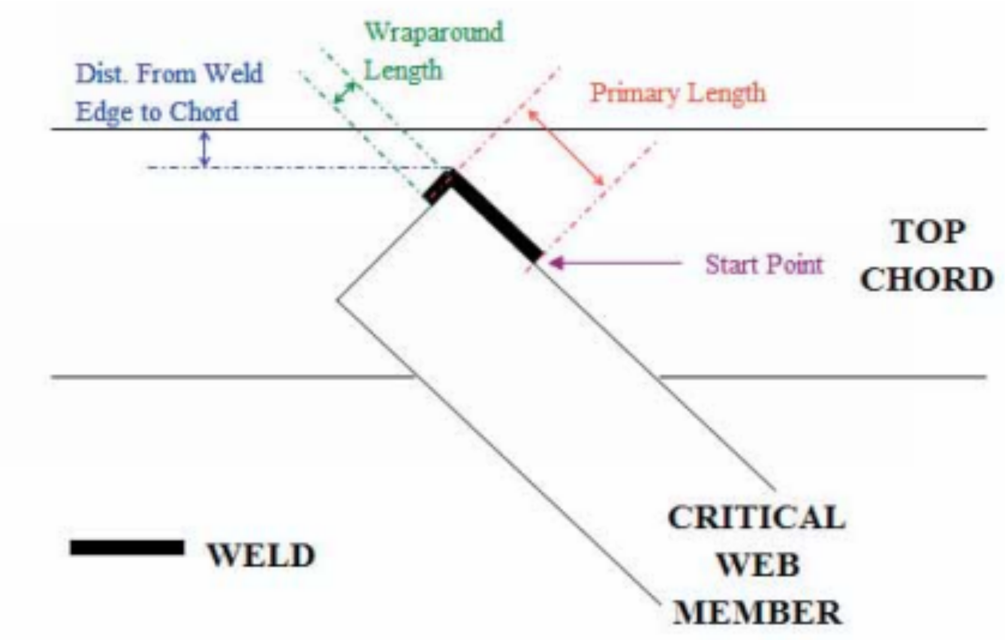
Common Welded Joints in Steel Joists:

- Three Primary Types of Web Members:
- Round Bars:
  - Bent Rod in Continuous V or W Pattern
  - Typically used on smaller depth joists
  - Not efficient material usage for deeper joists
  - Welded on one side of bar to each chord angle
  - Flare-bevel-groove weld

Common Welded Joints in Steel Joists:

- Three Primary Types of Web Members:
- Single Member (inside the chord gap):
  - Angles crimped at ends (for constant chord gap)
  - Single rotated un-crimped angle (1” angle / 1” gap)
  - Angles formed along full length to create a U or C shape
  - Cold-Formed U or C channel section
  - Typically use combination of fillet and flare-bevel-groove welds
  - Usually conservatively design as fillet welds for simplicity
  - Usually welded along one side (to each chord angle) with return weld across the end.

Common Welded Joints in Steel Joists:



Weld Placement on Single Angles

Common Welded Joints in Steel Joists:

Cold-Rolled Channel Webs Welded to Top Chord

Common Welded Joints in Steel Joists:

Cold-Rolled Channel Webs Welded to Bottom Chord

Common Welded Joints in Steel Joists:

- Three Primary Types of Web Members:
- Double Member (placed outside the chord angle vertical legs)
  - Typically welded across both toe and heel at the ends
  - SJI Standard Specification does not require balanced welds
  - May use full-thickness fillet welds on materials greater than ¼" thickness
  - Often connected at center with a tie-clip (batten)

Common Welded Joints in Steel Joists:

Fillet Welded Double-Angle Web Members to Top Chord

Common Welded Joints in Steel Joists:

Lapped Seat Angle to Top Chord Fillet Welds

Modern Joist Manufacturing Welding Processes

- 2006 SJI Member Company Survey:
- Shielded Metal Arc Welding (SMAW)
  - "Stick" welding
  - Solid-core wire electrodes
  - 1/8 inch to ¼ inch diameter
  - Surrounded by "flux" shielding material
  - Commonly used for temporary "tack" welds during assembly

Modern Joist Manufacturing Welding Processes

- 2006 SJI Member Company Survey:
- Flux Cored Arc Welding (FCAW)
  - Flux-cored tubular electrode
  - Flux (shielding) material located inside the tubular metal core
  - 0.030 inch to 1/8 inch diameter
  - Spooled into different packaging needs

Modern Joist Manufacturing Welding Processes

- 2006 SJI Member Company Survey:
- Gas Metal Arc Welding (GMAW)
  - “MIG” (Metal Inert Gas) welding
  - Shielding gas surrounds the weld pool
  - Solid electrodes use no “flux” material, resulting in a “slag free” weld pool
  - 0.035 inch to 0.052 inch diameter
  - Most commonly used in joist manufacturing

Modern Joist Manufacturing Welding Processes

- 2006 SJI Member Company Survey:
- Resistance Welding
  - Joint fused through combined pressure and localized heat
  - Heat generated by passing current through the work pieces melts contact surface
  - No electrodes are consumed

Modern Joist Manufacturing Welding Processes

- 3 Resistance Welding Process used in Joist Industry
  - Resistance Spot Welding (RSW)
    - Small localized weld
    - Electrode determines weld size and shape
  - Flash Welding (FW)
    - Electric arc between joining pieces melts steel
    - Then pressed together to form weld
    - Commonly used for material butt splices
  - Upset Welding (UW)
    - Similar to Flash Welding except pieces are pressed together prior to applying electric current

Field Welding on Steel Joists:

- The performance of open web steel joists and the safety of the steel erection workers are greatly influenced by the welding executed in the field.

- Proper welding techniques and inspection are essential to the satisfactory performance of the joists during the construction phase and the life of a given structure.

