

**Night School 27:
Fundamentals of
Welding and Bolting**

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**AISC
Night School**



Session 3 – Special Welding Applications

October 18, 2021 | Duane K. Miller



**Smarter.
Stronger.
Steel.**

**AISC
Night School**

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Course Description

Special Welding Applications October 18, 2021

This session covers atypical welding applications for buildings. The live webinar presents practical, straightforward solutions to challenging situations including: welding of steel headed stud anchors, welding on coated steels, welding AESS, welding on existing structures, welding heavy sections, welding under high restraint, field welding, heat shrinking, cold temperature applications and more.





Learning Objectives

1. Describe tolerance issues that may affect welded connections in AESS structures.
2. Identify welded HSS connections where member configurations could prevent proper welding, inspection or assembly.
3. List considerations for welded connections on rolled heavy shapes.
4. List consideration for welded connections in cold temperature applications.



Night School 27: Fundamentals of Welding and Bolting



Curtis L. Decker, PhD,
PE, SE, The Lincoln
Electric Company



Duane K. Miller, PE,
ScD, The Lincoln
Electric Company



Chad Larson, LeJeune
Bolt Company



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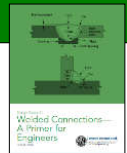
Night School 27: Fundamentals of Welding and Bolting

Welding Part 3: Special Welding Applications
October 18, 2021

Duane K. Miller, PE, ScD, The Lincoln Electric Company



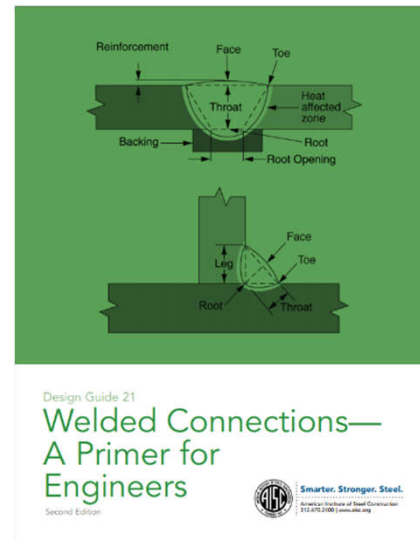
SPECIAL WELDING APPLICATIONS



AISC Design Guide 21, 2nd Edition

Welded Connections—
A Primer for Engineers

Chapter 14 Special Welding Applications



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SPECIAL WELDING APPLICATIONS

Chapter 14 Special Welding Applications

- 14.1 Welding of Steel Headed Stud Anchors
- 14.2 Welding on Galvanized Steels
- 14.3 Welding on Primed and Painted Steel
- 14.4 Welding on Heavy Shapes
- 14.5 Welding on Highly Restrained Members
- 14.6 Welding HSS



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SPECIAL WELDING APPLICATIONS



- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.10 Welds and Mechanical Fasteners
- 14.11 Welding on Members to be Hot-Dip Galvanized
- 14.12 Cold Temperature Applications
- 14.13 Deck Welding



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SPECIAL WELDING APPLICATIONS



- 14.14 Welding on In-Place Embed Plates
- 14.15 Heat Shrinking
- 14.16 Buttering



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SPECIAL WELDING APPLICATIONS

Today's Webinar



- ➔ 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



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SPECIAL WELDING APPLICATIONS

W14x730



22 in.

5 in.

3 in.

18 in.

“Jumbo Shapes”



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AISC 360-16 SPECIFICATION

Commentary A3



1c. Rolled Heavy Shapes

The web-to-flange intersection and the web center of heavy hot-rolled shapes, as well as the interior portions of heavy plates, may contain a more coarse grain structure and/or lower notch toughness material than other areas of these products.

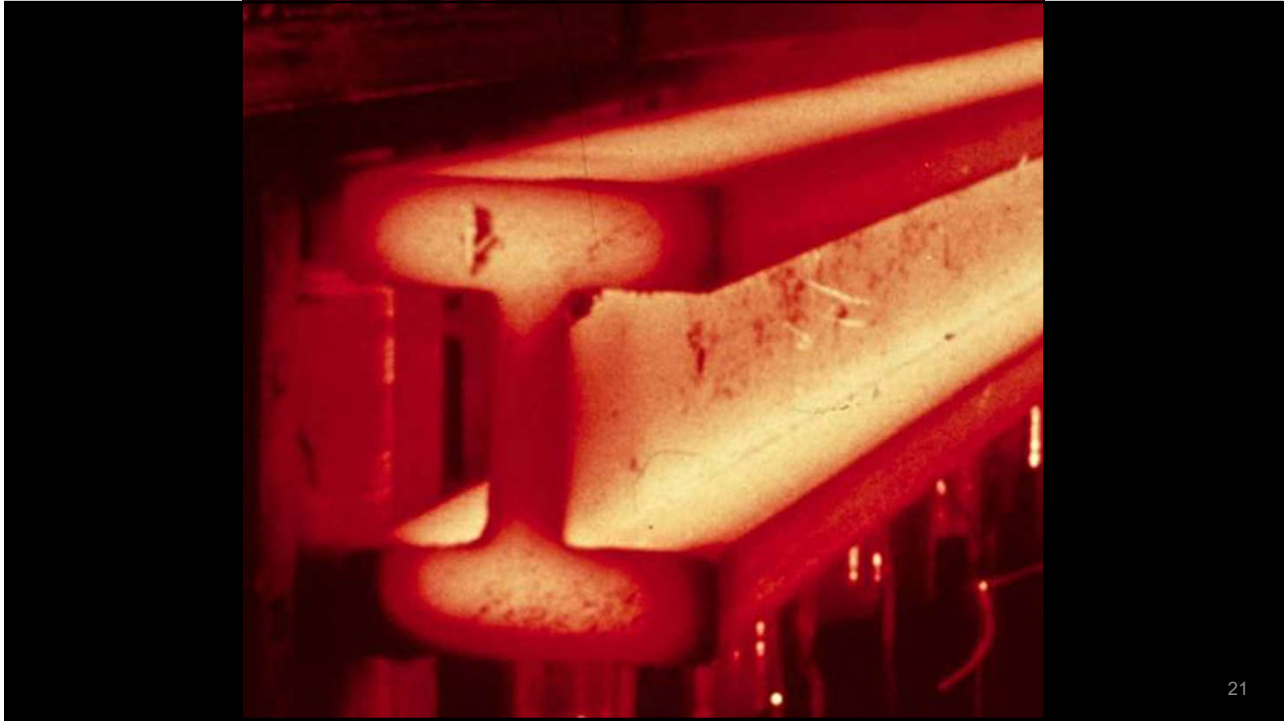
Segregation

Reduced Rolling

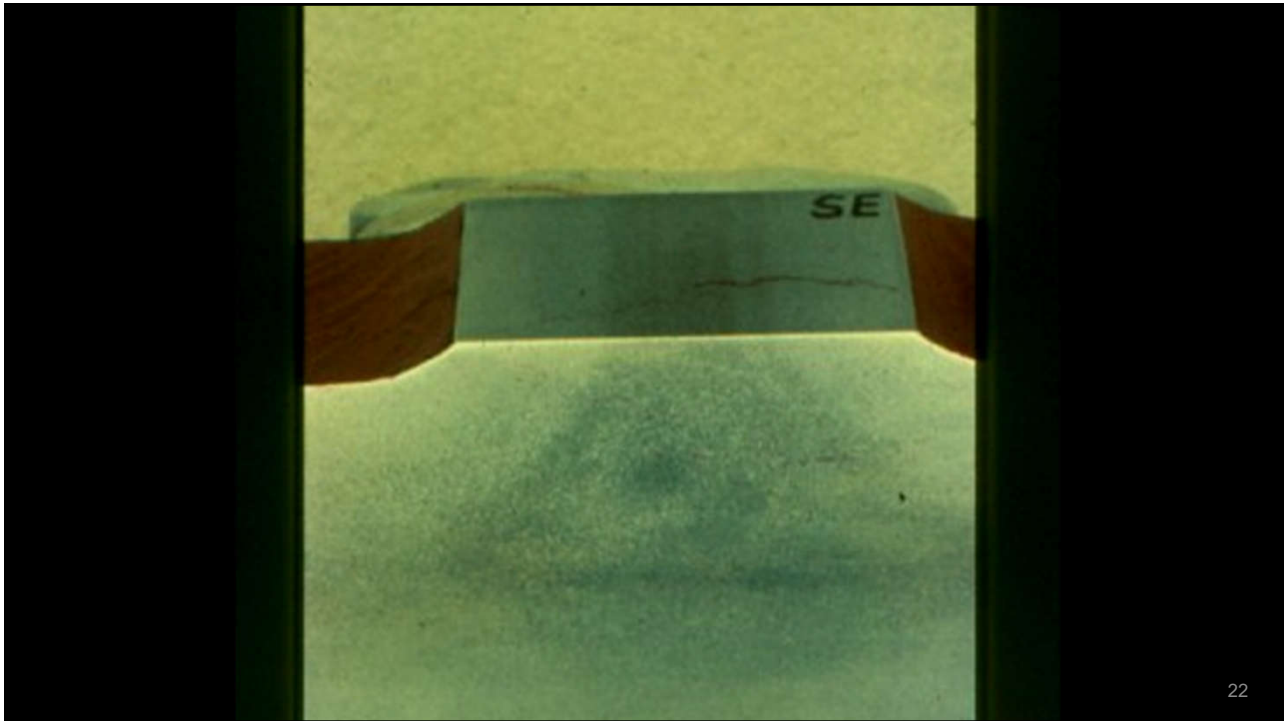
Slower Cooling



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Commentary A3


1c. Rolled Heavy Shapes

This characteristic is not detrimental to suitability for compression members or for non-welded members. However, when heavy cross sections are joined by splices or connections using complete-joint-penetration groove welds that extend through the coarser and/or low notch-tough interior portions, tensile strains induced by welding may result in cracking.



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Commentary A3

1a. ASTM Designations

Rolled Steel is anisotropic, especially insofar as ductility is concerned; therefore, weld contraction strain in the region of highly restrained welded connections may exceed the strength of the material if special attention is not given to material selection, details, workmanship and inspection.



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AISC 360-16 Specification for Structural Steel Buildings


CHAPTER A
GENERAL PROVISIONS

Material

A3. MATERIAL

1c. Rolled Heavy Shapes

ASTM A6/A6M hot-rolled shapes with a flange thickness exceeding 2 in. (50 mm) are considered to be rolled heavy shapes. Rolled heavy shapes used as members subject to primary (computed) tensile forces due to tension or flexure and spliced or connected using complete-joint-penetration groove welds that fuse through the thickness of the flange or the flange and the web, shall be specified as follows. The structural design documents shall require that such shapes be supplied with Charpy V-notch (CVN) impact test results in



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CHAPTER A
GENERAL PROVISIONS

Material

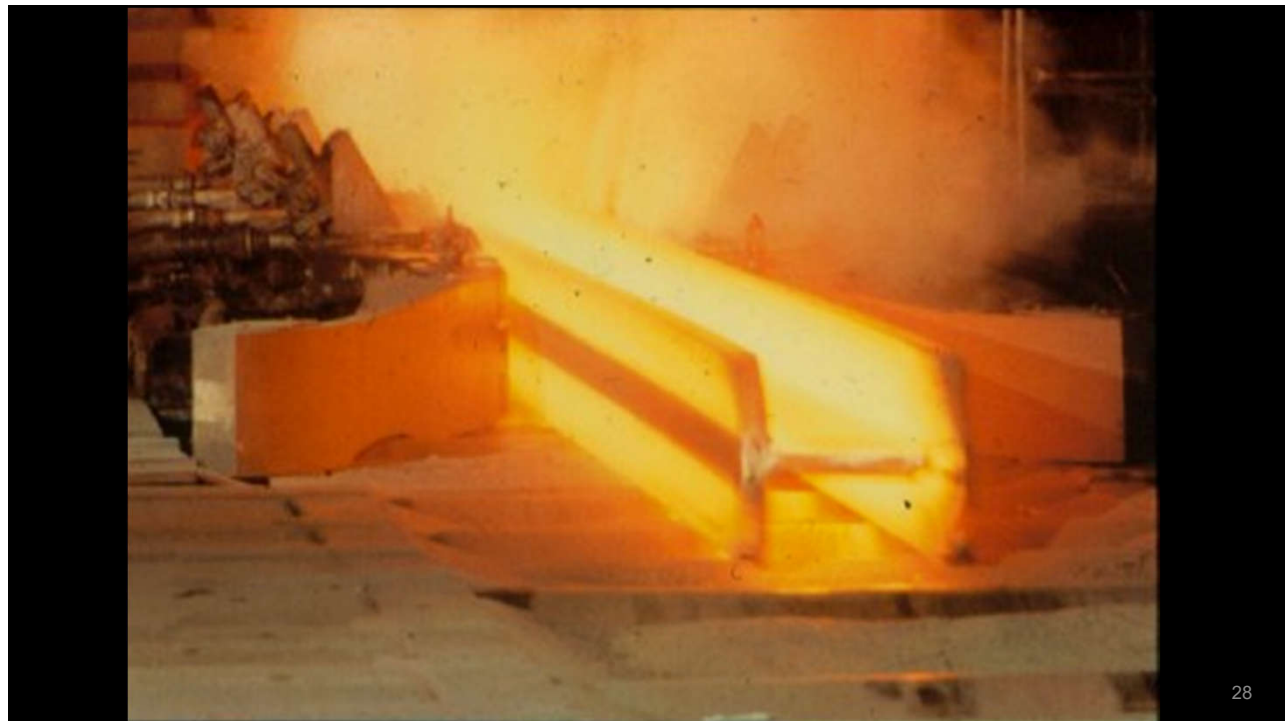
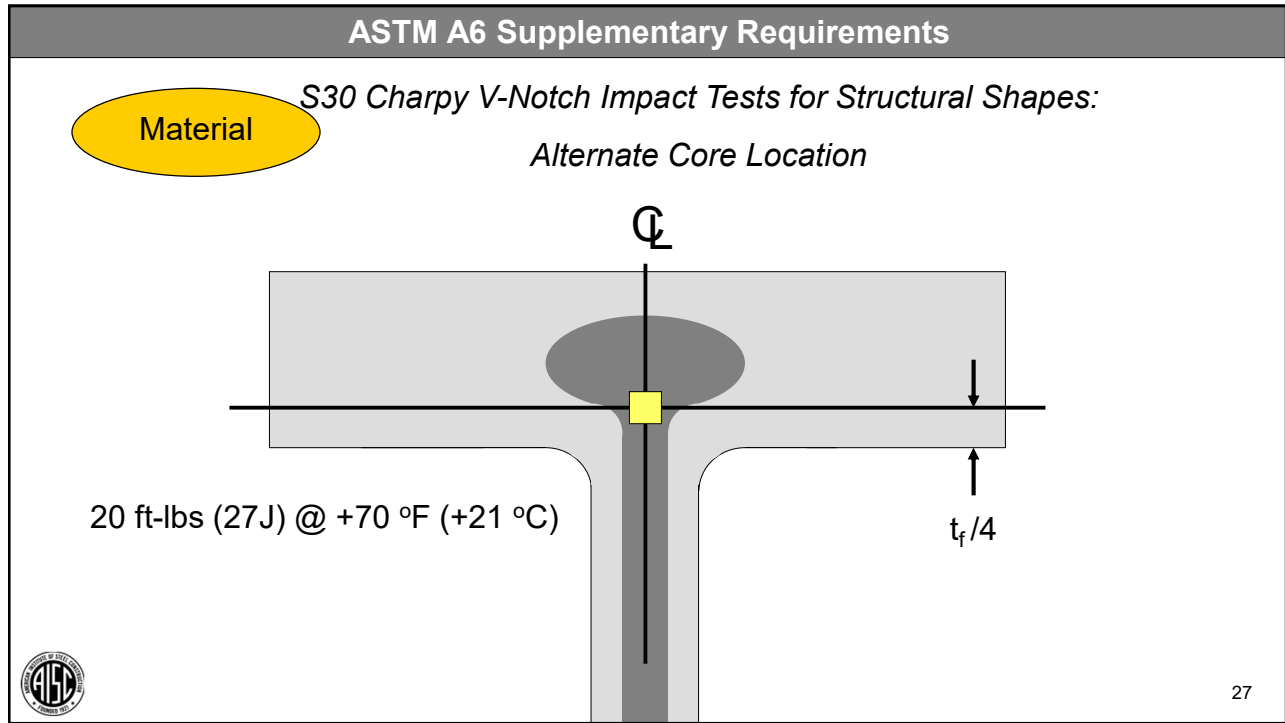
A3. MATERIAL

1c. Rolled Heavy Shapes (cont'd)

The structural design documents shall require that such shapes be supplied with Charpy V-notch (CVN) impact test results in accordance with ASTM A6/A6M, Supplementary Requirement S30, Charpy V-Notch Impact Test for Structural Shapes—Alternate Core Location. The impact test shall meet a minimum average value of 20 ft-lb (27 J) absorbed energy at a maximum temperature of +70°F (+21°C).



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CHAPTER A
GENERAL PROVISIONS

Material

A3 MATERIAL

1d. Built-Up Heavy Shapes

Built-up cross sections consisting of plates with a thickness exceeding 2 in. (50 mm) are considered built-up heavy shapes. Built-up heavy shapes used as members subject to primary (computed) tensile forces due to tension or flexure and spliced or connected to other members using complete-joint-penetration groove welds that fuse through the thickness of the plates, shall be specified as follows. The structural design documents shall require that the steel be supplied with Charpy V-notch impact test results in accordance with ASTM A6/A6M,



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CHAPTER A
GENERAL PROVISIONS

Material

A3 MATERIAL

1d. Built-Up Heavy Shapes (cont'd)

The structural design documents shall require that the steel be supplied with Charpy V-notch impact test results in accordance with ASTM A6/A6M, Supplementary Requirement S5, Charpy V-Notch Impact Test. The impact test shall be conducted in accordance with ASTM A673/A673M, Frequency P, and shall meet a minimum average value of 20 ft-lb (27 J) absorbed energy at a maximum temperature of +70°F (+21°C).




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ASTM A6 Supplementary Requirements

S5 Charpy V-Notch Impact Test

Material



20 ft-lbs (27 J) @ +70 °F (+21 °C)

For built-up cross sections

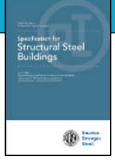
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CHAPTER J

DESIGN OF CONNECTIONS

Material




J2. 6. Filler Metal Requirements

Filler metal with a specified minimum Charpy V-notch toughness of 20 ft-lb (27 J) at 40°F (4°C) or lower shall be used in the following joints:

- (a) CJP groove welded T- and corner joints with steel backing left in place, subject to tension normal to the effective area, unless the joints are designed using the nominal strength and resistance factor or safety factor, as applicable, for a PJP groove weld
- (b) CJP groove welded splices subject to tension normal to the effective area in heavy sections, as defined in Sections A3.1c and A3.1d

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Material


J2.6 Filler Metal Requirements

20 ft-lbs (27 J) @ +40 °F (+4 °C)



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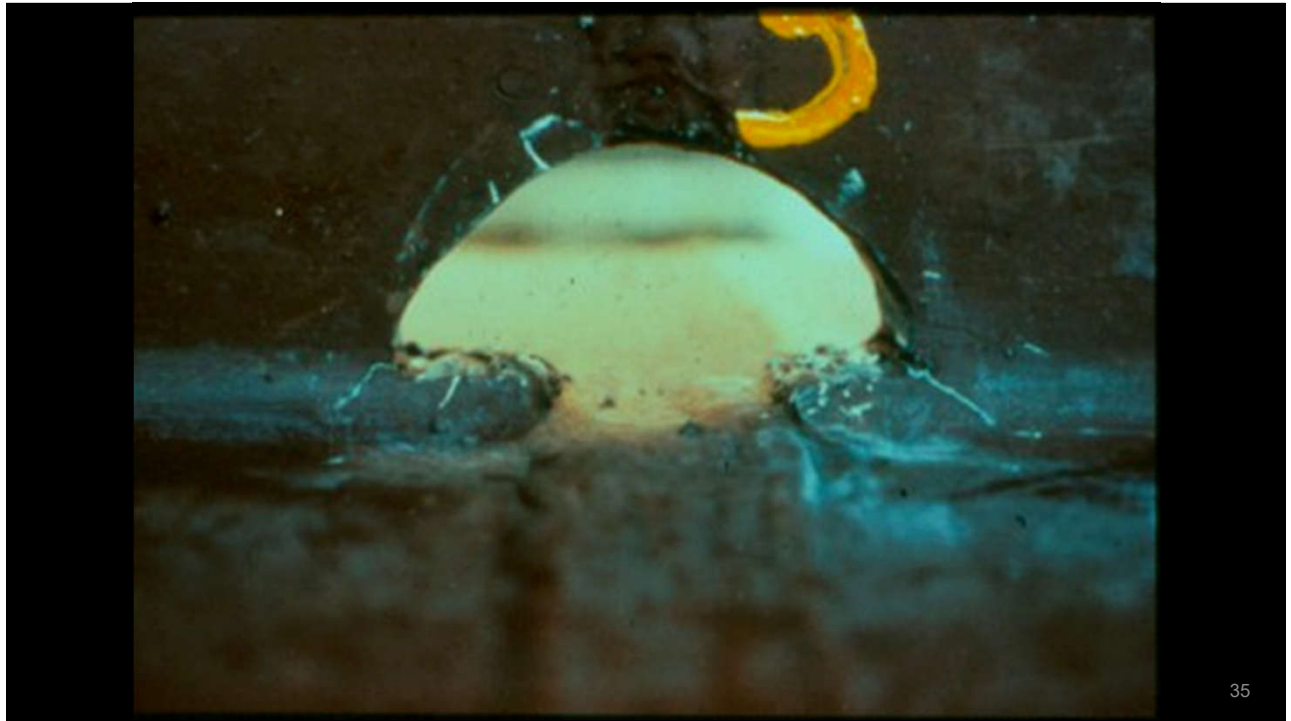
Commentary A3