Field Welding on Steel Joists:

- Field welding shall be in accordance with:
  - AWS D1.1 Structural Welding Code – Steel and
  - AWS D1.3 Structural Welding Code – Sheet Steel
- The welding must be performed with electrodes conforming to:
  - AWS A5.1 Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding or
  - AWS 5.20 Specification for Carbon Steel Electrodes for Flux Cored Arc Welding.
- Electrodes must be properly stored to maintain flux quality.
- Inspection shall be limited to the welding executed in the field and shall be performed by qualified personnel.

Field Welding on Steel Joists:

- Three Primary Areas of Joist Field Welding
  - Joist End Anchorage
  - Joist Bridging
  - Metal Decking

Field Welding – Joist End Anchorage:

- Joist End Anchorage
  - In most instances the minimum end anchorage welds specified by SJI are adequate for Joist Girders, K-, LH-, or DLH-Series joists.
  - However, special attention from the Specifying Professional is required when joists are subjected to:
    - uplift forces
    - axial forces transferred to supporting structure
    - joists utilized in rigid frames
    - larger and/or longer welds may be required to transfer these reaction forces to the supporting structure.

Field Welding – Joist End Anchorage - Uplift:

- Typically, joists and Joist Girders with bolted end anchorage also require a final connection by welding in order to provide lateral stability to the supporting member. However, only the bolts are relied on to provide uplift anchorage. The bolt type and diameter designed by the specifying professional shall provide sufficient tensile strength to resist the uplift end reaction resulting from the specified uplift. Bolts of higher strength than the minimum required by the Steel Joist Institute Standard Specifications may be required. (SJI-COSP-2015)

Field Welding – Joist End Anchorage - Uplift:

- When the bearing seats are detailed for a bolted connection, bolts shall be installed. If the bolts are not installed, an equivalent welded connection may be permitted by the specifying professional, provided the weld is deposited in the slot on the side farthest from the edge of the seat. Additional weld required to meet that specified for the welded connection shall be placed at a location on the seat away from the outer edge of the slot as shown in Figure 2.10-1. (SJI-COSP-2015)

Field Welding – Joist End Anchorage - Uplift:

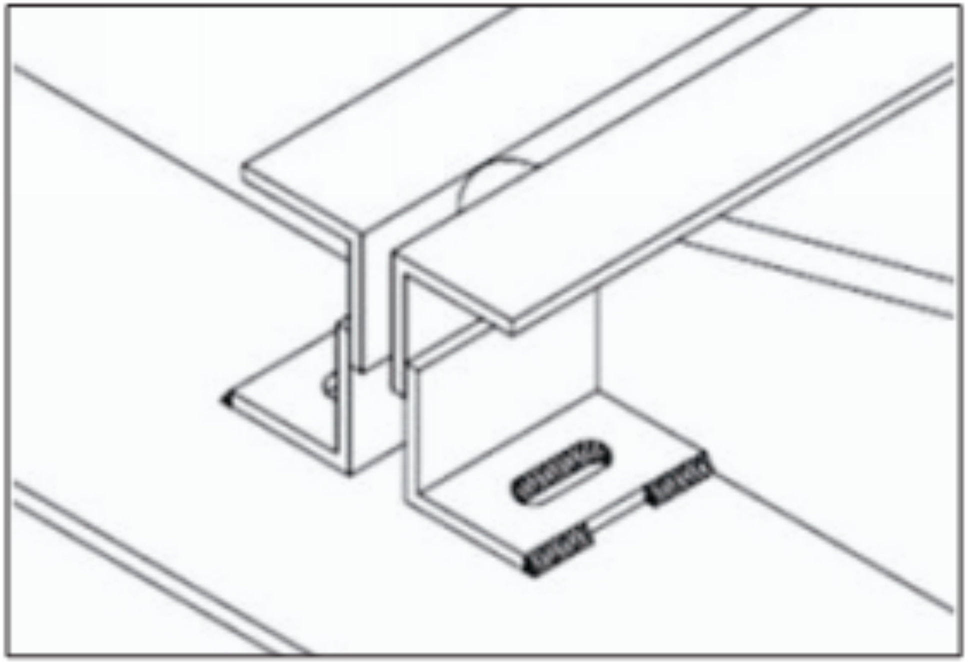


Figure 2.10-1

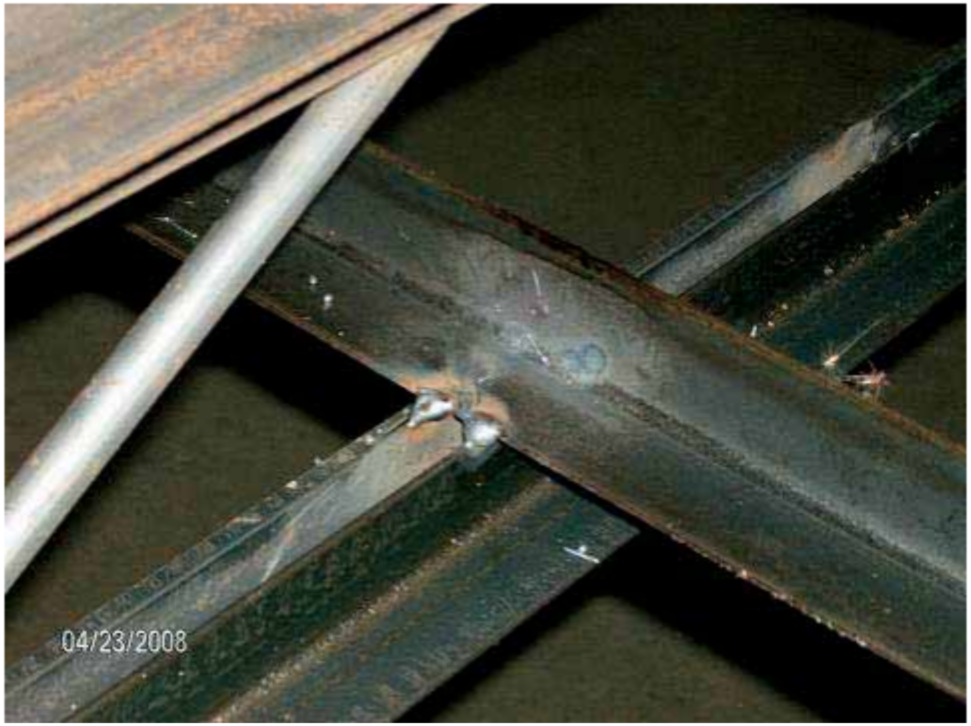
Field Welding – Joist Bridging:

- Joist bridging stabilizes joists during the construction phase
- Essential to the safety of the field workers
- Also essential to the performance of the joists particularly:
  - when uplift forces encountered, or
  - when joist top chords are not laterally supported by decking (standing seam roof)
- Attachment of the bridging to the joists chord members must:
  - resist anticipated bracing forces
  - be in conformance with the Standard Specifications of the relevant joist series
  - be fillet welds
  - four point spot/ tack welds are not acceptable

Field Welding – Joist Bridging:

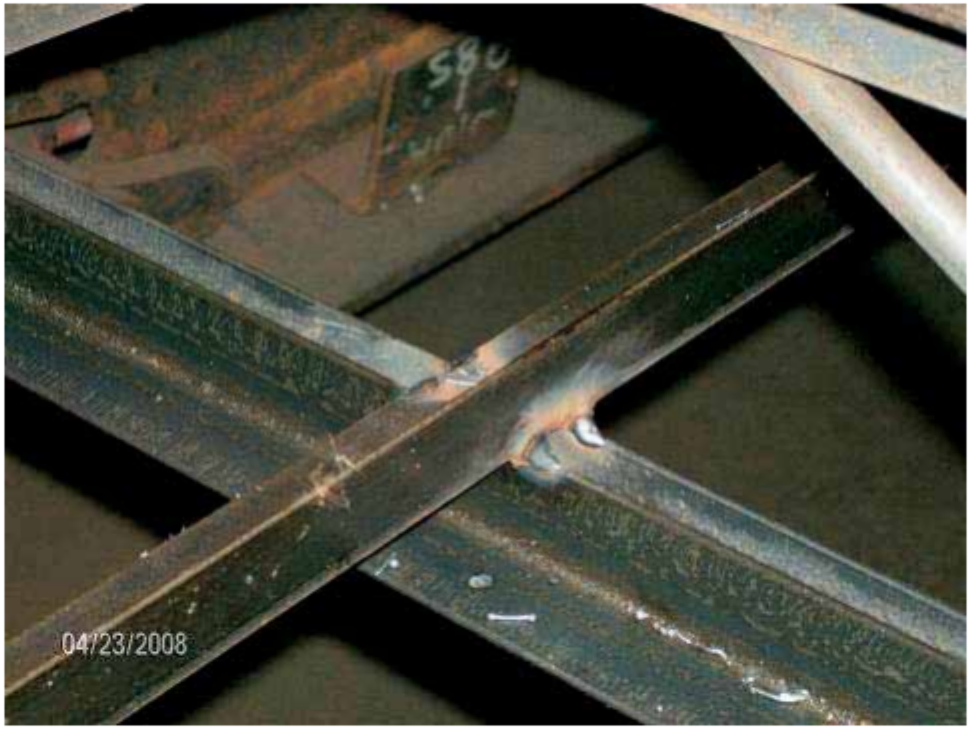
Acceptable Weld of Bridging Angle to Bottom Chord

Field Welding – Joist Bridging:



Unacceptable Weld of Bridging Angle to Bottom Chord

Field Welding – Joist Bridging:



Unacceptable Weld of Bridging Angle to Bottom Chord

Field Welding – Metal Decking:

- Welding of metal decking shall be in accordance with:
  - AWS D1.3, Structural Welding Code - Sheet Steel and
  - the Steel Deck Institute requirements
- Welding washers shall be used on all deck units with metal thickness less than 0.028”
- Where welding washers are not used, a minimum visible 5/8” diameter arc puddle weld shall be used.
- Weld metal shall penetrate all layers of deck material at end laps and shall have good fusion to the supporting members.
- When used, fillet welds shall be at least 1½ inch (38 mm) long.
- Special care required welding deck to K-Series joists:
  - Top chords are relatively thin (1/8” thick)
  - Potential for melt through is therefore increased and,
  - If melt through occurs, it must be reported to the joist manufacturer for evaluation and recommendation.

Joist Welding Standard History

- Early Steel Joist Institute member companies used a wide range of welding processes. Some of those processes were fairly new and lacked well-defined parameters.

- As a result, SJI adopted an early policy of a Performance-Based Welding Specification, based on manufacturer welding standards combined with weld strength testing.

Joist Welding Standard History

- As Joist Manufacturers embraced new welding technologies, they were able to achieve better weld access and better weld penetration with smaller diameter weld wires than was possible with older SMAW “stick” welding.

- As a result, the flare-bevel-groove welds on rod-web joists had better throat dimensions and higher strength than that predicted by AWS and AISC design equations at that time.

Joist Welding Standard History

- In the 1970's SJI sponsored research at Washington University, conducted by Dr. Theodore Galambos, exploring throat dimensions and weld strengths of an array of various joist sizes produced by various joist manufacturers.

- The results of those test were published in 1983, in the first edition of SJI Technical Digest 8, "Welding of Open-Web Steel Joists and Joist Girders."