1c. Rolled Heavy Shapes

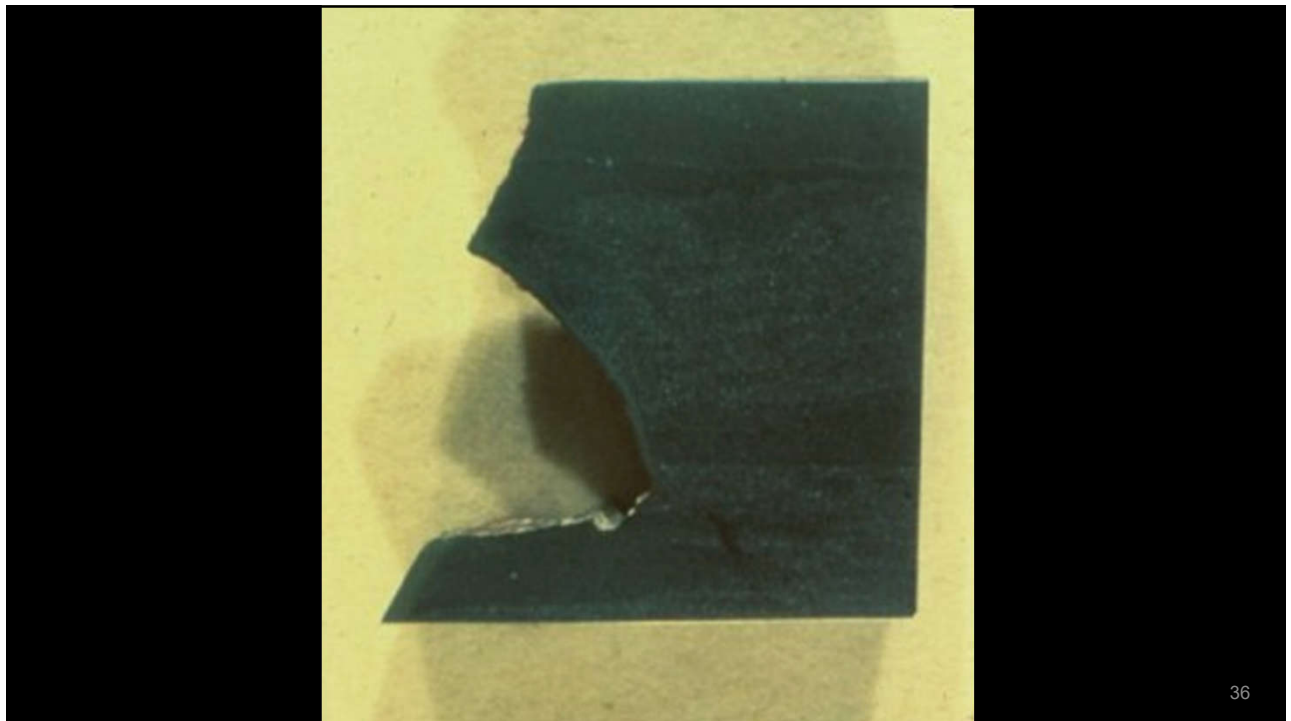
To minimize the potential for fracture, the notch toughness requirements of Section A3.1c must be used in conjunction with good design and fabrication procedures. Specific requirements are given in Sections J1.5, J1.6, J2.6 and J2.7.



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Details

CHAPTER J
DESIGN OF CONNECTIONS

J1.6. Weld Access Holes

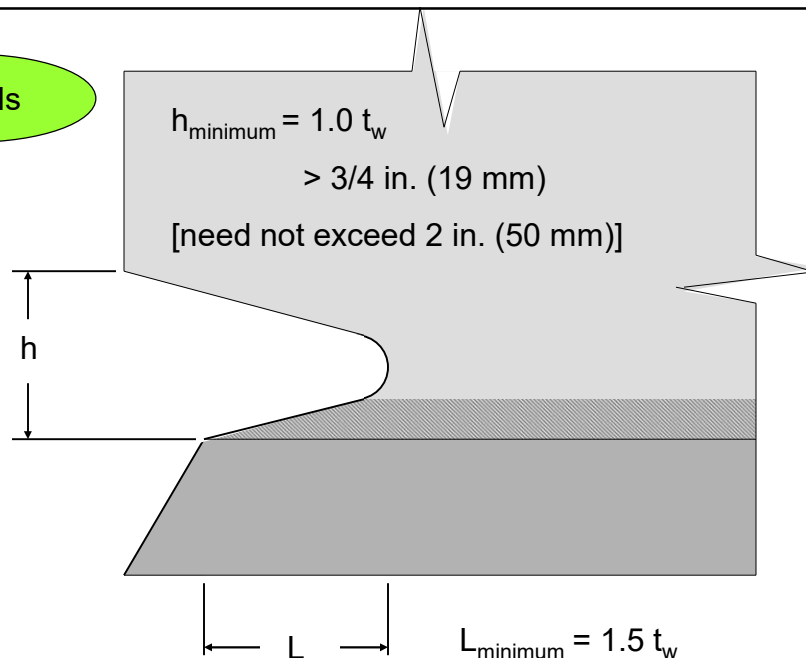
Weld access holes shall meet the following requirements:

(a) All weld access holes required to facilitate welding operations shall be detailed to provide room for weld backing as needed.

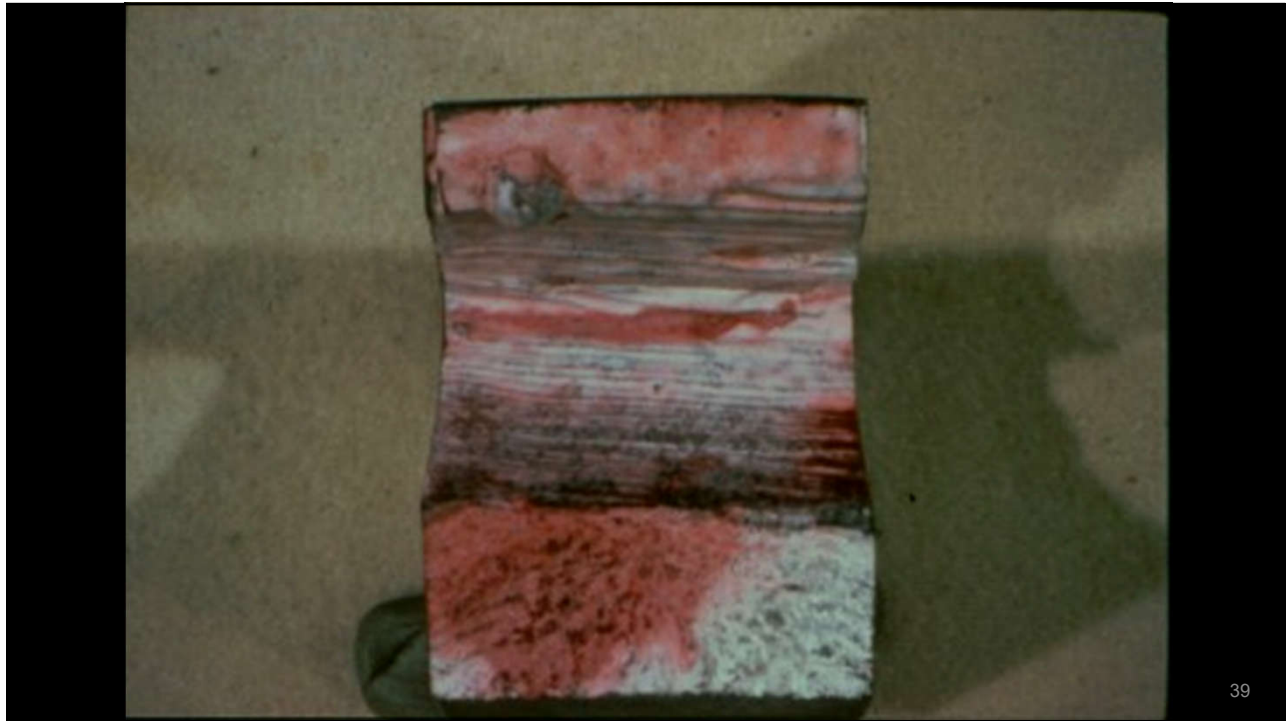
(b) The access hole shall have a length from the toe of the weld preparation not less than 1-1/2 times the thickness of the material in which the hole is made, nor less than 1-1/2 in. (38 mm).

(c) The access hole shall have a height not less than the thickness of the material with the access hole, nor less than 3/4 in. (19 mm), nor does it need to...³⁷

Details



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Workmanship

CHAPTER M

FABRICATION AND ERECTION

M2.2. Thermal Cutting

For beam copes and weld access holes in which the curved part of the access hole is thermally cut in ASTM A6/A6M hot-rolled shapes with a flange thickness exceeding 2 in. (50 mm) and welded built-up shapes with material thickness greater than 2 in. (50 mm), a preheat temperature of not less than 150°F (66°C) shall be applied prior to thermal cutting. The thermally cut surface of access holes in ASTM A6/A6M hot-rolled shapes with a flange thickness exceeding 2 in. (50 mm) and built-up shapes with a material thickness greater than 2 in. (50 mm) shall be ground.



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AWS D1.1:2020 STRUCTURAL WELDING CODE

Table 5.8 (Continued)
Prequalified Minimum Preheat and Interpass Temperature (see 5.7)

Table 5.8
**Prequalified Minimum
 Preheat/Interpass Temperatures**

C A T E G O R Y	Steel Specification	Welding Process	Thickness of Thickest Part at Point of Welding		Minimum Preheat and Interpass Temperature		
			in	mm	°F	°C	
B (cont'd)	ASTM A710	Grade A, Class 2 -> 2 in (50 mm)					
	ASTM A847	Grade 50					
	ASTM A913	Grade 50					
	ASTM A992	Grade 50					
	ASTM A1008 HSLAS	Grade 45 Class 1 Grade 45 Class 2 Grade 50 Class 1 Grade 50 Class 2 Grade 55 Class 1 Grade 55 Class 2					
	ASTM A1008 HSLAS-F	Grade 50					
	ASTM A1011 SS	Grades 50, 55					
	ASTM A1011 HSLAS	Grade 45 Class 1 Grade 45 Class 2 Grade 50 Class 1 Grade 50 Class 2 Grade 55 Class 1 Grade 55 Class 2	SMAW with low-hydrogen electrodes, SAW, GMAW, FCAW	1/8 to 3/4 incl.	3 to 20 incl.	32 ^a	0 ^a
	ASTM A1011 HSLAS-F	Grade 50		Over 3/4 thru 1-1/2	Over 20 thru 38	50	10
	ASTM A1018 HSLAS	Grade 45 Class 1 Grade 45 Class 2 Grade 50 Class 1 Grade 50 Class 2 Grade 55 Class 1 Grade 55 Class 2		Over 1-1/2 thru 2-1/2	Over 38 thru 65	150	65
	ASTM A1018 HSLAS-F	Grade 50		Over 2-1/2	Over 65	225	110
	ASTM A1018 SS	Grades 30, 33, 36, 40					
	ASTM A1066	Grade 50					
	ASTM A1085	Grade 50					
	API 5L	Grades B, X42					
	API Spec. 2H	Grades 42, 50					
	API 2MT1	Grade 50					
	API 2W	Grades 42, 50, 50T					
	API 2Y	Grades 42, 50, 50T					
	ABS	Grades A, B, D, E AH 32, 36 DH 32, 36 EH 32, 36					

(Continued) 41

AWS D1.1:2020 STRUCTURAL WELDING CODE

B (Cont'd)	ASTM A808						
	ASTM A913 ^b	Grade 50					
	ASTM A992	Grade 50					
	ASTM A1008 HSLAS	Grade 45 Class 1 Grade 45 Class 2 Grade 50 Class 1 Grade 50 Class 2 Grade 55 Class 1 Grade 55 Class 2	SMAW with low- hydrogen electrodes, SAW, GMAW, FCAW	1/8 to 3/4 incl.	3 to 20 incl.	32 ^a	0 ^a
	ASTM A1008 HSLAS-F	Grade 50		Over 3/4 thru 1-1/2	Over 20 thru 38	50	10
	ASTM A1011 HSLAS	Grade 45 Class 1 Grade 45 Class 2 Grade 50 Class 1 Grade 50 Class 2 Grade 55 Class 1 Grade 55 Class 2		Over 1-1/2 thru 2-1/2	Over 38 thru 65	150	65
	ASTM A1011 HSLAS-F	Grade 50		Over 2-1/2	Over 65	225	110
	ASTM A1018 HSLAS	Grade 45 Class 1 Grade 45 Class 2 Grade 50 Class 1 Grade 50 Class 2 Grade 55 Class 1 Grade 55 Class 2					

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Inspection

Commentary J1

J1.5. Splices in Heavy Sections

Previous editions of this Specification required magnetic particle or dye-penetrant inspection of thermally cut weld access holes for splices in heavy sections. This requirement was deliberately removed as anecdotal evidence suggested this inspection was not necessary because cracks from thermal cutting rarely occurred when the other Specification requirements were met. The previously prescribed magnetic particle testing or penetrant testing was replaced with a requirement for visual inspection of weld access holes after welding (see Table N5.4-3).





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SPECIAL WELDING APPLICATIONS

Welding Heavy Sections: Summary

- Material notch toughness requirements (≥ 2 in [50 mm])
- Weld access hole geometry
- Preheat for thermal cutting, grinding
- MT and PT no longer required, but good visual needed
- Preheat for welding
- Follow other “good practices” for welding on highly restrained members

Material **Details** **Workmanship** **Inspection**



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SPECIAL WELDING APPLICATIONS

Today's Webinar



- 14.4 Welding on Heavy Shapes
- ➔ 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



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SPECIAL WELDING APPLICATIONS

14.6 Welding HSS

- ➔ • Connections and HSS member size
- Overall configuration
- Cutting and preparing HSS



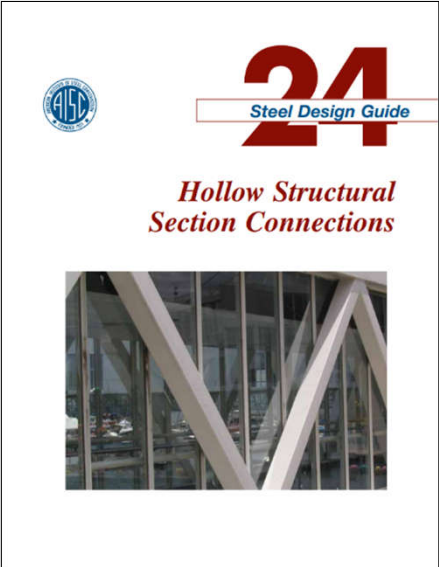
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Design Guide 24

Hollow Structural Section Connections

by


Packer, Sherman, Lecce



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Design Guide 24 Hollow Structural Section Connections

Chapter 1
Introduction



“Connections usually have been the challenging aspect for the designer of structures that involve HSS....Note that, in many cases, the local strength of the HSS at the connection is an integral part—and perhaps a limitation--of the design.”

HSS member size may need to be increased to accommodate connection design.

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Design Guide 24 Hollow Structural Section Connections



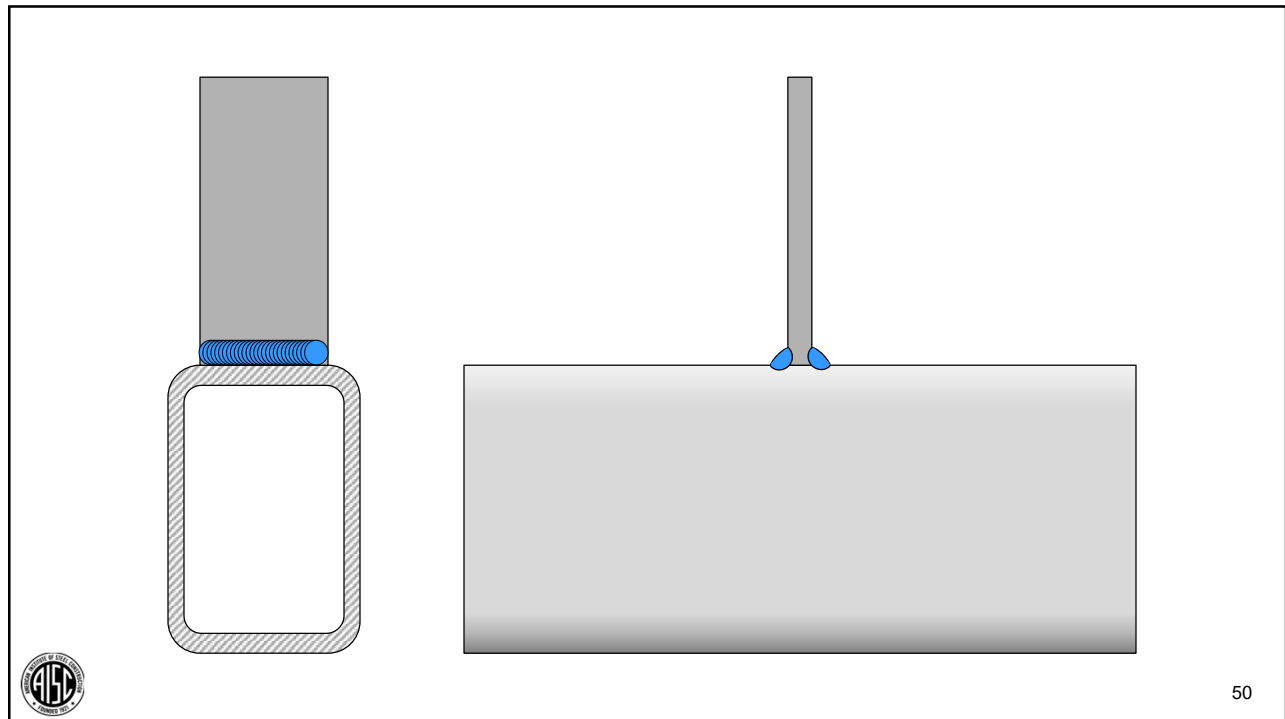
Chapter 2 Welding

2.4 EFFECTIVE WELD LENGTH

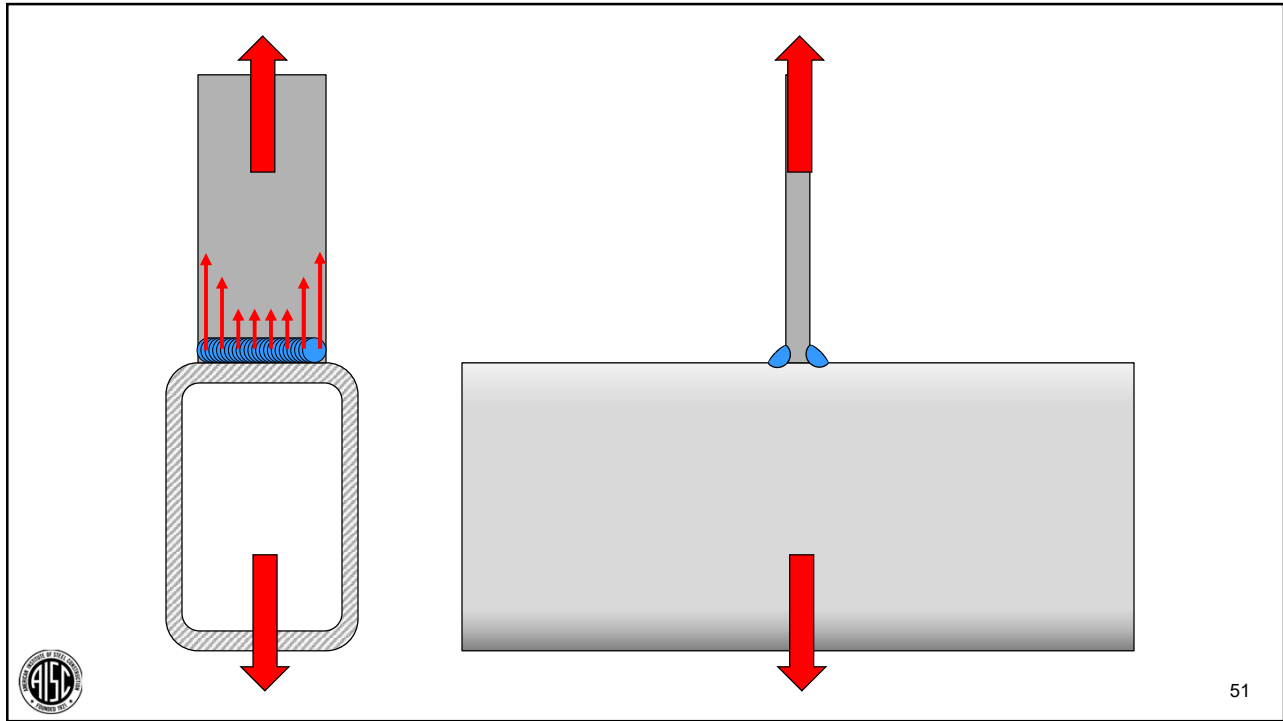
Due to the variation in flexural stiffness of the wall across the width of a rectangular HSS, a force transmitted through a weld is often not uniformly distributed. This can be accounted for in design using an effective weld length approach. This reduced effective length applies both to the weld and to the force in the connected element.