Joist Welding Standard History

- Based on that research, the technical digest presented a new equation for flare-bevel-groove weld throat calculation, that is used to this day:

$$T = 0.12D + 0.11 \text{ (Equation of minimum weld throat)}$$

$$S = 21T \text{ (Based on 0.3 x nominal tensile strength of E70 electrode)}$$

Where
D = web diameter, inches
T = weld throat, inches
S = weld strength, kips/in.

Joist Welding Standard History

- In 1983, this new weld throat equation was substantially less conservative than the 5/16 R that used by AWS and AISC, at that time.

- However, around 2005, AWS and AISC adopted 5/8 R for the flare-bevel-groove weld throat when GMAW welding process is used. In most cases, this results in an AWS calculated design weld throat that is actually slightly higher than the SJI design weld throat.

Joist Welding Standard History

- With the addition of the new weld throat equation based on testing and the emerging use of GMAW as the predominate welding process used for web-to-chord connections in the joist industry, SJI began to work toward standardizing both weld design procedures and minimum weld quality requirements.

- However, this was done in such a manner as to retain the fundamental concept of a Performance-Based Welding Specification.

Joist Welding Standard History

- The resulting SJI weld specification left much to be desired.

- There were many areas it did not address simply because they did not usually apply to joist manufacturing, or because the member companies could not agree on a single standard.

- It also resulted in frequent clashes with jobsite inspectors who did not understand the differences between SJI welding criteria and AWS welding criteria.

Joist Welding Standard History

- Moreover, their were discrepancies in approach to weld design criteria between K-Series, LH-Series and Joist Girder design specifications.

- Specifying Professionals were often suspicious of the SJI welding criteria and sometimes called for AWS welding standards on SJI standard products, further clouding issues.

A New Approach – Best of AWS and SJI

- In their 2015 specification, SJI took a bold new approach.
- K-Series, LH-Series, DLH-Series and Joist Girders have all been combined into a single specification.
- Retains all the prior SJI inspection and testing criteria…AND…
- The welding criteria has been completely rewritten to explicitly require AWS welding standards with clearly defined exceptions applicable to the joist industry, as permitted by AWS D1.1:2015, Section 6.8.

Assessment Question

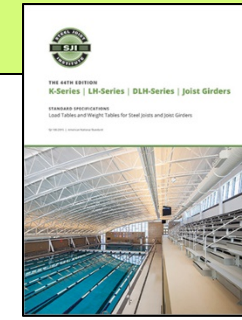
- What welding process is used by Joist Manufacturers, today?
- a) Shielded Metal Arc Welding (SMAW) “Stick” welding
  b) Flux Cored Arc Welding (FCAW) welding
  c) Gas Metal Arc Welding (GMAW) “MIG” (Metal Inert Gas) welding
  d) Resistance Welding
  e) All the above

Steel Joist Institute

Standard Specifications

44^{th} Edition

Steel Joist Institute Standard Specifications 44th Edition



4.5 CONNECTIONS

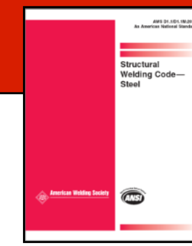
4.5.1 Methods

Member connections and splices shall be made by attaching the members to one another by arc or resistance welding or other accredited methods in accordance with the following:

Steel Joist Institute Standard Specifications 44th Edition

a) Steel joist and Joist Girder arc welded joints shall be in accordance with the American Welding Society, “Structural Welding Code—Steel”, D1.1, and/or the “Structural Welding Code Sheet Steel”, D1.3 with the following seven modified acceptance criteria as permitted by AWS D1.1 Clause 6.8:

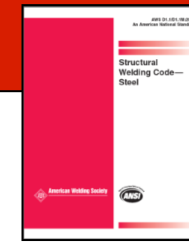
AWS D1.1:2015 Structural Welding Code--Steel



6.8 Engineer's Approval for Alternate Acceptance Criteria

The fundamental premise of the code is to provide general stipulations applicable to most situations.

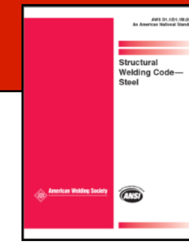
AWS D1.1:2015 Structural Welding Code--Steel



6.8 Engineer's Approval for Alternate Acceptance Criteria (cont'd)

Acceptance criteria for production welds different from those described in the code may be used for a particular application, provided they are suitably documented by the proposer and approved by the Engineer.

AWS D1.1:2015 Structural Welding Code--Steel



6.8 Engineer's Approval for Alternate Acceptance Criteria (cont'd)

These alternate acceptance criteria may be based upon evaluation of suitability for service using past experience, experimental evidence or engineering analysis considering material type, service load effects, and environmental factors.

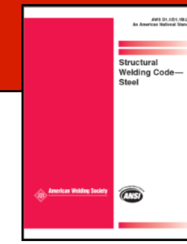
AWS D1.1:2015 Structural Welding Code--Steel

C-6.8 Engineer's Approval for Alternate Acceptance Criteria

The criteria provided in Clause 5 Fabrication are based upon knowledgeable judgment of what is achievable by a qualified welder.

AWS D1.1 is primarily a workmanship-based code.

AWS D1.1:2015 Structural Welding Code--Steel

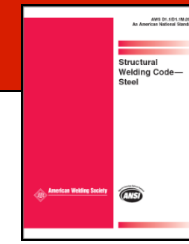


C-6.8 Engineer’s Approval for Alternate Acceptance Criteria (cont’d)

The criteria in Clause 5 should not be considered as a boundary of suitability for service.

AWS D1.1 is not a fitness-for-service code.

AWS D1.1:2015 Structural Welding Code--Steel



C-6.8 Engineer's Approval for Alternate Acceptance Criteria (cont'd)

Suitability for service analysis would lead to widely varying workmanship criteria unsuitable for a standard code.