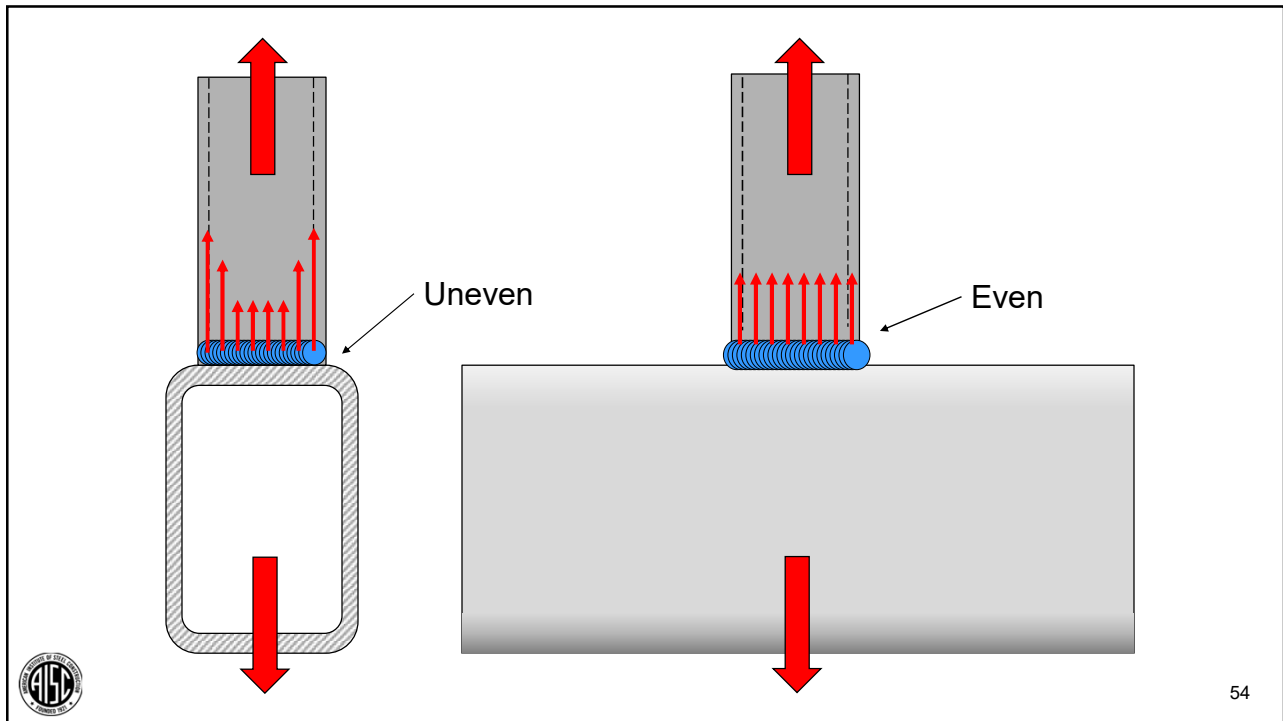
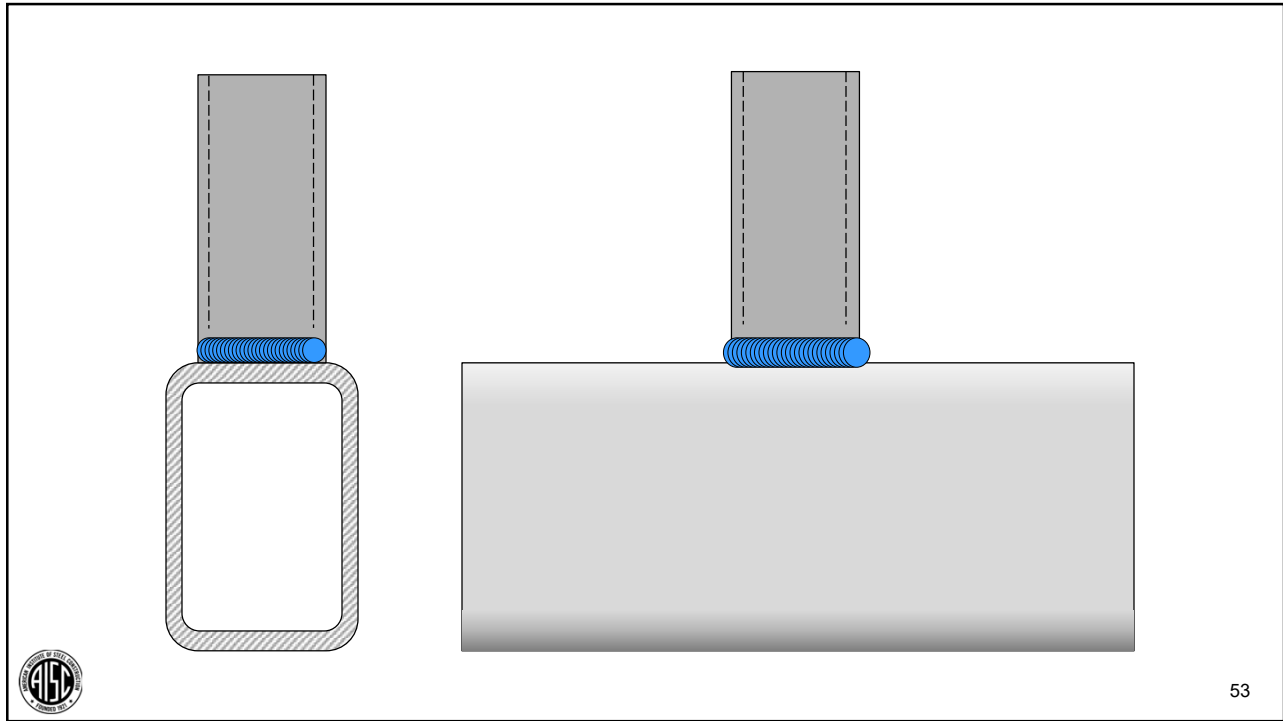


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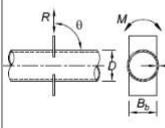
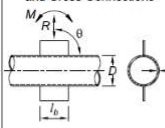
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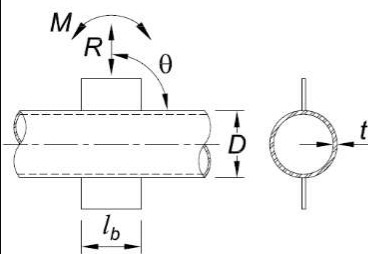
AISC 360:16 Specification for Structural Steel Buildings

TABLE K2.1
 Available Strength of Plate-to-Round HSS Connections

TABLE K2.1 Available Strengths of Plate-to-Round HSS Connections			
Connection Type	Connection Available Strength	Plate Bending	
Transverse Plate T- and Cross-Connections 	Limit State: HSS Local Yielding		
	Plate Axial Load	In-Plane	Out-of-Plane
	$R_n \sin \theta = F_y t^2 \left(\frac{5.5}{1 - 0.81 \frac{B_p}{D}} \right) Q_f$ (K2-1a)	—	$M_n = 0.5 B_p R_n$ (K2-1b)
$\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)			
Longitudinal Plate T-, Y- and Cross-Connections 	Limit State: HSS Plastification		
	Plate Axial Load	In-Plane	Out-of-Plane
	$R_n \sin \theta = 5.5 F_y t^2 \left(1 + 0.25 \frac{l_b}{D} \right) Q_f$ (K2-2a)	$M_n = 0.8 l_b R_n$ (K2-2b)	—
$\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)			
Functions $Q_f = 1$ for HSS (connecting surface) in tension $= 1.0 - 0.3U$ for HSS (connecting surface) in compression (K2-3)			
$U = \frac{P_{co} + M_{co}}{F_c A_c + F_c S}$ (K2-4)			
where P_{co} and M_{co} are determined on the side of the joint that has the lower compression stress. P_{co} and M_{co} refer to required strengths in the HSS: $P_{co} = P_u$ for LRFD, and P_u for ASD; $M_{co} = M_u$ for LRFD, and M_u for ASD.			



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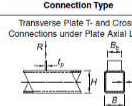
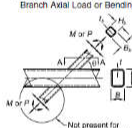
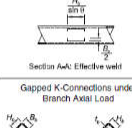
Longitudinal Plate T-, Y- and Cross-Connections 	Limit State: HSS Plastification		
	Plate Axial Load	In-Plane	Out-of-Plane
	$R_n \sin \theta = 5.5 F_y t^2 \left(1 + 0.25 \frac{l_b}{D} \right) Q_f$ (K2-2a)	$M_n = 0.8 l_b R_n$ (K2-2b)	—
$\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)			



AISC 360:16 Specification for Structural Steel Buildings

TABLE K5.1
 Effective Weld Properties for
 Connection to Rectangular HSS

TABLE K5.1
 Effective Weld Properties for
 Connections to Rectangular HSS

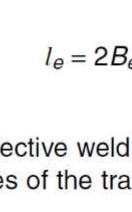
Connection Type	Weld Properties
Transverse Plate T- and Cross-Connections under Plate Axial Load 	Effective Weld Properties $l_e = 2B_e \quad (K5-4)$ where l_e = total effective weld length for welds on both sides of the transverse plate
T, Y, and Cross-Connections under Branch Axial Load or Bending 	Effective Weld Properties $l_e = \frac{2H_b}{\sin \theta} \geq 2B_e \quad (K5-5)$ $S_w = \frac{t_p}{2} \left(\frac{H_b}{\sin \theta} \right)^2 + L_w B_e \left(\frac{H_b}{\sin \theta} \right) \quad (K5-6)$ $S_w = t_p \left(\frac{H_b}{\sin \theta} \right) B_e + \frac{1}{3} (t_p)^2 \left(\frac{L_w}{B_e} \right) \left(\frac{H_b}{\sin \theta} - B_e \right)^2 \quad (K5-7)$ When $\beta > 0.85$ or $\theta > 60^\circ$, $B_e/2$ shall not exceed $B_b/4$.
Gapped K-Connections under Branch Axial Load 	Effective Weld Properties When $\theta \leq 60^\circ$: $l_e = \frac{2(H_b - 1.2t_p)}{\sin \theta} + 2(B_b - 1.2t_p) \quad (K5-8)$ When $\theta \geq 60^\circ$: $l_e = \frac{2(H_b - 1.2t_p)}{\sin \theta} + B_b - 1.2t_p \quad (K5-9)$ When $50^\circ < \theta < 60^\circ$, linear interpolation shall be used to determine l_e .

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TABLE K5.1
 Effective Weld Properties for
 Connections to Rectangular HSS

TABLE K5.1
 Effective Weld Properties for
 Connections to Rectangular HSS

Connection Type	Weld Properties
Transverse Plate T- and Cross-Connections under Plate Axial Load 	<div style="border: 2px solid red; padding: 5px; text-align: center;">Effective Weld Properties</div> $l_e = 2B_e \quad (K5-4)$ where l_e = total effective weld length for welds on both sides of the transverse plate

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SPECIAL WELDING APPLICATIONS



Welded Connections—
A Primer for
Engineers


14.6 Welding HSS

- Connections and HSS member size
- ➔ • Overall configuration
- Cutting and preparing HSS



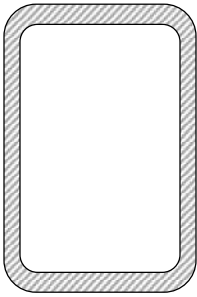
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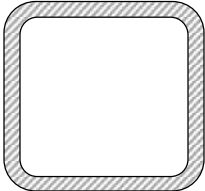
SPECIAL WELDING APPLICATIONS



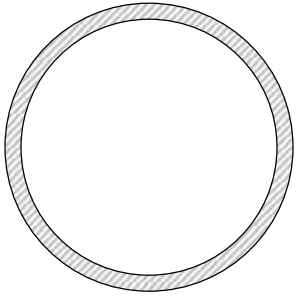
Welded Connections—
A Primer for
Engineers

Rectangular






Round



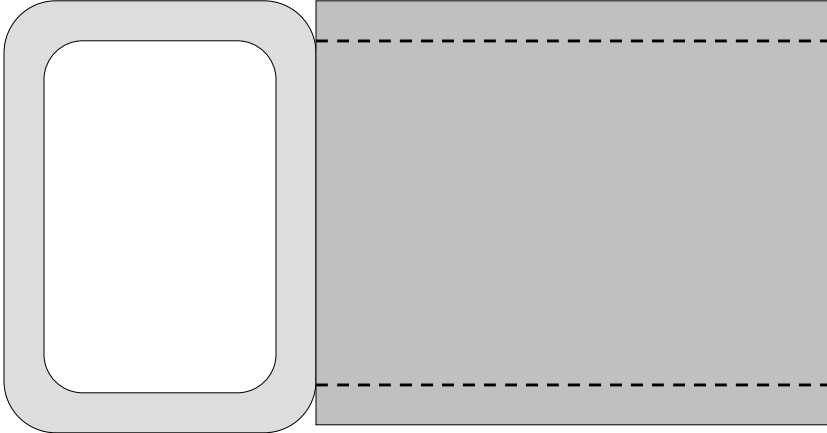
Rectangular is nearly always
easier to fabricate





60

SPECIAL WELDING APPLICATIONS

Matched Connection

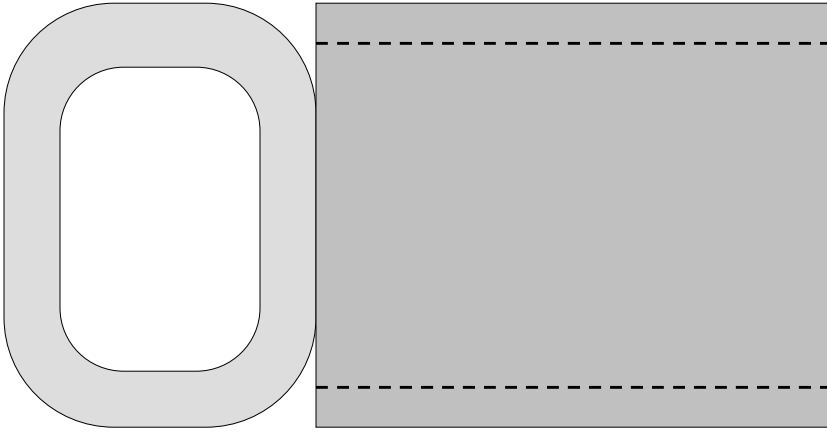


The diagram shows a cross-section of a column on the left and a beam on the right. The column has a rounded rectangular shape with a central void. The beam is a solid rectangular shape. A dashed line indicates the top and bottom edges of the beam's web, which are aligned with the top and bottom edges of the column's web. The column's web is wider than the beam's web, and the column's flanges are wider than the beam's flanges. The connection is shown as a 'Matched Connection'.





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SPECIAL WELDING APPLICATIONS

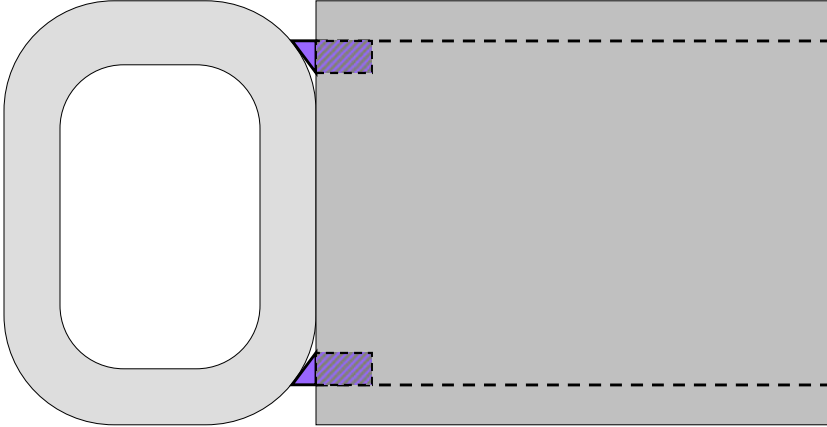


The diagram shows a cross-section of a column on the left and a beam on the right. The column has a rounded rectangular shape with a central void. The beam is a solid rectangular shape. A dashed line indicates the top and bottom edges of the beam's web, which are aligned with the top and bottom edges of the column's web. The column's web is wider than the beam's web, and the column's flanges are wider than the beam's flanges. The connection is shown as a 'Matched Connection'.





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SPECIAL WELDING APPLICATIONS

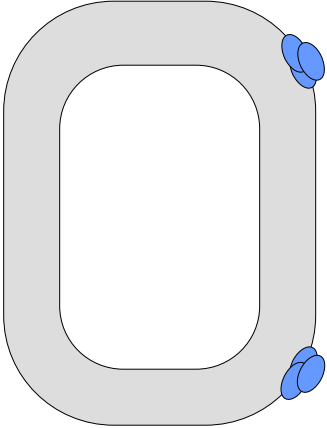


The diagram shows a grey channel section on the left and a grey rectangular plate on the right. Two purple hatched rectangular areas represent welds connecting the channel's web to the plate. Dashed lines indicate the original boundaries of the channel and plate.





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SPECIAL WELDING APPLICATIONS

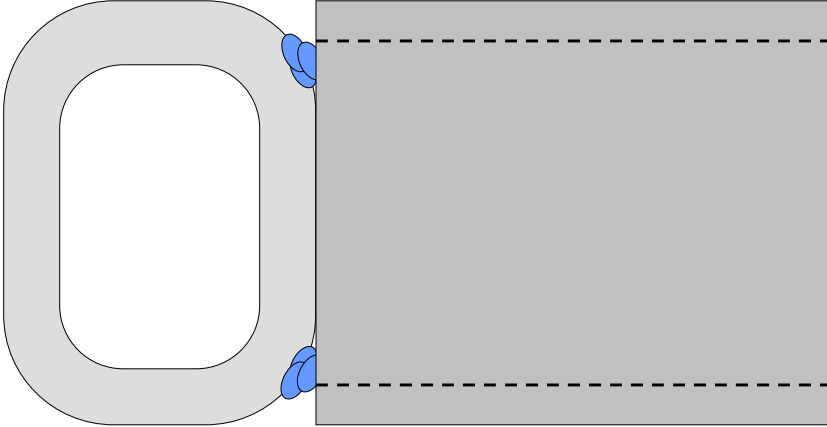


The diagram shows a grey channel section. Two blue circular welds are shown on the right side of the channel's web, representing a specific welding application.





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SPECIAL WELDING APPLICATIONS

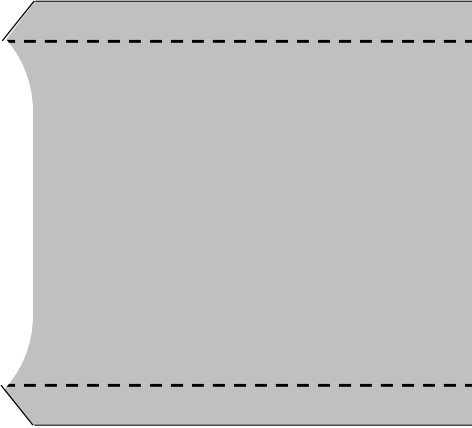


The diagram shows a light gray channel section on the left and a dark gray rectangular plate on the right. Two blue welds are shown at the top and bottom corners of the channel's web, connecting it to the plate. Dashed lines on the plate indicate the weld lines.





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SPECIAL WELDING APPLICATIONS

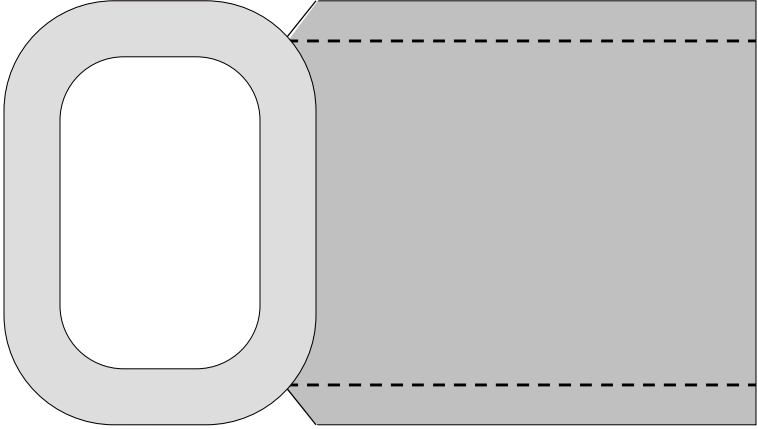


The diagram shows a light gray channel section on the left and a dark gray rectangular plate on the right. The top and bottom edges of the channel's web are curved. Two blue welds are shown at the top and bottom corners of the channel's web, connecting it to the plate. Dashed lines on the plate indicate the weld lines.




66

SPECIAL WELDING APPLICATIONS



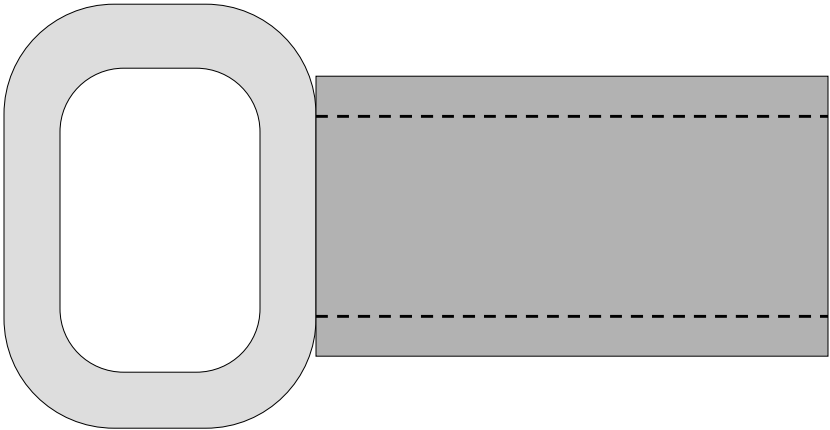
Welded Connections—
A Primer for
Engineers




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SPECIAL WELDING APPLICATIONS

Stepped Connection




Welded Connections—
A Primer for
Engineers




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SPECIAL WELDING APPLICATIONS




14.6 Welding HSS

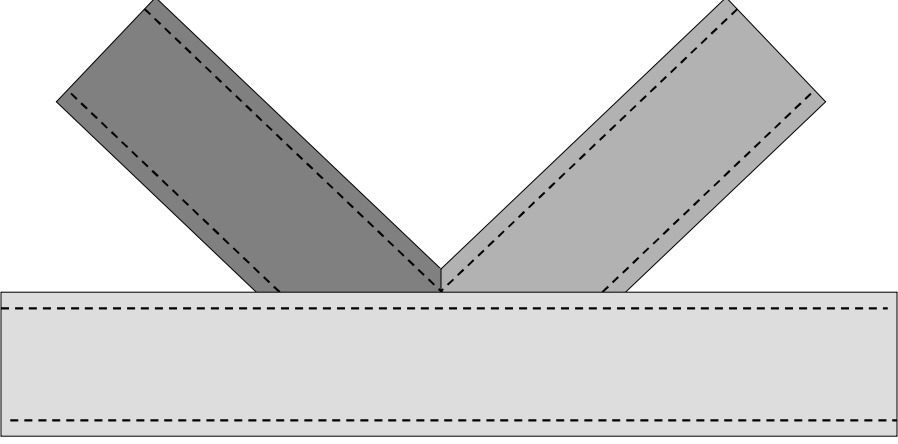
- Connections and HSS member size
- ➔ • Overall configuration
- Cutting and preparing HSS


69

SPECIAL WELDING APPLICATIONS



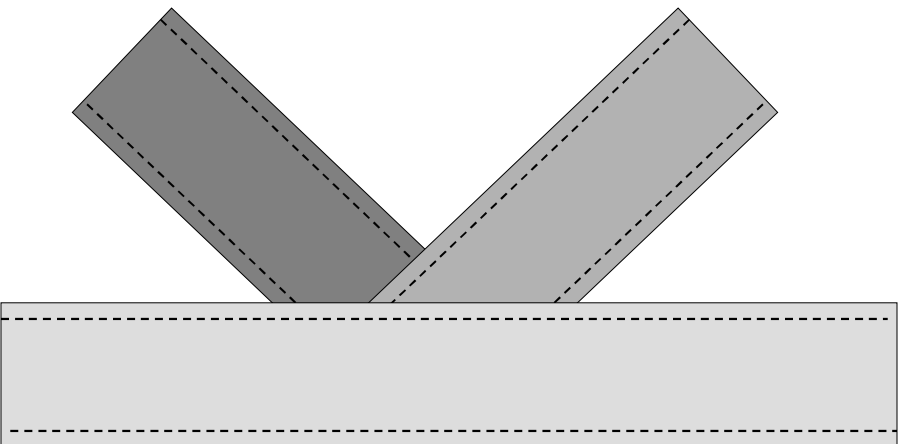
Overlapped





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SPECIAL WELDING APPLICATIONS

Overlapped



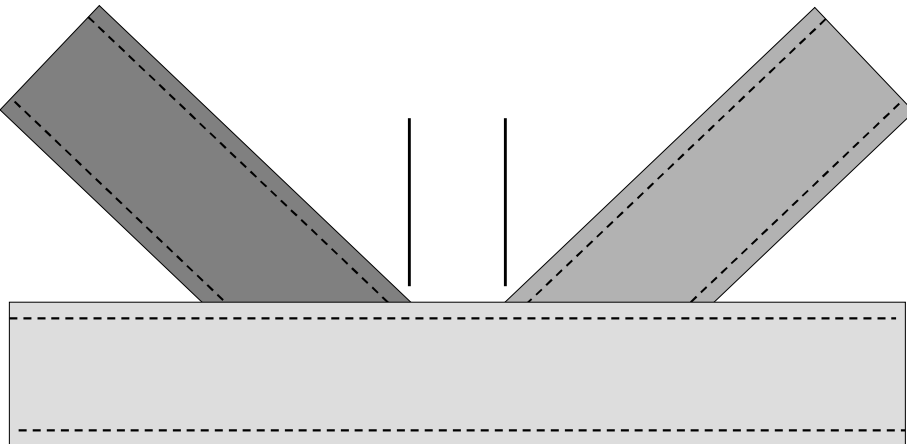

Welded Connections—
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SPECIAL WELDING APPLICATIONS

Gapped




Preferred


Welded Connections—
A Primer for
Engineers

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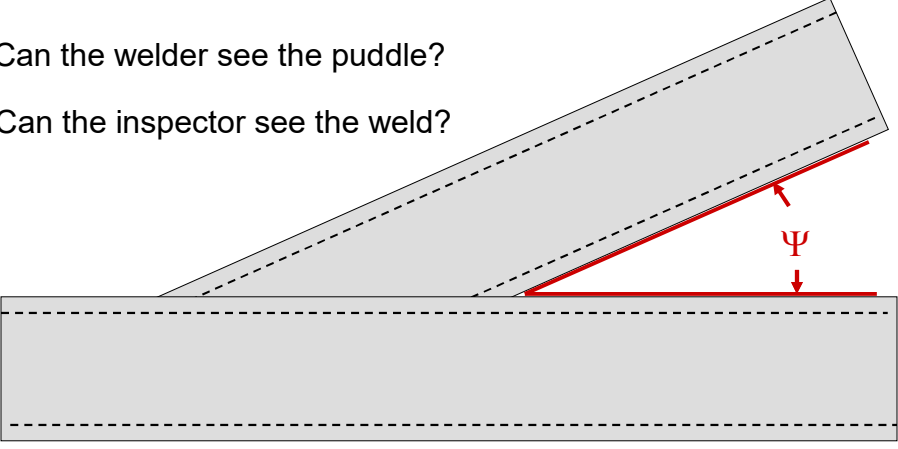
SPECIAL WELDING APPLICATIONS




Welded Connections—
A Primer for
Engineers

Provide Access for Welding and Inspection

- Can the welder see the puddle?
- Can the inspector see the weld?




Ψ = 30° minimum



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SPECIAL WELDING APPLICATIONS



Welded Connections—
A Primer for
Engineers

14.6 Welding HSS



- Connections and HSS member size
- Overall configuration
- ➔ • Cutting and preparing HSS



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SPECIAL WELDING APPLICATIONS


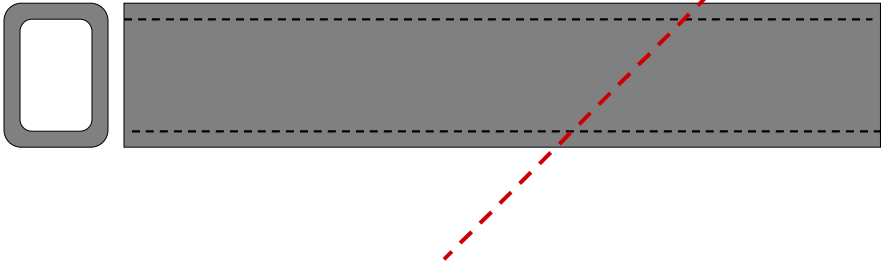
Box HSS



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SPECIAL WELDING APPLICATIONS


Box HSS




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SPECIAL WELDING APPLICATIONS

Box HSS



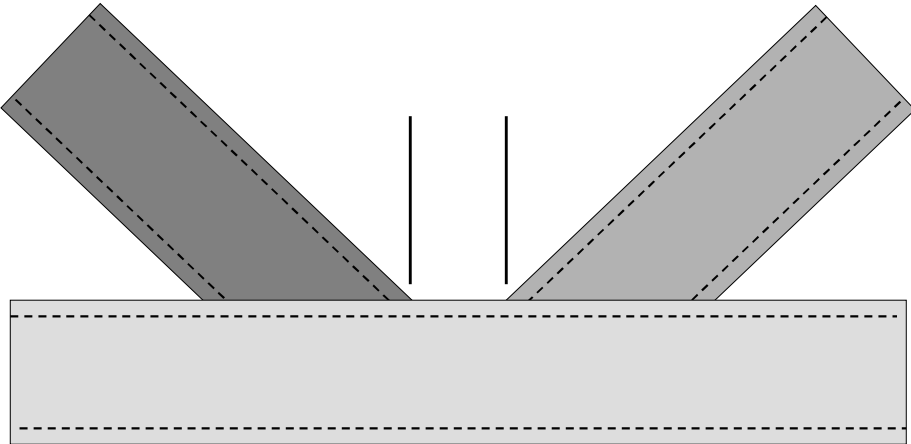
Welded Connections—
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Engineers




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SPECIAL WELDING APPLICATIONS

Gapped



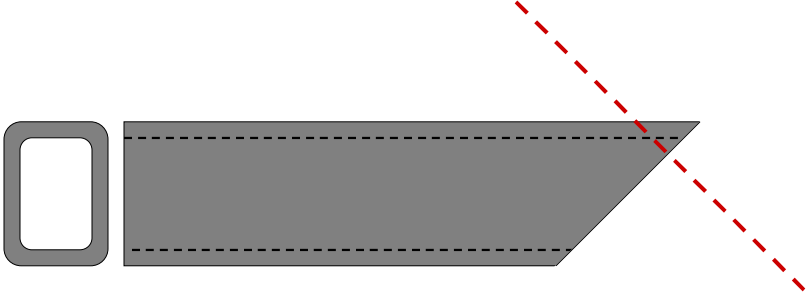
Welded Connections—
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Engineers





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SPECIAL WELDING APPLICATIONS

Box HSS




The diagram shows a cross-section of a Box HSS (Hollow Structural Section) with a rectangular opening on the left. The section is shaded gray. A red dashed line is drawn diagonally across the top flange, indicating a cut through the section. Dashed lines represent the internal cavity of the section.





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SPECIAL WELDING APPLICATIONS

Box HSS



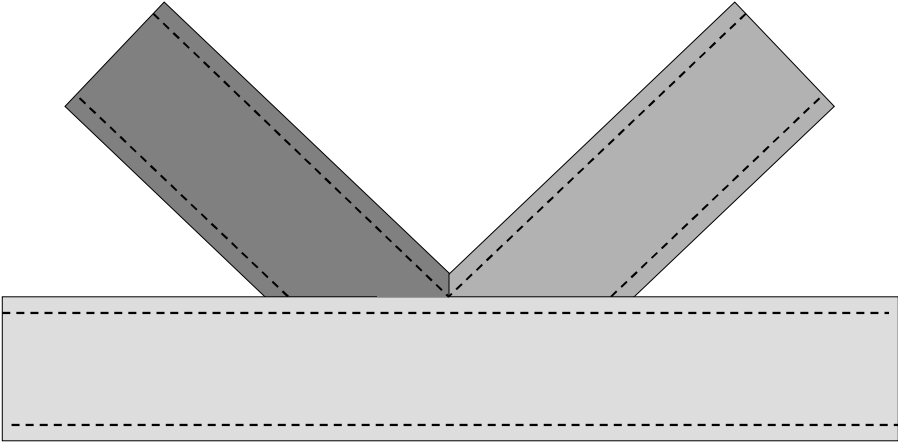
The diagram shows a cross-section of a Box HSS (Hollow Structural Section) with a rectangular opening on the left. The section is shaded gray and has a pointed end on the right. Dashed lines represent the internal cavity of the section.




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SPECIAL WELDING APPLICATIONS

Overlapped




Welded Connections—
A Primer for
Engineers




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SPECIAL WELDING APPLICATIONS

Round HSS



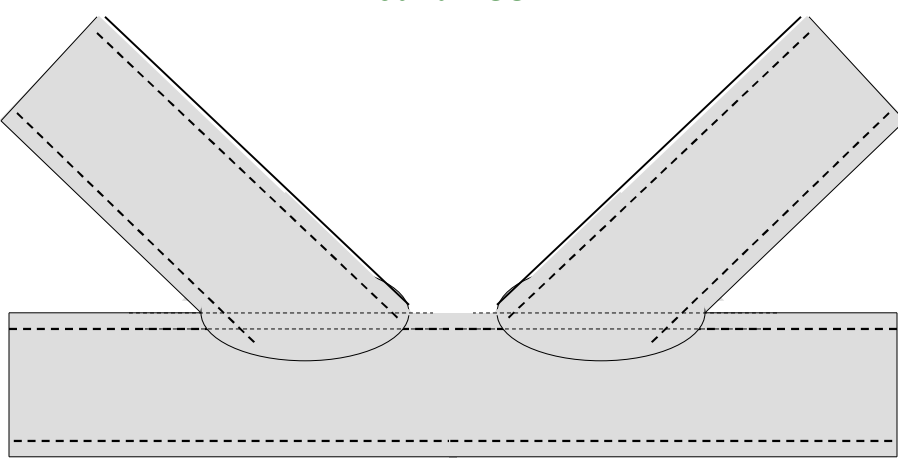
Welded Connections—
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Engineers





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SPECIAL WELDING APPLICATIONS

Round HSS



The diagram illustrates the welding of Round HSS (Hollow Structural Steel) components. It shows a horizontal section of a pipe with two angled sections being attached to its top surface. Dashed lines indicate the original positions of the pipe and the angled sections before they were bent into their final positions. The welds are shown as solid lines connecting the angled sections to the horizontal pipe.



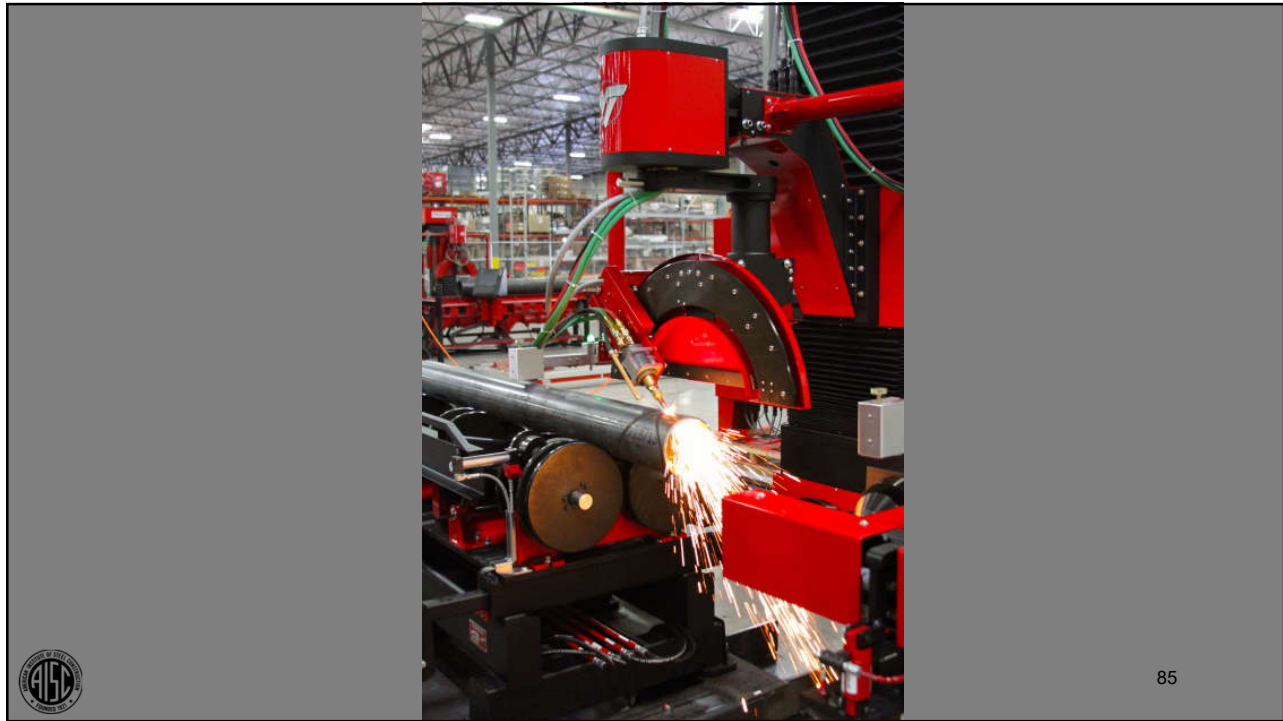
83




The image shows a large industrial welding machine, likely a robotic or semi-automatic system, used for welding steel components. The machine is primarily red and black, with a long horizontal base supported by several legs. A vertical column with a red top section is positioned over the base. Various cables and hoses are connected to the machine.




84



90 degree saddle cut



90 Degree Saddle



90 DEGREE SADDLE	
MACHINE	Vernon Tool MPM
PLASMA CUTTER	Flexcut® 200
AMPERAGE	200 amps
GAS TYPE	Oxygen/Air
STRAIGHT CUT SPEED	60 ipm
BEVEL CUT SPEED	45-50 ipm
CUTTING HEIGHT	0.25 in
PIPE DIAMETER	8 in

00:00:14:19

86

Size on size, 45 degree lateral



Size on Size 45 Degree Lateral

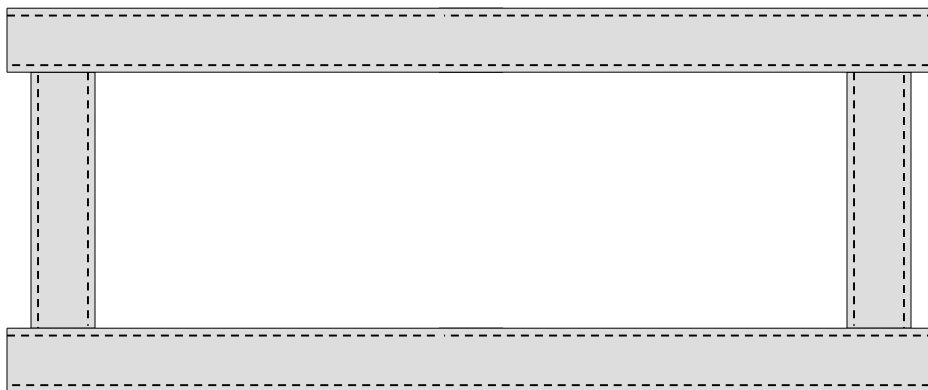
SIZE ON SIZE 45 DEGREE LATERAL	
MACHINE	Vernon Tool MPM
PLASMA CUTTER	Flexcut® 200
AMPERAGE	200 amps
GAS TYPE	Oxygen/Air
STRAIGHT CUT SPEED	60 ipm
BEVEL CUT SPEED	45-50 ipm
CUTTING HEIGHT	0.25 in
MAX TORCH BEVEL	±45°
PIPE DIAMETER	8 in

00:00:35:09



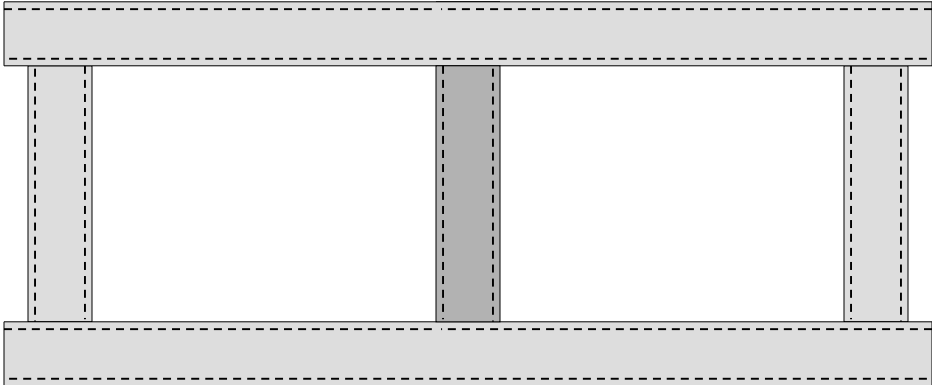
SPECIAL WELDING APPLICATIONS

Box HSS





SPECIAL WELDING APPLICATIONS

Box HSS



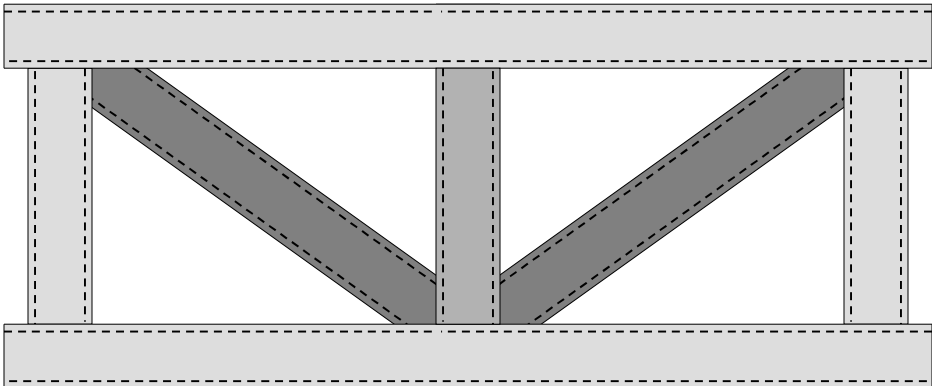
The diagram shows a cross-section of a Box HSS (Hollow Structural Section) with three vertical stiffeners. The stiffeners are represented by vertical gray bars. Dashed lines indicate the original boundaries of the box section. The stiffeners are positioned at the top and bottom flanges, and a central vertical stiffener is also shown.