It is hard to manage projects with multiple workmanship standards.

AWS D1.1:2015 Structural Welding Code--Steel

C-6.8 Engineer's Approval for Alternate Acceptance Criteria (cont'd)

Furthermore, in some cases, the criteria would be more liberal than what is desirable and producible by a qualified welder.

Steel Joist Institute Standard Specifications 44th Edition

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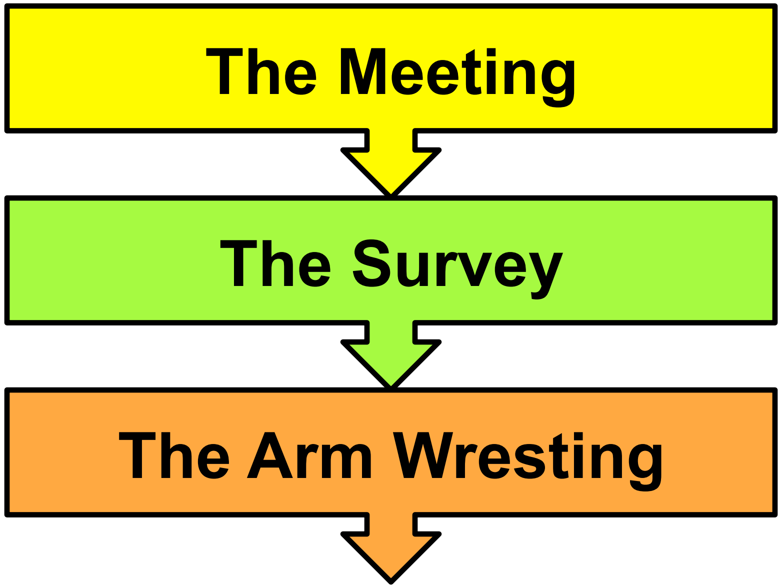
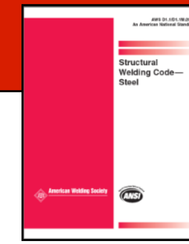

The Meeting
The Survey
The Arm Wresting

AWS D1.1:2015 Structural Welding Code--Steel



6.8 Engineer's Approval for Alternate Acceptance Criteria (cont'd)

These alternate acceptance criteria may be based upon evaluation of suitability for service using past experience, experimental evidence or engineering analysis considering material type, service load effects, and environmental factors.

The Meeting

↓

The Survey

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The Arm Wresting

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The Analysis

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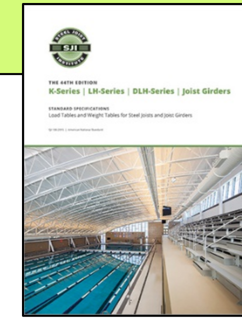
The Results

Steel Joist Institute Standard Specifications 44th Edition



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Steel Joist Institute Standard Specifications 44th Edition

1) Undercut shall not exceed 1/16 inch (2 mm) for welds oriented parallel to the principle stress.

User Note: The typical diagonal web member connection to one leg of a cord angles is considered to be parallel to the principal stress.

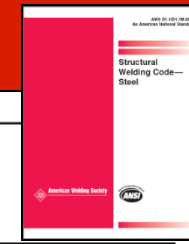
AWS D1.1:2015 Structural Welding Code--Steel

Table 6.1
Visual Inspection Acceptance Criteria (see 6.9)

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections
(1) Crack Prohibition Any crack shall be unacceptable, regardless of size or location.	X	X
(2) Weld/Base-Metal Fusion Complete fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X
(3) Crater Cross Section All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X
(4) Weld Profiles Weld profiles shall be in conformance with 5.23.	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 HPS 100W [HPS 690W] steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X
(6) Undersized Welds The size of a fillet weld in any continuous weld may be less than the specified nominal size (L) without correction by the following amounts (U): L, specified nominal weld size, in [mm] — U, allowable decrease from L, in [mm] ≤ 3/16 [5] — ≤ 1/16 [2] 1/4 [6] — ≤ 3/32 [2.5] ≥ 5/16 [8] — ≤ 1/8 [3] In all cases, the undersize portion of the weld shall not exceed 10% of the weld length. On web-to-flange welds on girders, underrun shall be prohibited at the ends for a length equal to twice the width of the flange.	X	X
(7) Undercut (A) For material less than 1 in [25 mm] thick, undercut shall not exceed 1/32 in [1 mm], with the following exception: undercut shall not exceed 1/16 in [2 mm] for any accumulated length up to 2 in [50 mm] in any 12 in [300 mm]. For material equal to or greater than 1 in [25 mm] thick, undercut shall not exceed 1/16 in [2 mm] 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
(8) Porosity (A) CJP 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 [20 mm] in any 12 in [300 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 [2.5 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 [20 mm] in any 12 in [300 mm] length of weld.		X
(C) CJP 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 [2.5 mm].		X

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

AWS D1.1:2015 Structural Welding Code--Steel



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(3) Crater Cross Section All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X
(4) Weld Profiles Weld profiles shall be in conformance with 5.23.	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 HPS 100W [HPS 690W] steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X

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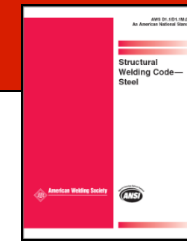
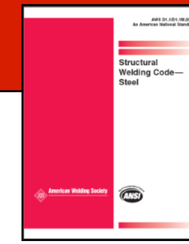


(7) Undercut (A) For material less than 1 in [25 mm] thick, undercut shall not exceed 1/32 in [1 mm], with the following exception: undercut shall not exceed 1/16 in [2 mm] for any accumulated length up to 2 in [50 mm] in any 12 in [300 mm]. For material equal to or greater than 1 in [25 mm] thick, undercut shall not exceed 1/16 in [2 mm] 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

AWS D1.1:2015 Structural Welding Code--Steel



(7) Undercut

(A) For material less than 1 in [25 mm] thick, undercut shall not exceed 1/32 in [1 mm], with the following exception: undercut shall not exceed 1/16 in [2 mm] for any accumulated length up to 2 in [50 mm] in any 12 in [300 mm]. For material equal to or greater than 1 in [25 mm] thick, undercut shall not exceed 1/16 in [2 mm] for any length of weld.