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SPECIAL WELDING APPLICATIONS

Box HSS



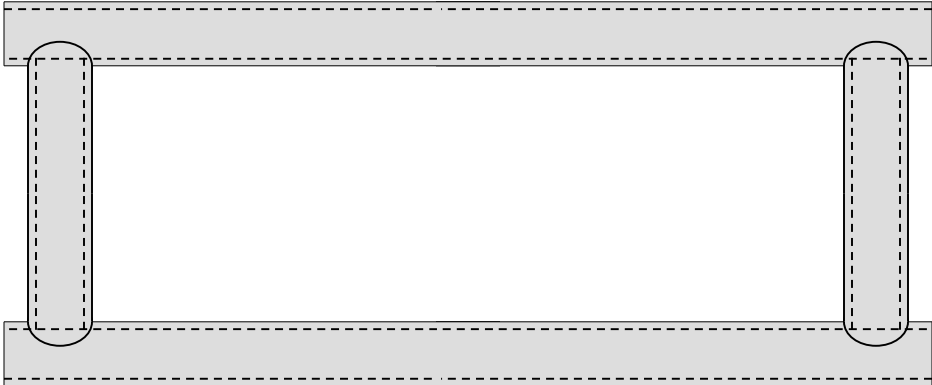
The diagram shows a cross-section of a Box HSS with a diagonal stiffener. The stiffener is a gray bar oriented diagonally, connecting the top and bottom flanges. Dashed lines indicate the original boundaries of the box section. The stiffener is positioned between the top and bottom flanges, and a central vertical stiffener is also shown.





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SPECIAL WELDING APPLICATIONS

Round HSS



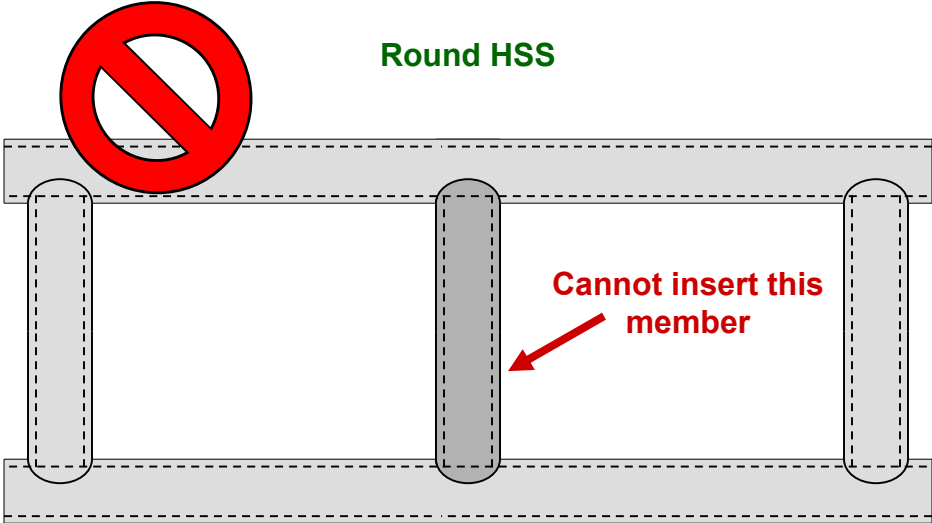
The diagram shows a rectangular frame composed of four Round HSS members. Two horizontal members are at the top and bottom, and two vertical members are on the left and right. The vertical members are inserted into the top and bottom horizontal members, with their ends flush with the inner faces of the horizontal members. Dashed lines indicate the original positions of the horizontal members before the vertical members were inserted.





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SPECIAL WELDING APPLICATIONS

Round HSS



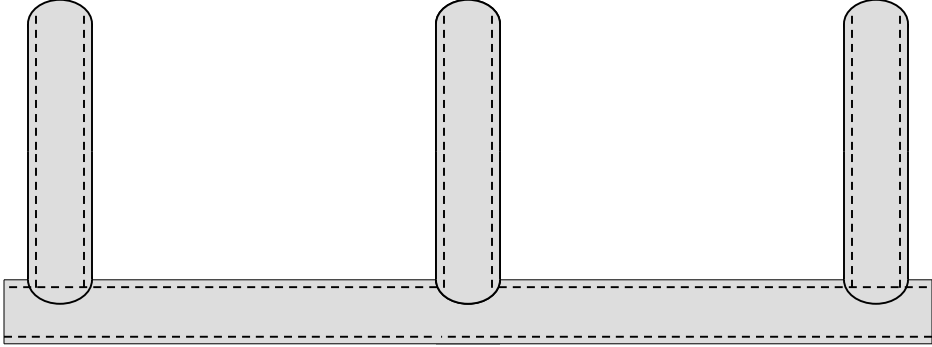
The diagram shows a rectangular frame composed of four Round HSS members. Two horizontal members are at the top and bottom, and three vertical members are on the left, center, and right. A red prohibition sign (a circle with a diagonal slash) is placed over the top horizontal member. A red arrow points to the middle vertical member with the text "Cannot insert this member". Dashed lines indicate the original positions of the horizontal members before the vertical members were inserted.





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SPECIAL WELDING APPLICATIONS

Round HSS



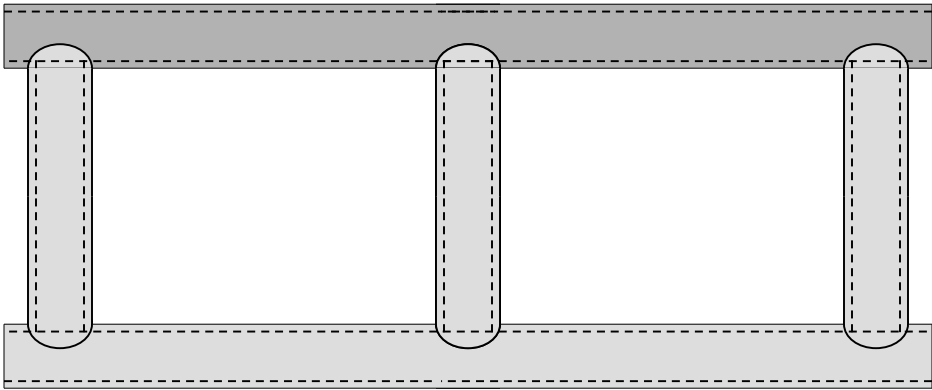
The diagram shows three vertical Round HSS tubes, each with a rounded top, welded to a horizontal base plate. The tubes are positioned at the left, center, and right of the base plate. Dashed lines indicate the weld lines connecting the tubes to the base plate.





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SPECIAL WELDING APPLICATIONS

Round HSS



The diagram shows a horizontal Round HSS tube welded to a vertical base plate. The tube is positioned at the top of the base plate. Dashed lines indicate the weld lines connecting the tube to the base plate.




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SPECIAL WELDING APPLICATIONS

Round HSS

Welded Connections—
A Primer for
Engineers




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SPECIAL WELDING APPLICATIONS

Round HSS

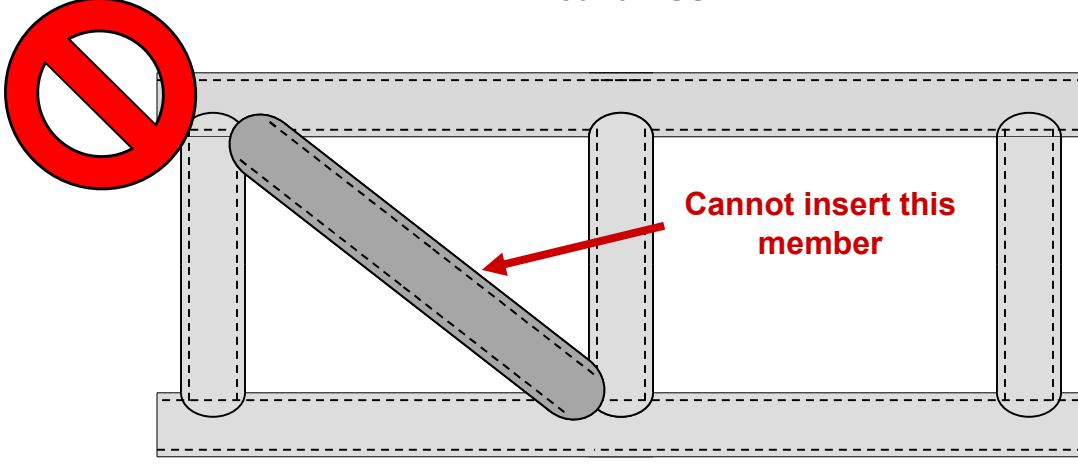
Welded Connections—
A Primer for
Engineers





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SPECIAL WELDING APPLICATIONS

Round HSS








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AWS D1.1:2020 STRUCTURAL WELDING CODE

9. Tubular Structures



9.1 General

This Clause supplements Clauses 1–8. The specific requirements of Clause 9 apply only to tubular connections. For design purposes this clause shall be used with the applicable requirements of Clause 2, Part A. All provisions of Clause 9 apply to static applications and cyclic applications, with the exception of the fatigue provisions of 9.2.7, which are unique to cyclic applications.

This clause is divided into parts, as follows:

- Part A— **Design of Tubular Connections**
- Part B— **Pregualification of Welding Procedure Specifications (WPSs)**
- Part C— **Welding Procedure Specification (WPS) Qualification**
- Part D— **Performance Qualification**
- Part E— **Fabrication**

9.2.3 Tubular Section Limitations. Limitations on diameter/thickness for circular sections, and largest flat width/thickness ratio for box sections, beyond which local buckling or other local failure modes shall be considered, shall be in conformance with the governing design code. Limits of applicability for the criteria given in 9.6 shall be observed as follows:

- (1) Circular tubes: $D/t < 3300/F_y$ [for F_y in ksi], $22\ 800/F_y$ (for F_y in MPa)
- (2) Box section gap connections: $D/t \leq 210/\sqrt{F_y}$ [for F_y in ksi], $550/\sqrt{F_y}$ (for F_y in MPa) but not more than 35
- (3) Box section overlap connections: $D/t \leq 190/\sqrt{F_y}$ [for F_y in ksi], $500/\sqrt{F_y}$ (for F_y in MPa)

9.2.4 Welds Stresses. The allowable stresses in welds shall not exceed those given in Table 9.2, or as allowed

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SPECIAL WELDING APPLICATIONS



Welding HSS: Summary

- Welds are usually unevenly stressed
- Connection details may control member sizes
- Round vs square/rectangular: box tubes usually easier
- Cutting and assembly
- Access for welding and inspection
- May also have AECS concerns



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SPECIAL WELDING APPLICATIONS



Today's Webinar

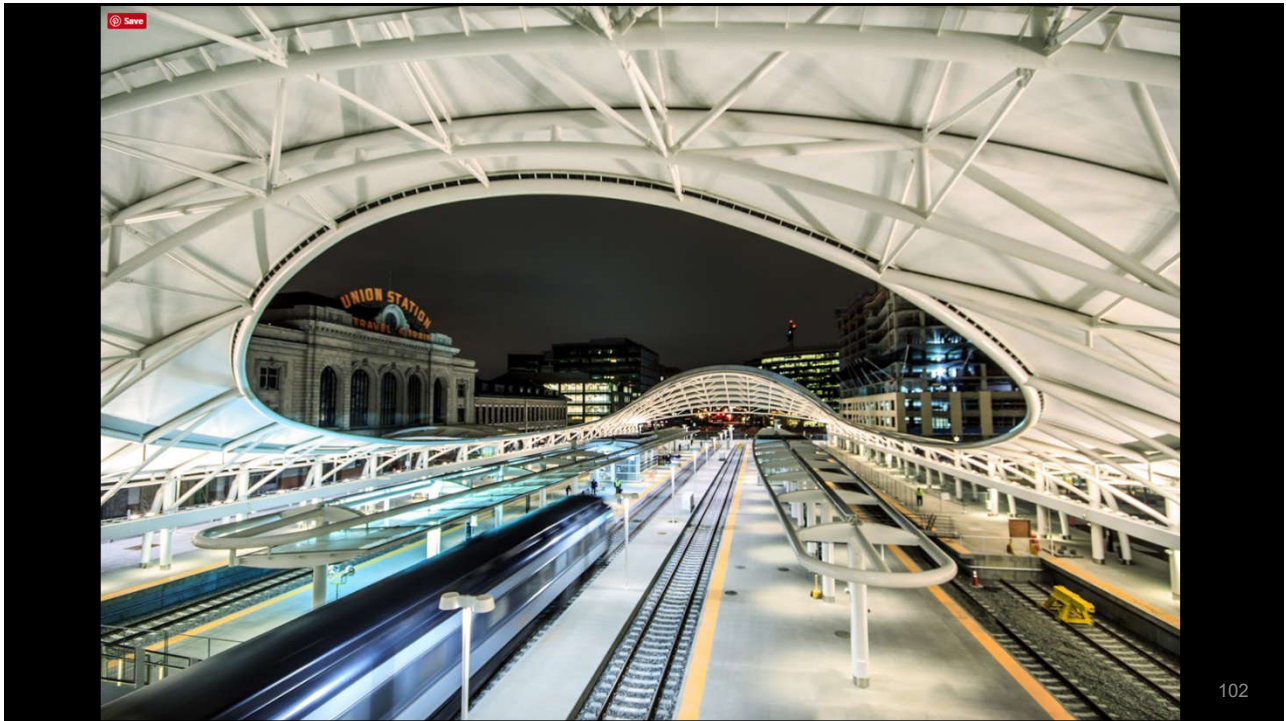
- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- ➔ 14.7 Welding AECS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



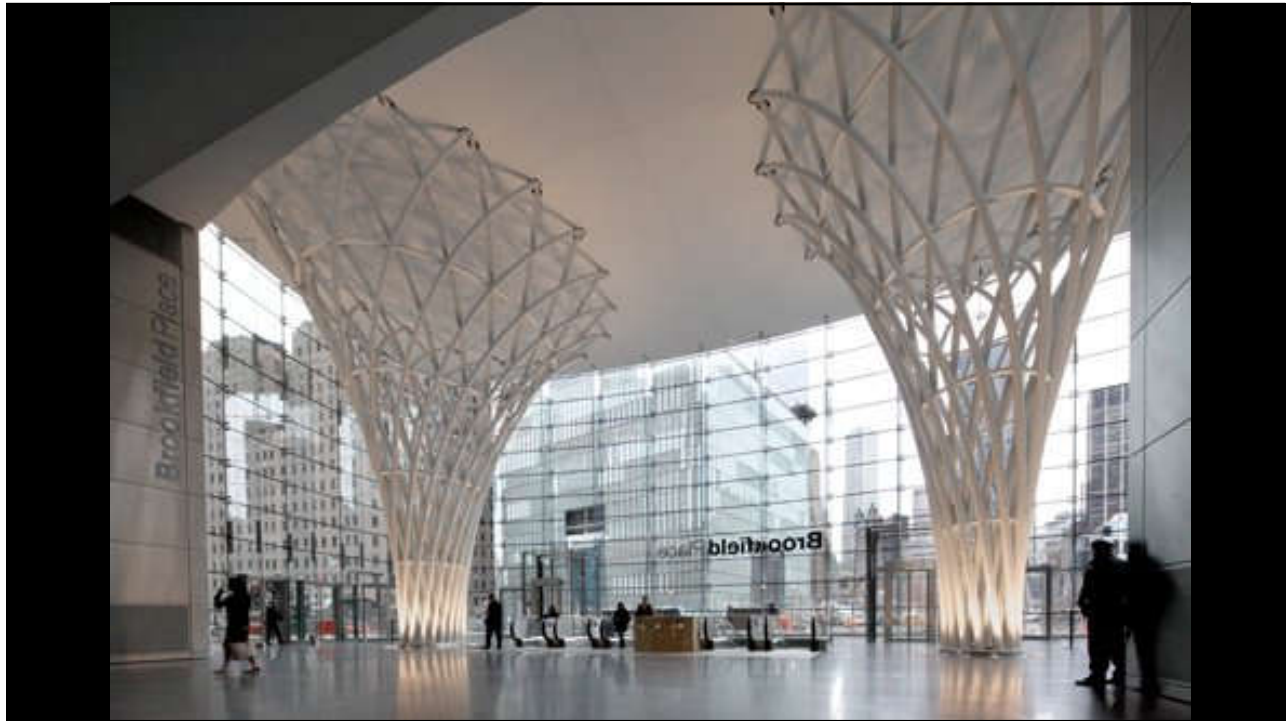
100




101



102




SPECIAL WELDING APPLICATIONS




Welding AESS

• Defining “pretty”

- Use of Mock-ups
- Technical issues
- Note requirements on drawings


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AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges



AISC 303-16


Code of Standard Practice for Steel Buildings and Bridges

Section 10.
Architecturally Exposed Structural Steel

**TABLE 10.1
AESS Category Matrix**

Id	Category Characteristics	AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS Standard Structural Steel
		Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	
1.1	Surface preparation to SSPC-SP 6		*	*	*	*	
1.2	Sharp edges ground smooth		*	*	*	*	
1.3	Continuous weld appearance		*	*	*	*	
1.4	Standard structural bolts		*	*	*	*	
1.5	Weld spatters removed		*	*	*	*	
2.1	Visual samples		*	*	optional		
2.2	One-half standard fabrication tolerances		*	*	*	*	
2.3	Fabrication marks not apparent		*	*	*	*	
2.4	Welds uniform and smooth		*	*	*	*	
3.1	Mill marks removed		*	*			
3.2	Butt and plug welds ground smooth and filled		*	*			
3.3	HSS weld seam oriented for reduced visibility		*	*			
3.4	Cross sectional abutting surface aligned		*	*			
3.5	Joint gap tolerances minimized		*	*			
3.6	All welded connections		optional	optional			
4.1	HSS seam not apparent		*				
4.2	Welds contoured and blended		*				
4.3	Surfaces filed and sanded		*				
4.4	Weld show-through minimized		*				
C.1							
C.2							
C.3							
C.4							
C.5							

User Note:
 1.1 Prior to blast cleaning, grease and oil are removed by solvent cleaning to meet SSPC-SP1.
 1.2 Rough surfaces are deburred and ground smooth. Sharp edges resulting from flame cutting, grinding and especially shearing are softened.
 1.3 Intermittent welds are made continuous either with additional welding or body filler. For corrosion control.


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AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges							
TABLE 10.1 AESS Category Matrix							
Category		AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Id	Characteristics	Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
1.1	Surface preparation to SSPC-SP 6		*	*	*	*	
1.2	Sharp edges ground smooth		*	*	*	*	
1.3	Continuous weld appearance		*	*	*	*	
1.4	Standard structural bolts		*	*	*	*	
1.5	Weld spatters removed		*	*	*	*	
2.1	Visual samples		*	*	optional		
2.2	One-half standard fabrication tolerances		*	*	*		
2.3	Fabrication marks not apparent		*	*	*		
2.4	Welds uniform and smooth		*	*	*		
3.1	Mill marks removed		*	*			
3.2	Butt and plug welds ground smooth and filled		*	*			
3.3	HSS weld seam oriented for reduced visibility		*	*			
3.4	Cross sectional abutting surface aligned		*	*			
3.5	Joint gap tolerances minimized		*	*			
3.6	All welded connections		optional	optional			
4.1	HSS seam not apparent		*				
4.2	Welds contoured and blended		*				
4.3	Surfaces filed and sanded		*				
4.4	Weld show-through minimized		*				
C.1							
C.2							
C.3							
C.4							
C.5							

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges							
TABLE 10.1 AESS Category Matrix							
Category		AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Id	Characteristics	Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
1.1	Surface preparation to SSPC-SP 6		*	*	*	*	
1.2	Sharp edges ground smooth		*	*	*	*	
1.3	Continuous weld appearance		*	*	*	*	
1.4	Standard structural bolts		*	*	*	*	
1.5	Weld spatters removed		*	*	*	*	
2.1	Visual samples		*	*	optional		
2.2	One-half standard fabrication tolerances		*	*	*		
2.3	Fabrication marks not apparent		*	*	*		
2.4	Welds uniform and smooth		*	*	*		

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**TABLE 10.1
 AESS Category Matrix**

Category		AESS C	AESS 4	AESS 3	AESS 2	AESS 1	SSS
Id	Characteristics	Custom Elements	Showcase Elements	Feature Elements in close view	Feature Elements not in close view	Basic Elements	Standard Structural Steel
1.1	Surface preparation to SSPC-SP 6		•	•	•	•	
1.2	Sharp edges ground smooth		•	•	•	•	
1.3	Continuous weld appearance		•	•	•	•	
1.4	Standard structural bolts		•	•	•	•	
1.5	Weld spatters removed		•	•	•	•	
2.1	Visual samples		•	•	optional		
2.2	One-half standard fabrication tolerances		•	•	•		
2.3	Fabrication marks not apparent		•	•	•		
2.4	Welds uniform and smooth		•	•	•		
3.1	Mill marks removed		•	•			
3.2	Butt and plug welds ground smooth and filled		•	•			
3.3	HSS weld seam oriented for reduced visibility		•	•			
3.4	Cross sectional abutting surface aligned		•	•			
3.5	Joint gap tolerances minimized		•	•			
3.6	All welded connections		optional	optional			
4.1	HSS seam not apparent		•				
4.2	Welds contoured and blended		•				
4.3	Surfaces filed and sanded		•				
4.4	Weld show-through minimized		•				

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AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges


	1.1	Surface preparation to SSPC-SP 6		•	•	•	•	
	1.2	Sharp edges ground smooth		•	•	•	•	
→	1.3	Continuous weld appearance		•	•	•	•	
→	1.4	Standard structural bolts		•	•	•	•	
→	1.5	Weld spatters removed		•	•	•	•	
→	2.1	Visual samples		•	•	optional		
→	2.2	One-half standard fabrication tolerances		•	•	•		
	2.3	Fabrication marks not apparent		•	•	•		
→	2.4	Welds uniform and smooth		•	•	•		
→	3.1	Mill marks removed		•	•			
→	3.2	Butt and plug welds ground smooth and filled		•	•			
	3.3	HSS weld seam oriented for reduced visibility		•	•			
→	3.4	Cross sectional abutting surface aligned		•	•			
→	3.5	Joint gap tolerances minimized		•	•			
→	3.6	All welded connections		optional	optional			
→	4.1	HSS seam not apparent		•				
→	4.2	Welds contoured and blended		•				
→	4.3	Surfaces filed and sanded		•				
→	4.4	Weld show-through minimized		•				

Many welding-related issues


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SPECIAL WELDING APPLICATIONS





Welding AESS

- Defining “pretty”
-  • Use of Mock-ups
- Technical issues
- Note requirements on drawings



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AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges



1.1	Surface preparation to SSPC-SP 6		•	•	•	•
1.2	Sharp edges ground smooth		•	•	•	•
1.3	Continuous weld appearance		•	•	•	•
1.4	Standard structural bolts		•	•	•	•
1.5	Weld spatters removed		•	•	•	•
	2.1	Visual samples		•	•	optional
	2.2	One-half standard fabrication tolerances		•	•	•
	2.3	Fabrication marks not apparent		•	•	•
	2.4	Welds uniform and smooth		•	•	•
	3.1	Mill marks removed		•	•	
	3.2	Butt and plug welds ground smooth and filled		•	•	
	3.3	HSS weld seam oriented for reduced visibility		•	•	
	3.4	Cross sectional abutting surface aligned		•	•	
	3.5	Joint gap tolerances minimized		•	•	
	3.6	All welded connections		optional	optional	
	4.1	HSS seam not apparent		•		
	4.2	Welds contoured and blended		•		
	4.3	Surfaces filed and sanded		•		
	4.4	Weld show-through minimized		•		

Mock-ups


114

AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

SECTION 10. ARCHITECTURALLY EXPOSED STRUCTURAL STEEL

10.1.2. A mock-up shall be required for AESS 3, 4 and C. If a mock-up is to be used in other AESS categories, it shall be specified in the *contract documents*. When required, the nature and extent of the mock-up shall be specified in the *contract documents*. Alternatively, when a mock-up is not practical, the first piece of an element or *connection* can be used to determine acceptability.



AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges

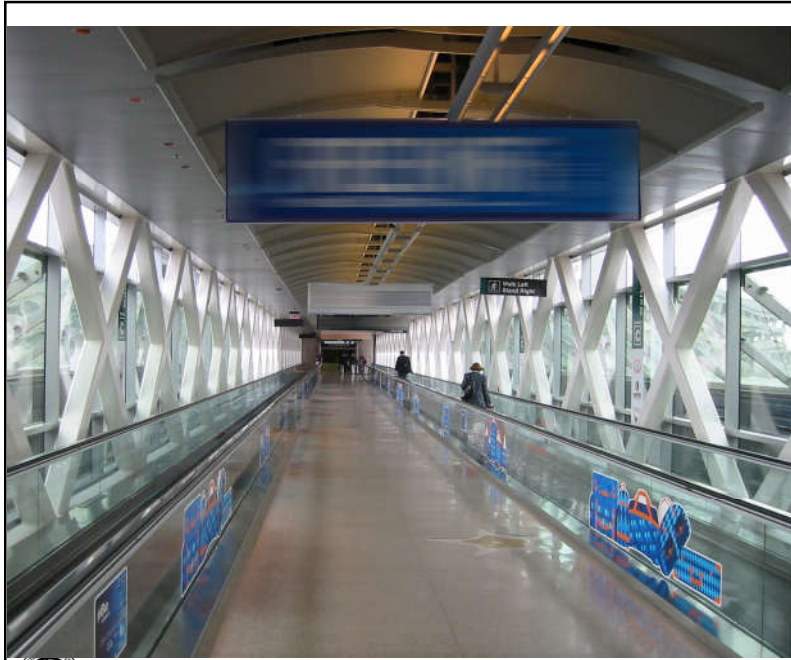
SECTION 10. ARCHITECTURALLY EXPOSED STRUCTURAL STEEL

Commentary:

Generally, a mock-up is produced and approved in the shop and subsequently placed in the field. The acceptability of the mock-up can be affected by many factors, including distance of view, lighting and finishing. The expectations for the location and conditions of the mock-up at time of approval should be defined in the *contract documents*.

Suggestion: View mock-up at the same distance as the viewer will be from the final welded connection in service.





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SPECIAL WELDING APPLICATIONS

Welding AESS

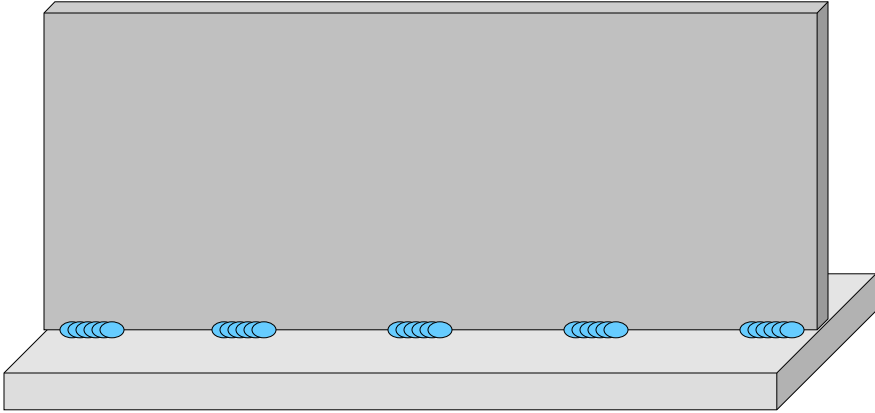
- Defining “pretty”
- Use of Mock-ups
- ➔ • Technical issues
- Note requirements on drawings





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SPECIAL WELDING APPLICATIONS

Sufficient for strength



The diagram shows a vertical steel plate connected to a horizontal base plate. Five discrete, parallel welds are shown along the bottom edge of the vertical plate, spaced evenly across its width. This configuration is described as being sufficient for strength.

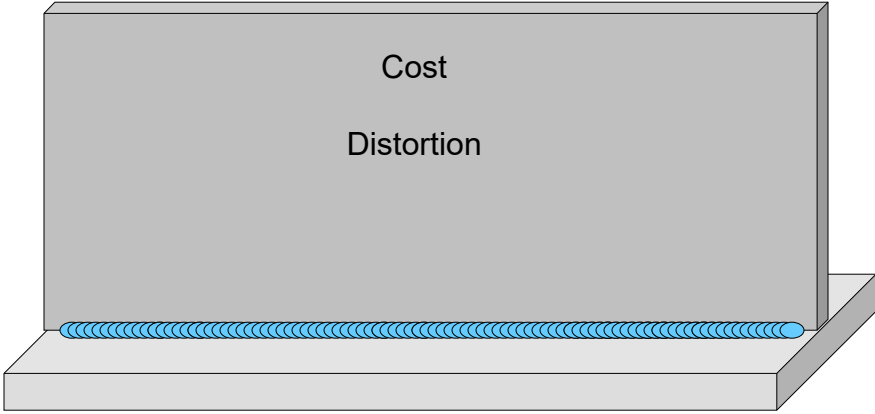


119



SPECIAL WELDING APPLICATIONS

May be required for AESS

Cost
Distortion



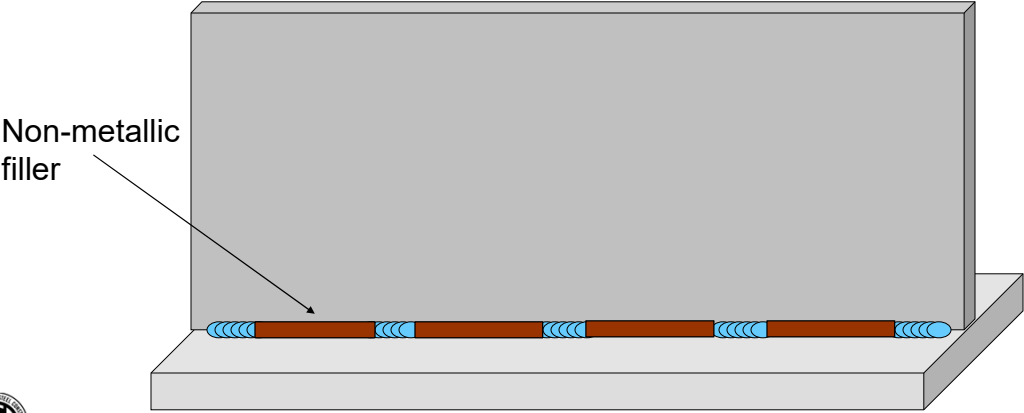
The diagram shows a vertical steel plate connected to a horizontal base plate. A single, continuous weld is shown along the entire bottom edge of the vertical plate. This configuration is noted as potentially required for AESS (Alternate End Restraint System) due to concerns about cost and distortion.





120

SPECIAL WELDING APPLICATIONS

Sufficient for strength



Non-metallic filler





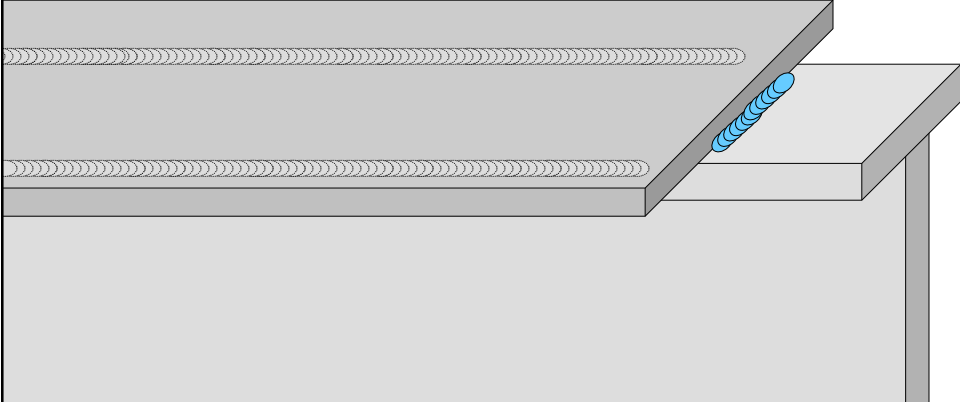
121

The diagram shows a 3D perspective of a steel beam-to-column connection. The beam is positioned horizontally, and the column is vertical. A weld is applied along the length of the beam's top flange. The weld is depicted with a series of blue, semi-circular ripples. A label 'Non-metallic filler' with an arrow points to the weld. The beam and column are shown in a light gray color.

SPECIAL WELDING APPLICATIONS

D1.1 code required practice*

*modified in 2015 edition



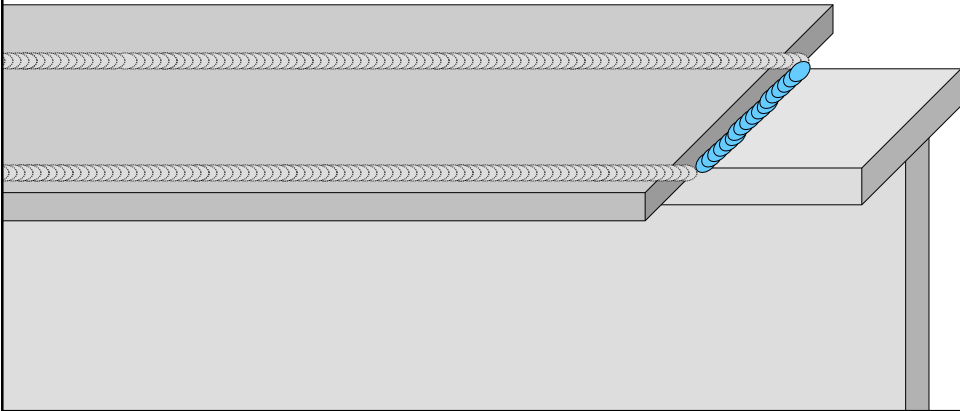
122

The diagram shows a 3D perspective of a steel beam-to-column connection. The beam is positioned horizontally, and the column is vertical. A weld is applied along the length of the beam's top flange. The weld is depicted with a series of blue, semi-circular ripples. The beam and column are shown in a light gray color.

SPECIAL WELDING APPLICATIONS

May be AESS specified practice

Workmanship Concerns
Inspection Concerns

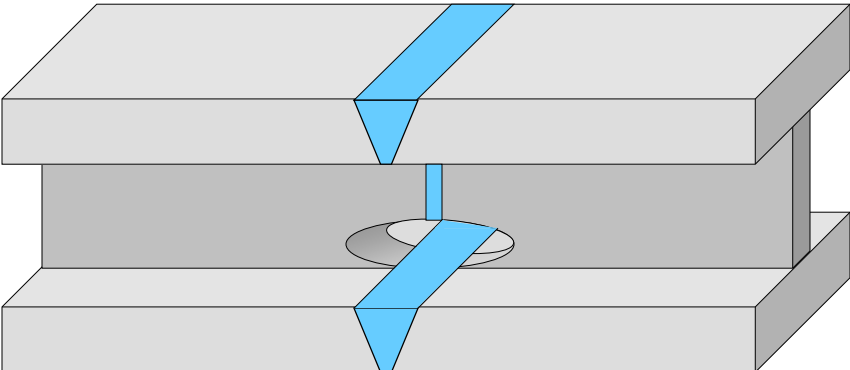


The diagram shows a lap joint between two steel plates. A fillet weld is applied to the end of the joint. The weld is depicted with a blue, scalloped pattern. The plates are shown in a 3D perspective view.


123

SPECIAL WELDING APPLICATIONS

Code required practice



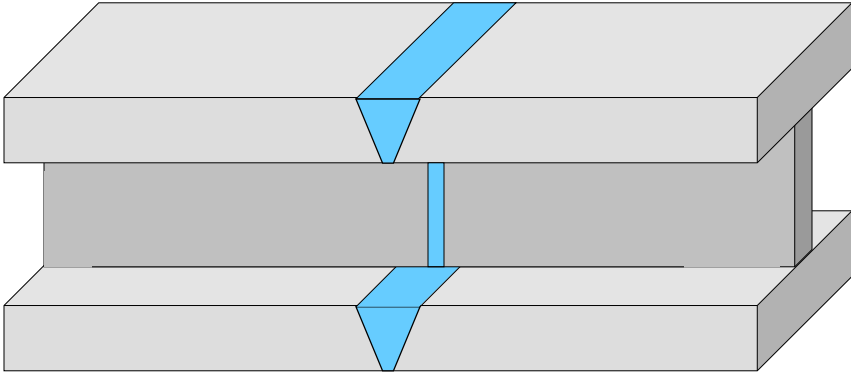
The diagram shows a butt joint between two steel plates. A groove weld is applied to the joint. The weld is depicted with a blue, V-shaped groove. The plates are shown in a 3D perspective view.





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SPECIAL WELDING APPLICATIONS

May be AESS specified practice



How can flange CJP groove weld be made?

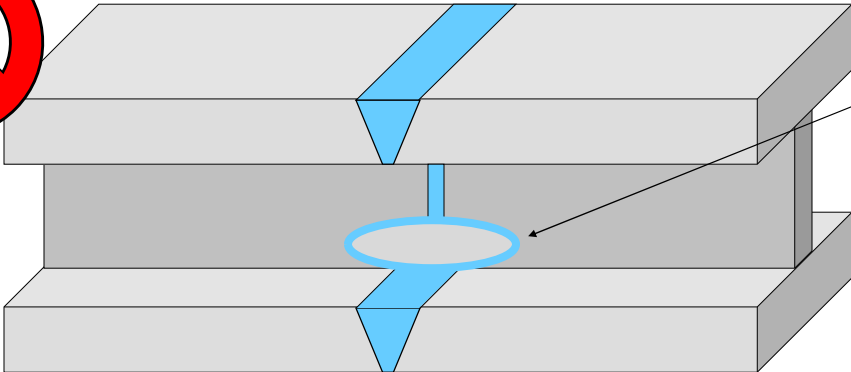


125



Detailed description: This slide features a green header with the text 'SPECIAL WELDING APPLICATIONS'. Below the header, the text 'May be AESS specified practice' is centered. The main content is a 3D perspective diagram of a flange connection. It shows two horizontal plates, one above and one below, with a vertical web plate between them. A groove weld is shown at the top flange of the upper plate, and another groove weld is shown at the bottom flange of the lower plate. A blue vertical line indicates the weld path through the web. Below the diagram, the text 'How can flange CJP groove weld be made?' is centered. In the bottom left corner is the AISC logo, and in the bottom right corner is the number '125'. A small book cover titled 'Welded Connections - A Primer for Engineers' is in the top right corner.

SPECIAL WELDING APPLICATIONS

May be AESS specified practice



Will splice crack when insert is welded?



126

Detailed description: This slide features a green header with the text 'SPECIAL WELDING APPLICATIONS'. Below the header, the text 'May be AESS specified practice' is centered. The main content is a 3D perspective diagram of a flange connection, similar to the one on slide 125. However, a blue oval representing a 'Welded insert' is shown in the web of the lower plate. A red prohibition sign (a circle with a diagonal slash) is placed to the left of the diagram. An arrow points from the text 'Welded insert' to the blue oval. Below the diagram, the text 'Will splice crack when insert is welded?' is centered. In the bottom left corner is the AISC logo, and in the bottom right corner is the number '126'. A small book cover titled 'Welded Connections - A Primer for Engineers' is in the top right corner.

SPECIAL WELDING APPLICATIONS

Distortion

Acceptable to D1.1

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Welded Connections—
A Primer for
Engineers

SPECIAL WELDING APPLICATIONS

Distortion

AESS limit



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Welded Connections—
A Primer for
Engineers

SPECIAL WELDING APPLICATIONS

Weld Throats

throat





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SPECIAL WELDING APPLICATIONS

Weld Throats

Project note:
1. Contour and blend all welds.

throat



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SPECIAL WELDING APPLICATIONS

Welding AESS

- Defining “pretty”
- Use of Mock-ups
- Technical issues
- ➔ • Note requirements on drawings



SPECIAL WELDING APPLICATIONS



Welding AESS: Summary

- Defining “pretty”; use AISC 303 Section 10
- Mock-ups are often critical; view from an appropriate distance
- Define all expectations; some requirement may conflict with code requirements



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SPECIAL WELDING APPLICATIONS



Today's Webinar

- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- ➔ 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



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SPECIAL WELDING APPLICATIONS

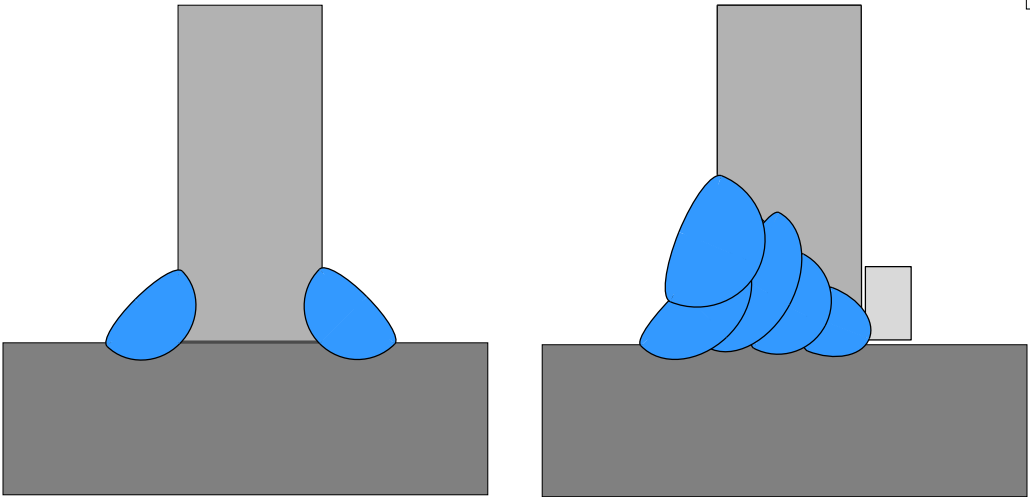
Shop versus Field Welding

- Primarily an issue of cost
- Some environmental issues (cold, wind, rain, etc.)
- Out-of-position welding may be needed




SPECIAL WELDING APPLICATIONS

Usually Preferred

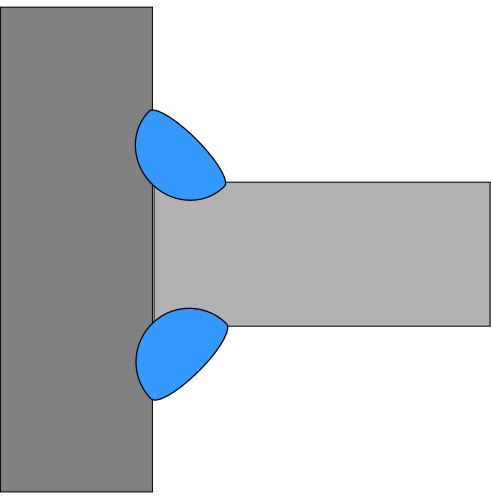


137

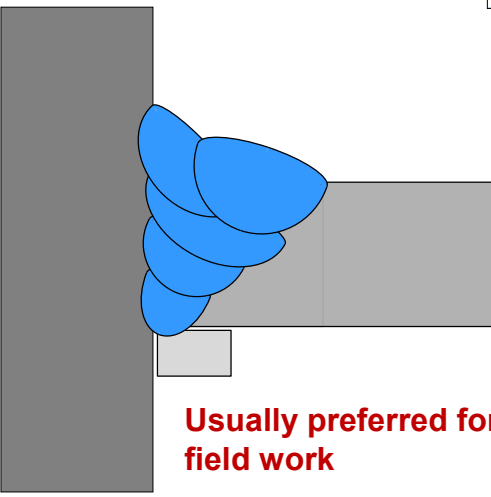


SPECIAL WELDING APPLICATIONS

Requires overhead welding




All flat welding



Usually preferred for field work

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SPECIAL WELDING APPLICATIONS



Shop versus Field Welding

- Primarily an issue of cost
- Some environmental issues (cold, wind, rain, etc.)
- Out-of-position welding may be needed
- Easier to control projects in a shop environment



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SPECIAL WELDING APPLICATIONS



Myths

- You can't get quality welds out-of-position



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AWS D1.1:2015 STRUCTURAL WELDING CODE			
Table 4.12 Welding Personnel Performance Essential Variable Changes Requiring Requalification (see 4.19)			
Essential Variable Changes to WPQR Requiring Requalification	Welding Personnel		
	Welders ^b	Welding Operators ^{b, c}	Tack Welders
(1) To a process not qualified (GMAW-S is considered a separate process)	X	X	X
(2) To an SMAW electrode with an F-number (see Table 4.13) higher than the WPQR electrode F-number	X		X
➔ (3) To a position not qualified	X	X	X
(4) To a diameter or thickness not qualified	X	X	
(5) To a vertical welding progression not qualified (uphill or downhill)	X		
(6) The omission of backing (if used in the WPQR test)	X	X	
(7) To multiple electrodes (if a single electrode was used in the WPQR test) but not vice versa		X ^a	



SPECIAL WELDING APPLICATIONS	
<p>Myths</p> <ul style="list-style-type: none"> • You can't get quality welds out-of-position • You can't get quality in the field 	





SPECIAL WELDING APPLICATIONS

Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding



AWS D1.1:2020 Structural Welding Code--Steel



7. Fabrication

7.1 Scope

This clause contains requirements for the fabrication and erection of welded assemblies and structures produced by any process applicable under this code (see 5.5 and 6.15) related to:

- (1) Materials
- (2) Processes and WPSs
- (3) Weld Details
- (4) Weld Quality and Repairs
- (5) Member Dimensional Tolerances



SPECIAL WELDING APPLICATIONS



Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)



AWS D1.1:2020 Structural Welding Code--Steel



6. Qualification

6.2.2.2 Qualification Responsibility

Each manufacturer or Contractor shall be responsible for the qualification of welders, welding operators and tack welders, whether the qualification is conducted by the manufacturer, Contractor, or an independent testing agency.



SPECIAL WELDING APPLICATIONS



Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)
- WPSs are not used in the field



AISC 360-16 Specification for Structural Steel Buildings

CHAPTER N

QUALITY CONTROL AND QUALITY ASSURANCE

TABLE N5.4-1
Inspection Tasks Prior to Welding

Inspection Tasks Prior to Welding	QC	QA
Welder qualification records and continuity records	P	O
WPS available	P	P
Manufacturer certifications for welding consumables available	P	P
Material identification (type/grade)	O	O
Welder identification system ^[a]	O	O
Fit-up of groove welds (including joint geometry) <ul style="list-style-type: none"> • Joint preparations • Dimensions (alignment, root opening, root face, bevel) • Cleanliness (condition of steel surfaces) • Tacking (tack weld quality and location) • Backing type and fit (if applicable) 	O	O
Fit-up of CJP groove welds of HSS T, Y- and K-joints without backing (including joint geometry) <ul style="list-style-type: none"> • Joint preparations • Dimensions (alignment, root opening, root face, bevel) • Cleanliness (condition of steel surfaces) • Tacking (tack weld quality and location) 	P	O
Configuration and finish of access holes	O	O
Fit-up of fillet welds <ul style="list-style-type: none"> • Dimensions (alignment, gaps at root) • Cleanliness (condition of steel surfaces) • Tacking (tack weld quality and location) 	O	O
Check welding equipment	O	-

^[a] The fabricator or erector, as applicable, shall maintain a system by which a welder who has welded a joint or member can be identified. Stamps, if used, shall be the low-stress type.

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AISC 360-16 Specification for Structural Steel Buildings

TABLE N5.4-1
Inspection Tasks Prior to Welding

Inspection Tasks Prior to Welding	QC	QA
Welder qualification records and continuity records	P	O
WPS available	P	P
Manufacturer certifications for welding consumables available	P	P
Material identification (type/grade)	O	O
Welder identification system ^[a]	O	O
Fit-up of groove welds (including joint geometry) <ul style="list-style-type: none"> • Joint preparations • Dimensions (alignment, root opening, root face, bevel) • Cleanliness (condition of steel surfaces) • Tacking (tack weld quality and location) • Backing type and fit (if applicable) 	O	O

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SPECIAL WELDING APPLICATIONS



Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)
- WPSs are not used in the field
- There is no audit program for field contractors



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AMERICAN INSTITUTE OF STEEL CONSTRUCTION CERTIFICATION PROGRAMS

PROUDLY RECOGNIZE THAT

ABC Company

MAINTAINS OPERATIONS LOCATED AT

123 Main St., Chicago, IL 60600

THAT SUCCESSFULLY MEET THE QUALITY CERTIFICATION REQUIREMENTS FOR

Erector (Advanced)
Bridge Endorsement
Seismic Endorsement
Metal Deck Endorsement

PRESIDENT

CERTIFICATION NUMBER

C-00011111

ISSUED

September 7, 2021

VALID THROUGH

September 30, 2021



SPECIAL WELDING APPLICATIONS



Myths

- You can't get quality welds out-of-position
- You can't get quality in the field
- Codes do not apply to field welding
- Field welders are not "certified" (qualified)
- WPSs are not used in the field
- There is no audit program for field contractors
- There are no contractor-supplied inspectors for field work



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AISC 360-16 Specification for Structural Steel Buildings



CHAPTER N

QUALITY CONTROL AND QUALITY ASSURANCE

N2. FABRICATOR AND ERECTOR QUALITY CONTROL PROGRAM

The **fabricator and erector** shall establish, maintain and implement QC procedures to ensure that their work is performed in accordance with this Specification and the construction documents.



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SPECIAL WELDING APPLICATIONS



Shop vs Field Welding: Summary

- There are some legitimate differences/concerns
- Shop operations generally preferred due to lower costs
- Mature codes control field welding
- Field contractor certification programs exist
- Inspection requirements have been made clearer in Chapter N



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SPECIAL WELDING APPLICATIONS



Today's Webinar

- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- ➔ 14.9 Welding on Existing Structures
- 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



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SPECIAL WELDING APPLICATIONS

14.9 Welding on Existing Structures

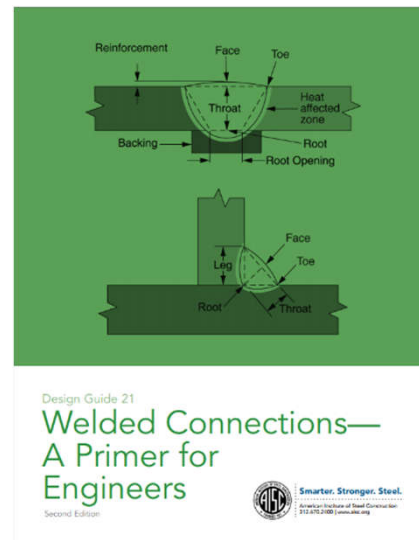
- ➔ • Historic steels
- Welding under load
- Fire
- Cold working / strain aging



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AISC Design Guide 21 Chapter 4 Metallurgical Issues

- Historic (obsolete) steels
 - ASTM A9
 - ASTM A7
 - ASTM A373
 - ASTM A242
- Check weldability of steel (especially if riveted)




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SPECIAL WELDING APPLICATIONS

14.9 Welding on Existing Structures

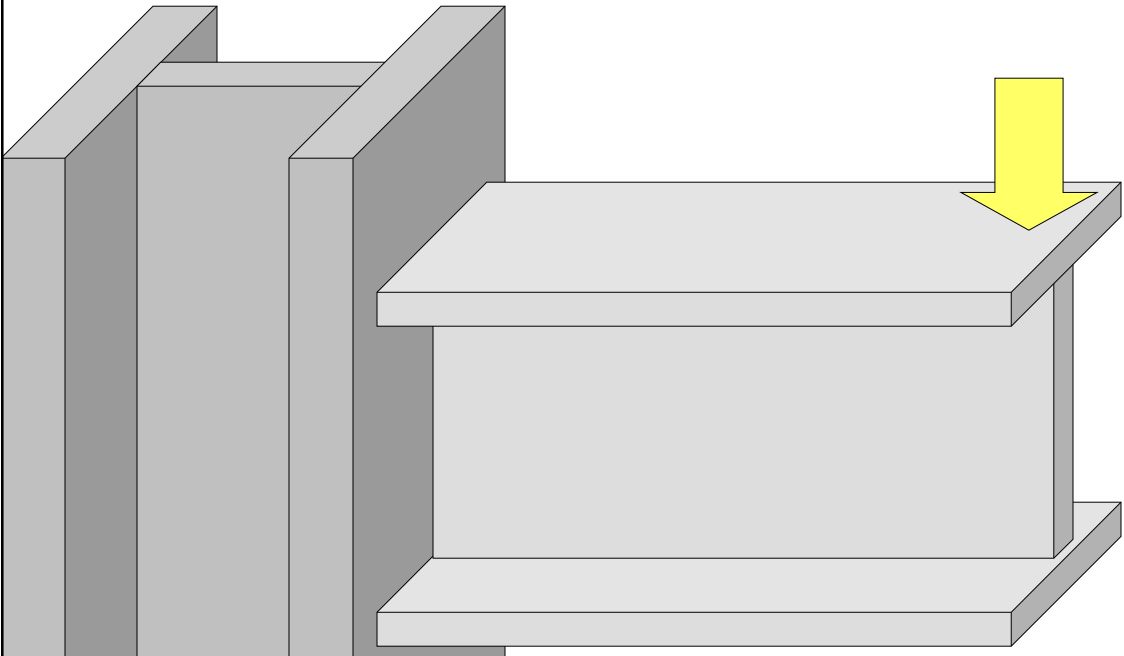
- Historic steels
- ➔ • Welding under load
- Fire
- Cold working / strain aging




Welded Connections—
A Primer for
Engineers

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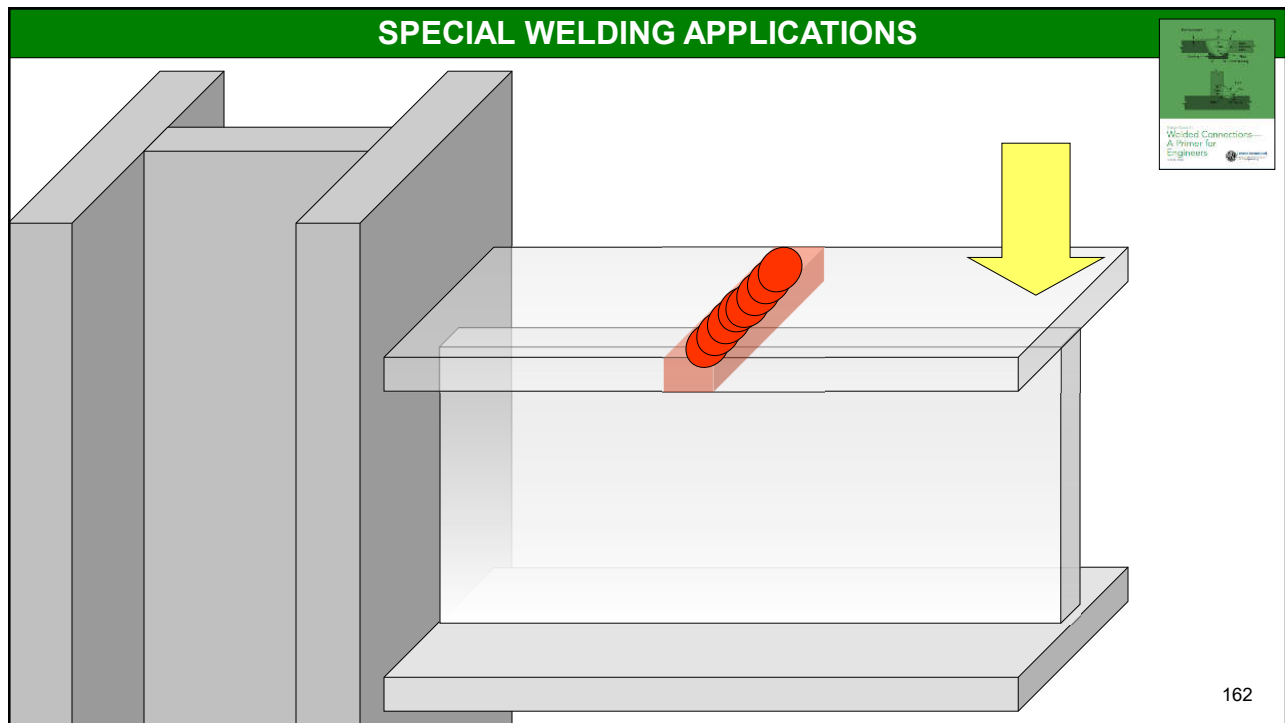
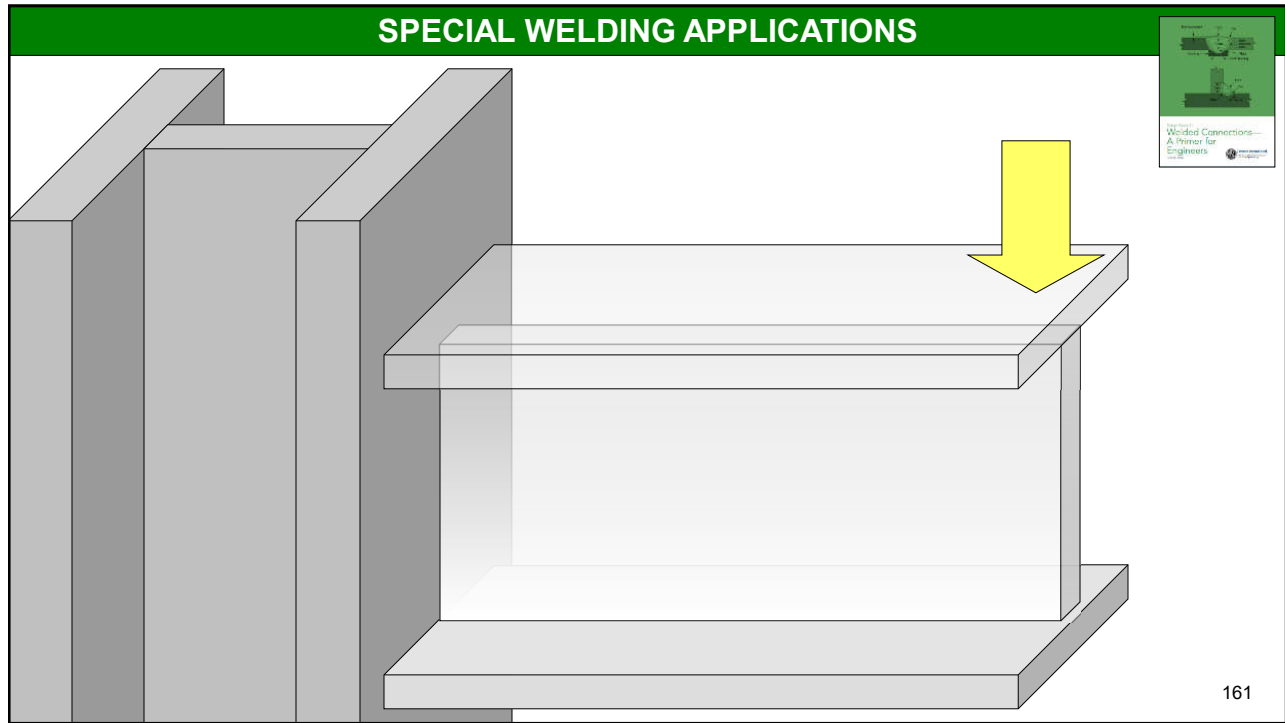
SPECIAL WELDING APPLICATIONS