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2) Discontinuities outside the weld design length shall be permitted providing no crack exists and undercut does not exceed the limits of item 1).

User Note: The weld design length is the minimum weld length needed for the connection force and weld thickness. Portions of the actual weld length with imperfections or discontinuities such as porosity or lack of a full profiles are not included when comparing the actual weld length to the weld design length.

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3) One unrepaired arc strike shall be permitted per joint provided it does not result in other unacceptable defects.

User Note: Minor arc strikes do not reduced the strength of AWS Group II materials (refer to Van Malssen, 1984).

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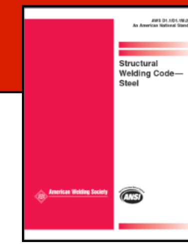

5.28 Arc Strikes

Arc strikes outside the area of permanent welds should be avoided on any base metal. Cracks or blemishes caused by arc strikes shall be ground to a smooth contour and checked to ensure soundness.

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4) The effective throat for flare bevel groove weld shall be calculated in accordance with equation 4.2-18.

User Note: The effective weld throat used by the SJI with round bars is based on SJI research and is more conservative than AWS D1.1 for GMAW for round bars in excess of 9/16” (14 mm). See Steel Joist Institute Technical Digest 8, “Welding of Open Web Steel Joists and Joist Girders.”

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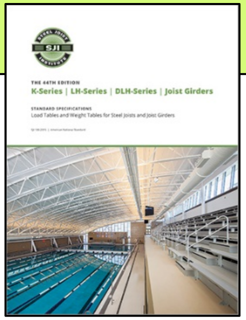

For flare bevel groove welds, the effective weld area is based on a weld throat width, T, where:

T (inches) = 0.12 D + 0.11

Where D = web diameter, inches

or,

T (mm) = 0.12 D +2.8

Where D + web diameter, mm

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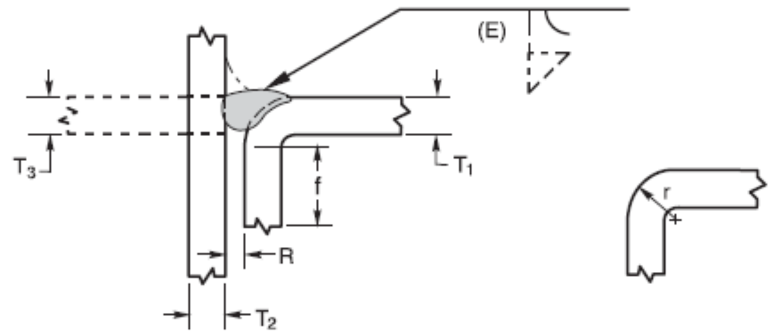
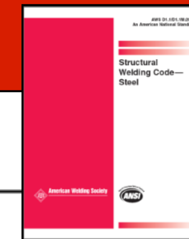
Flare-bevel-groove weld (10)
Butt joint (B)
T-joint (T)
Corner joint (C)



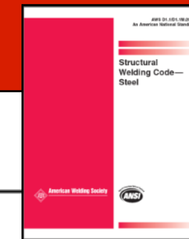
Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)			Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T_1	T_2	T_3	Root Opening Root Face Bend Radius	Tolerances: As Detailed (see 3.12.3)	Tolerances: As Fit-Up (see 3.12.3)			
SMAW FCAW-S	BTC-P10	3/16 min.	U	T_1 min.	R = 0 f = 3/16 min. $r = \frac{3T_1}{2}$ min.	+1/16, –0 +U, –0 +U, –0	+1/8, –1/16 +U, –1/16 +U, –0	All	5/16 r	e, g, j, l
GMAW FCAW-G	BTC-P10-GF	3/16 min.	U	T_1 min.	R = 0 f = 3/16 min. $r = \frac{3T_1}{2}$ min.	+1/16, –0 +U, –0 +U, –0	+1/8, –1/16 +U, –1/16 +U, –0	All	5/8 r	a, g, j, l, m
SAW	B-P10-S	1/2 min.	N/A	1/2 min.	R = 0 f = 1/2 min. $r = \frac{3T_1}{2}$ min.	±0 +U, –0 +U, –0	+1/16, –0 +U, –1/16 +U, –0	F	5/16 r	g, j, l, m

AWS D1.1:2015 Structural Welding Code--Steel



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)			Groove Preparation			Allowed Welding Positions	Weld Size (E)
					Root Opening Root Face Bend Radius	Tolerances			
		T_1	T_2	T_3		As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)		
SMAW FCAW-S	BTC-P10	3/16 min.	U	T_1 min.	R = 0 f = 3/16 min. $r = \frac{3T_1}{2}$ min.	+1/16, –0 +U, –0 +U, –0	+1/8, –1/16 +U, –1/16 +U, –0	All	5/16 r
GMAW FCAW-G	BTC-P10-GF	3/16 min.	U	T_1 min.	R = 0 f = 3/16 min. $r = \frac{3T_1}{2}$ min.	+1/16, –0 +U, –0 +U, –0	+1/8, –1/16 +U, –1/16 +U, –0	All	5/8 r
SAW	B-P10-S	1/2 min.	N/A	1/2 min.	R = 0 f = 1/2 min. $r = \frac{3T_1}{2}$ min.	±0 +U, –0 +U, –0	+1/16, –0 +U, –1/16 +U, –0	F	5/16 r