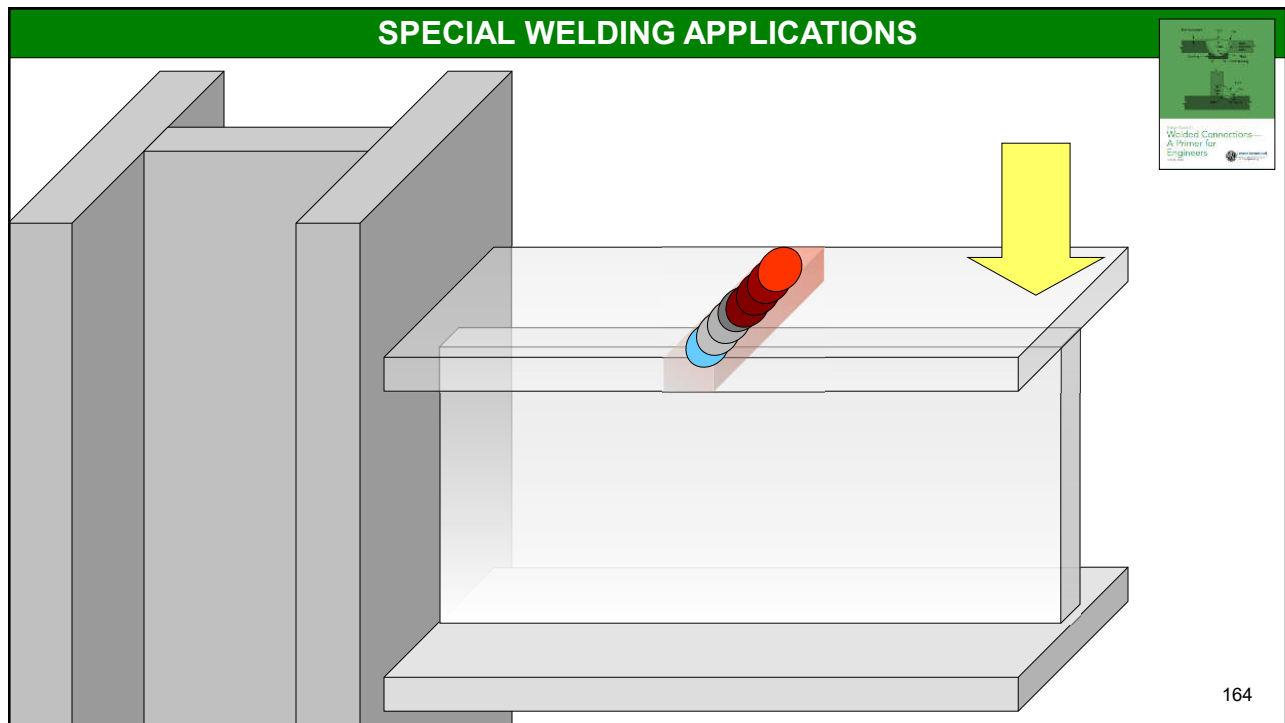
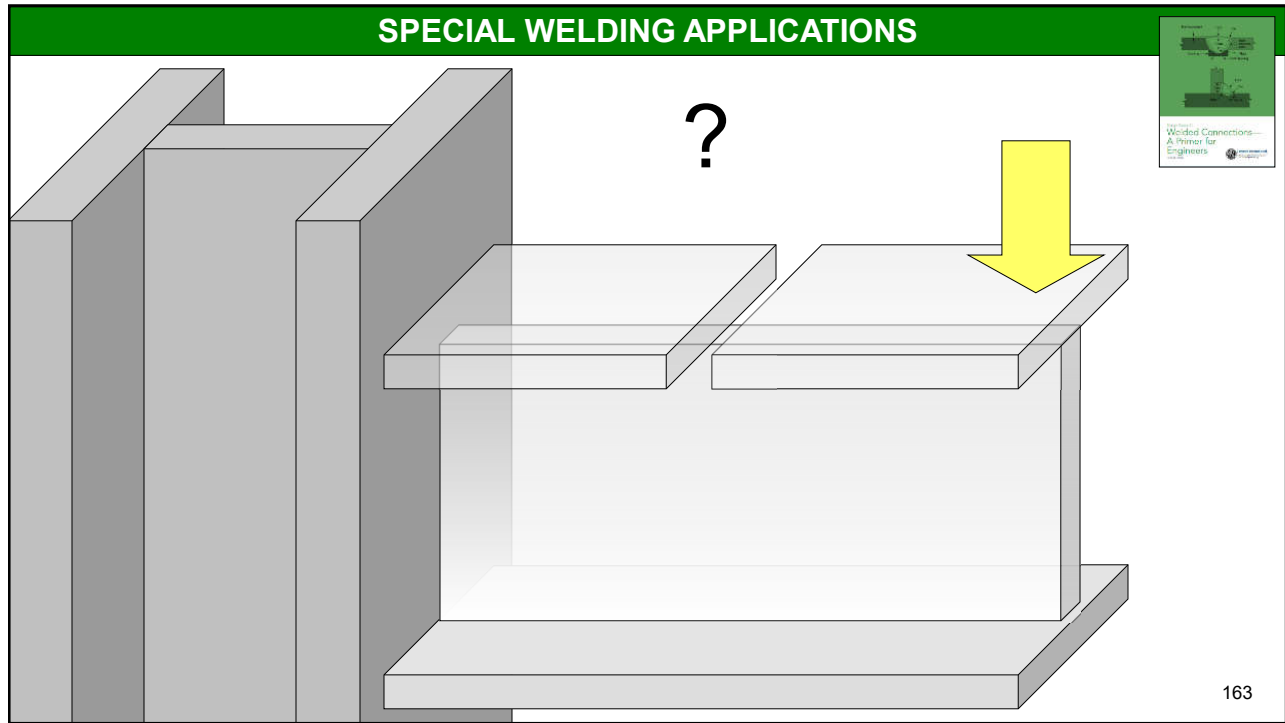


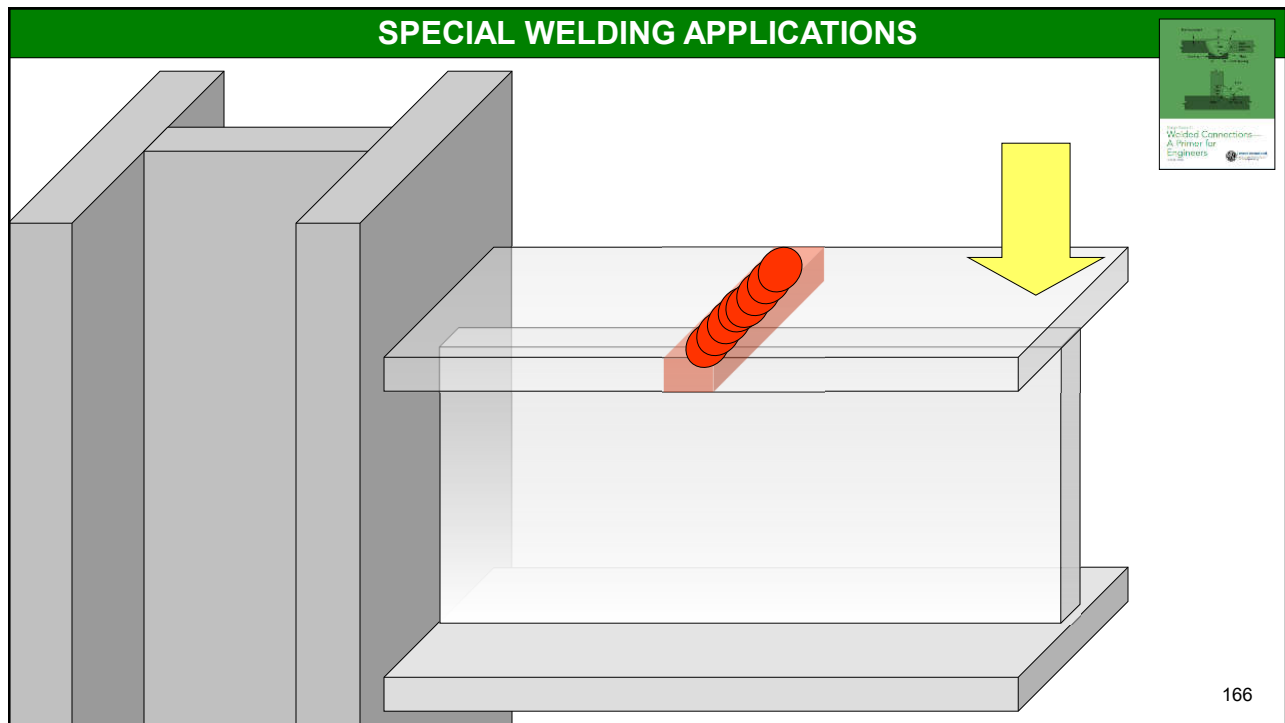
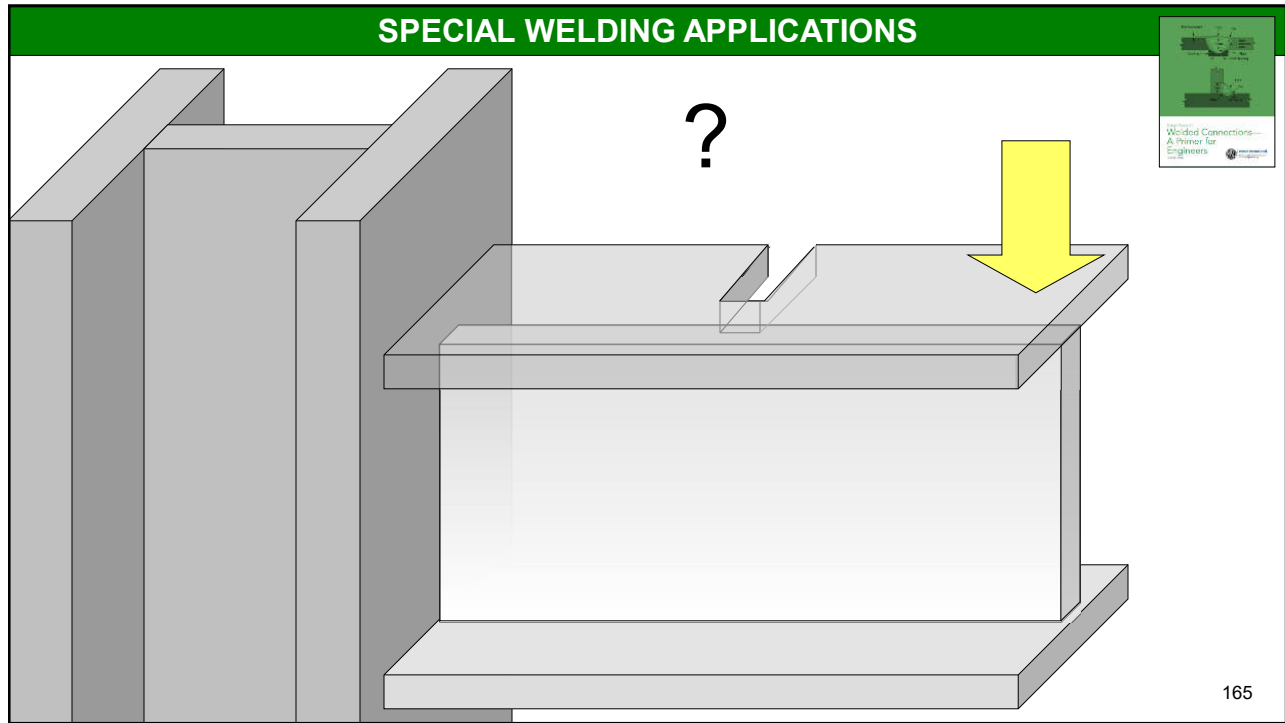


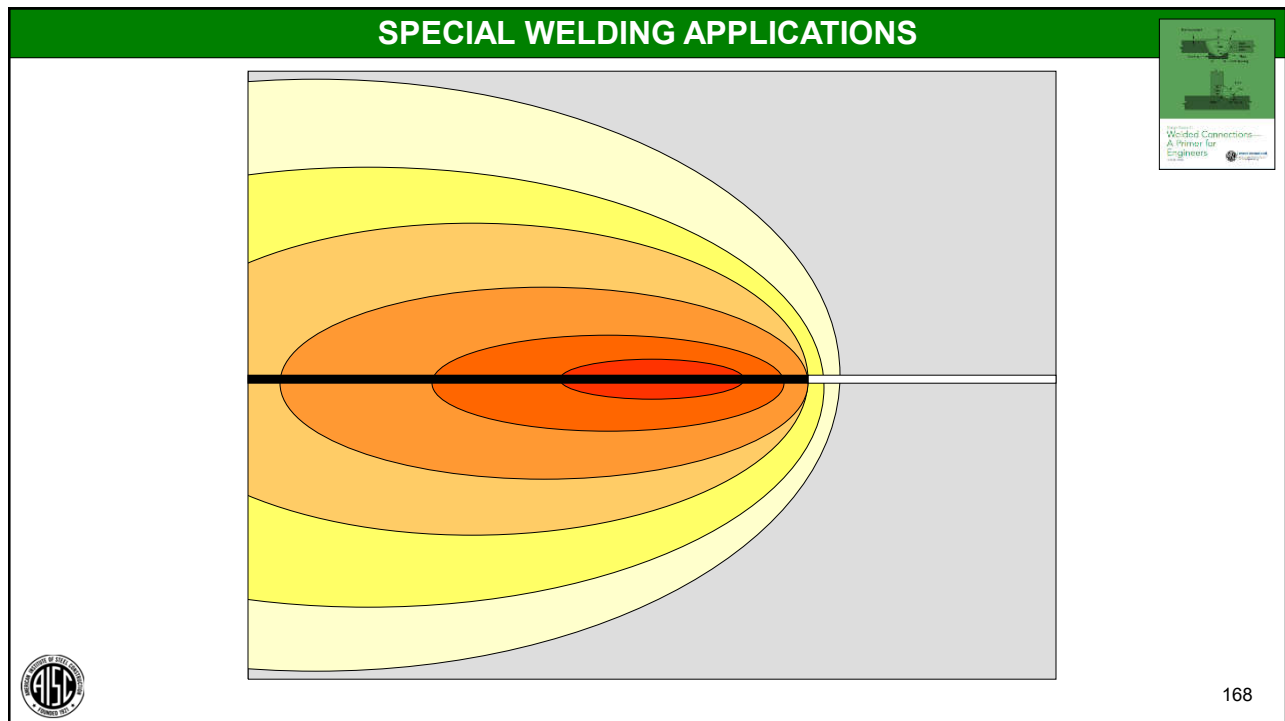
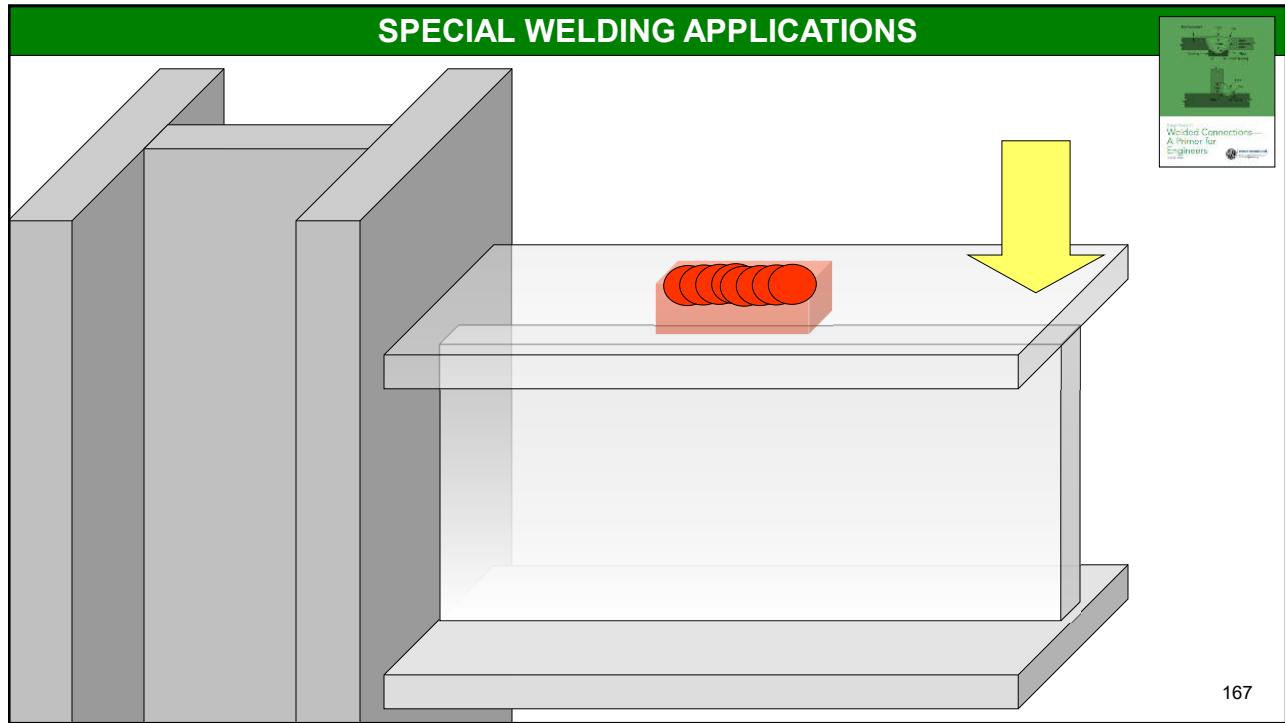
Welded Connections—
A Primer for
Engineers

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AISC 360-16 Specification for Structural Steel Buildings

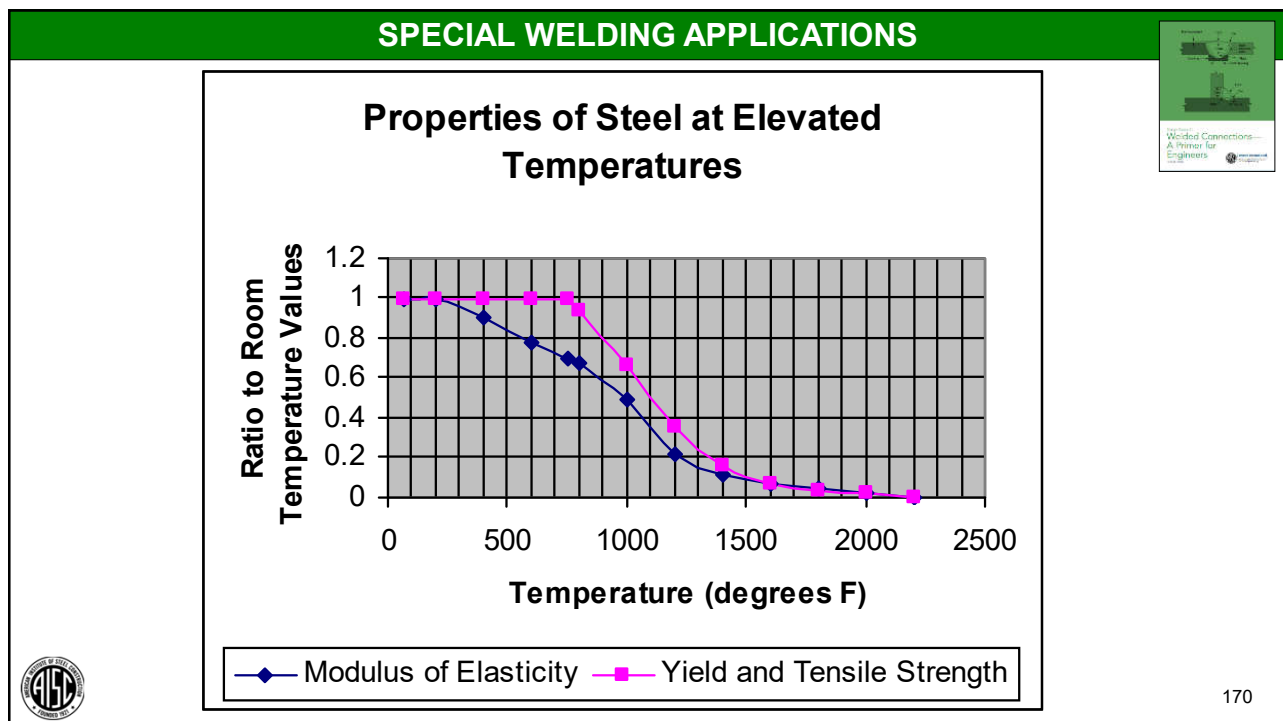
Specification for Structural Steel Buildings

**Table A-4.2.1
 Properties of Steel at Elevated Temperatures**

Steel Temperature (°F)[°C]	$k_E = E_m / E$	$k_y = F_{ym} / F_y$	$k_u = F_{um} / F_y$
68 [20]	*	*	*
200 [93]	1.00	*	*
400 [204]	0.90	*	*
600 [316]	0.78	*	*
750 [399]	0.70	1.00	1.00
800 [427]	0.67	0.94	0.94
1000 [538]	0.49	0.66	0.66
1200 [649]	0.22	0.35	0.35
1400 [760]	0.11	0.16	0.16
1600 [871]	0.07	0.07	0.07
1800 [982]	0.05	0.04	0.04
2000 [1093]	0.02	0.02	0.02
2200 [1204]	0.00	0.00	0.00

*Use ambient properties.

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SPECIAL WELDING APPLICATIONS



Welding on members under load

- The amount of material at temperatures >650 °F is negligible (Blodgett)
- Only a very small percentage of the cross section experiences reduced properties (Tide)
- The impact of the weld orientation (longitudinal versus transverse) is typically inconsequential (Ricker)
- Each situation should be checked

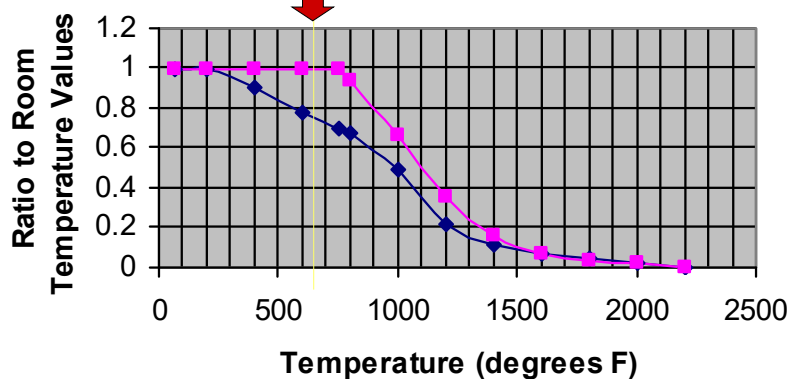


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SPECIAL WELDING APPLICATIONS



Properties of Steel at Elevated Temperatures



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SPECIAL WELDING APPLICATIONS

14.9 Welding on Existing Structures

- Historic steels
- Welding under load
- ➔ • Fire
- Cold working / strain aging



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SPECIAL WELDING APPLICATIONS


Welding on Existing Structures

- General precaution: Fire!
 - From combustibles
 - From unintended work circuits
 - Thermal cutting is typically >> problem than welding



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SPECIAL WELDING APPLICATIONS




Welded Connections—
A Primer for
Engineers

14.9 Welding on Existing Structures

- Historic steels
- Welding under load
- Fire
- ➔ • Cold working / strain aging

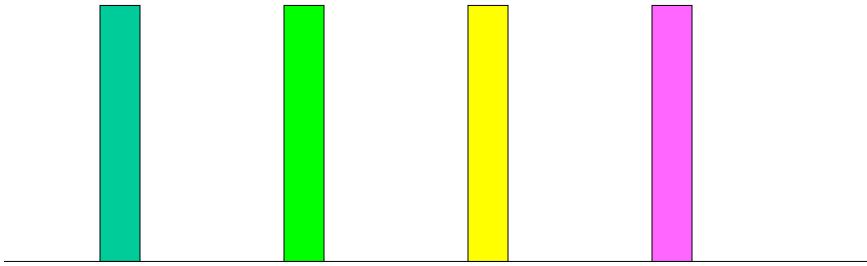
175

SPECIAL WELDING APPLICATIONS