AWS D1.1:2015 Structural Welding Code--Steel

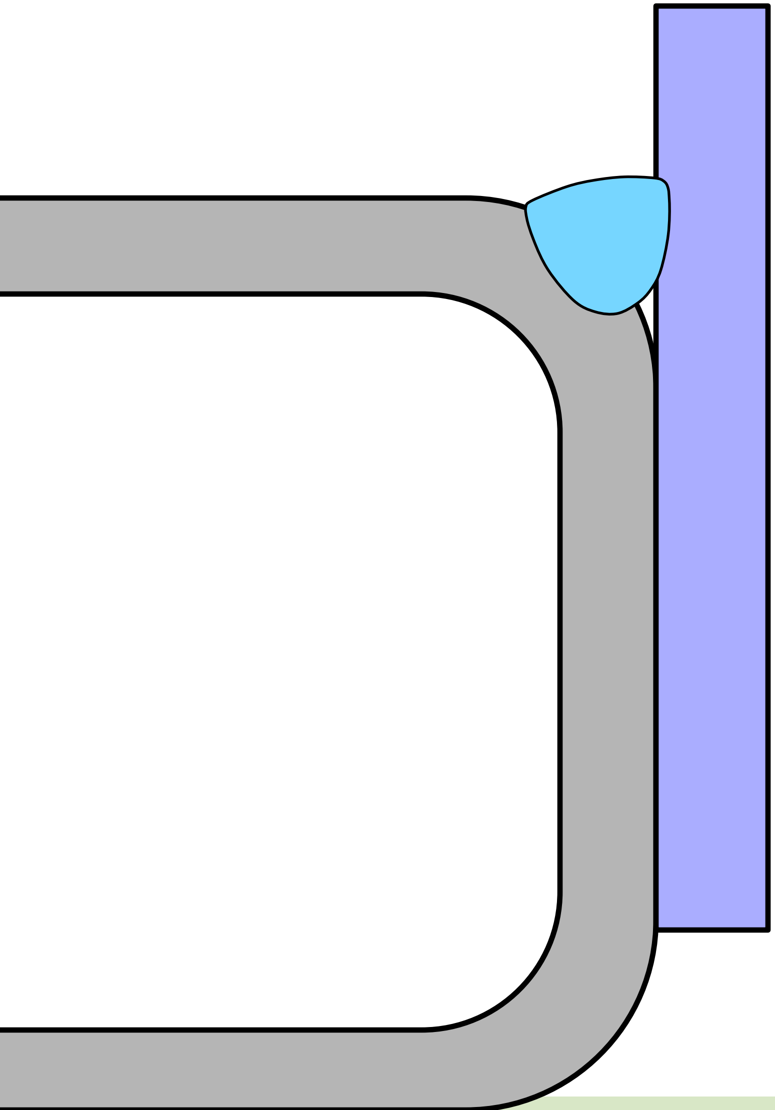


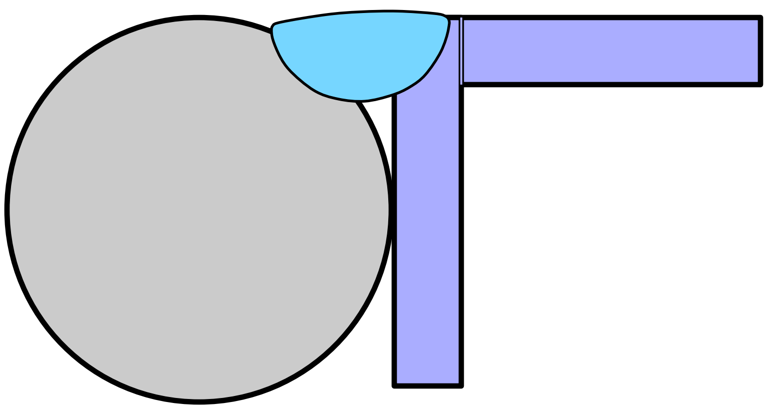
Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)			Groove Preparation			Allowed Welding Positions	Weld Size (E)
		T_1	T_2	T_3	Root Opening Root Face Bend Radius	Tolerances: As Detailed (see 3.12.3)	Tolerances: As Fit-Up (see 3.12.3)		
SMAW FCAW-S	BTC-P10	3/16 min.	U	T_1 min.	R = 0 f = 3/16 min. [illegible]	+1/16, –0 [illegible]	+1/8, –1/16 +U, –1/16 +U, –0	All	5/16 r
GMAW FCAW-G	BTC-P10-GF	3/16 min.	U	T_1 min.	[illegible] 2	[illegible]	+1/8, –1/16 +U, –1/16 +U, –0	All	5/8 r
SAW	B-P10-S	1/2 min.	N/A	1/2 min.	R = 0 f = 1/2 min. $r = \frac{3T_1}{2}$ min.	±0 +U, –0 +U, –0	+1/16, –0 +U, –1/16 +U, –0	F	5/16 r

For GMAW:

E = (5/8)R

Diameter	AWS D1.1	SJI	%
1/2	0.156	0.170	- 9
5/8	0.195	0.185	5
3/4	0.234	0.200	15
7/8	0.273	0.215	21
1	0.312	0.230	26





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5) Tack welds that are discontinuous from other welds shall meet the criteria for undercut, but shall be exempt from all other acceptance criteria.

User Note: Joist manufacturers use tack welds in the assemble process, and so long as they do not diminish the strength of the base metal and are not incorporated in the final weld for strength, they are not required to meet other inspection criteria.

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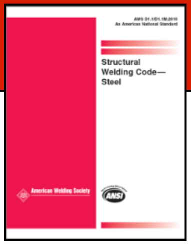

5.17.1 General Requirements

(1) Tack welds and construction aid welds shall be made with a qualified or prequalified WPS and by qualified personnel.

(2) Tack welds that are not incorporated in final welds, and construction aid welds that are not removed, shall meet visual inspection requirements before a member is accepted.

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6) The weld size shall be considered acceptable provided neither the leg nor the weld throat is undersized less than the AWS D1.1 limits within the weld design length.

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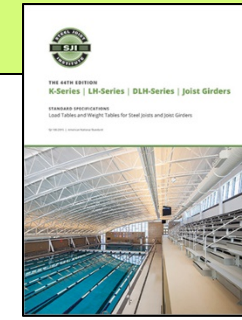

7) For material thicknesses less than 1/8”,

AWS D1.1 or D1.3 shall be considered appropriate.

User Note: AWS D1.1 does not address thicknesses less than 1/8” for hot rolled material and AWS D1.3 does not address hot rolled material, thus SJI has extended the ranges to include these materials and thicknesses.

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b) Steel joist and Joist Girder resistance welded joints shall follow a preproduction validation procedure and a production checking procedure and shall meet the strength requirements of this Specification.

User Note: Spot, flash or upset resistance welds should have a written welding procedure qualification record and a systematic quality plan. For further information, see Steel Joist Institute Technical Digest 8, "Welding of Open Web Steel Joists and Joist Girders."

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User Note: Spot, flash or upset resistance welds should have a written welding procedure qualification record and a systematic quality plan. For further information, see Steel Joist Institute Technical Digest 8, “Welding of Open Web Steel Joists and Joist Girders”.

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c) Welded Connections for Crimped-End Angle Web Members

1) The connection of each end of a crimped angle web member to each side of the chord shall consist of a weld group made of more than a single line of weld. The design weld length shall include an end return of no less than two times the nominal weld size.

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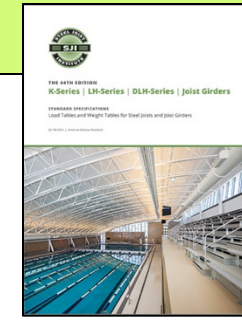

d) Welding Program

1) The manufacturer’s welders shall be qualified in accordance with either AWS D1.1 or AWS D1.3 for the applicable weld type, position, and material.

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d) Welding Program (cont’d)

2) Manufacturers shall have a program for establishing weld procedures and operator qualification, and for weld sampling and testing. Each manufacturing facility shall have trained inspectors, and an engineer responsible for all welding procedures.

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e) Weld Inspection by Outside Agencies (See Section 5.14)

1) The agency shall arrange for visual inspection to determine that welds meet the acceptance standards of Section 4.5.1.

User Note: Ultrasonic, X-ray, and magnetic particle testing are inappropriate for joists due to the configurations of the components and welds.

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5.14 INSPECTION

Joists shall be inspected by the manufacturer before shipment to verify compliance of materials and workmanship with the requirements of this Specification.

User Note: If the purchaser requires an inspection of the steel joists or Joist Girders by someone other than the manufacturer's own inspectors, they shall be permitted to reserve the right to do so in their "Invitation to Bid" or the accompanying "Job Specifications". Arrangements shall be made with

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User Note: If the purchaser requires an inspection of the steel joists or Joist Girders by someone other than the manufacturer's own inspectors, they shall be permitted to reserve the right to do so in their "Invitation to Bid" or the accompanying "Job Specifications". Arrangements shall be made with the manufacturer for such inspection of the joists or Joist Girders at the manufacturing shop by the purchaser's inspectors at purchaser's expense.

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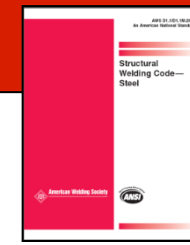
a) Steel joist and Joist Girder arc welded joints shall be in accordance with the American Welding Society, “Structural Welding Code—Steel”, D1.1, and/or the “Structural Welding Code Sheet Steel”, D1.3 with the following seven modified acceptance criteria as permitted by AWS D1.1 Clause 6.8:

AWS D1.1:2015 Structural Welding Code--Steel



Except for seven items,

- All of Clause 2 Design applies
- All of Clause 3 Prequalified WPSs applies
  - Prequalified Steels
  - Prequalified Filler Metals
  - Prequalified Joint Details, including tolerances
  - Prequalified Preheat Requirements

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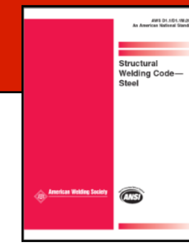

Except for seven items,

- All of Clause 4 Qualification applies
  - Qualification of WPSs
  - Qualification of Welding Personnel
- All of Clause 5 Fabrication applies
  - All Pre-Welding Conditions
  - All During Welding Conditions
  - All After Welding Conditions
- All of Clause 6 Inspection applies

Special thanks to:

Mr. Paul O’Connor, President, Gooder-Henrichsen

Dr. James “Jim” Fisher, Consultant, CSD

Mr. J. Kenneth “Ken” Charles III, Managing Director, SJI

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Assessment Question

- What changes are permitted to be made to AWS D1.1 by the latitude offered by clause 6.8?
- a) Alternate acceptance criteria that is less rigorous than standard D1.1 criteria.
  b) Alternate acceptance criteria that is more rigorous than standard D1.1 criteria.
  c) Alternate acceptance criteria that are based on research.
  d) All of the above

Assessment Question

- What welding process is used by Joist Manufacturers, today?
  - E) all of the above
- What changes are permitted to be made to AWS D1.1 by the latitude offered by clause 6.8?
  - d) All of the above

THANK YOU

Presented by: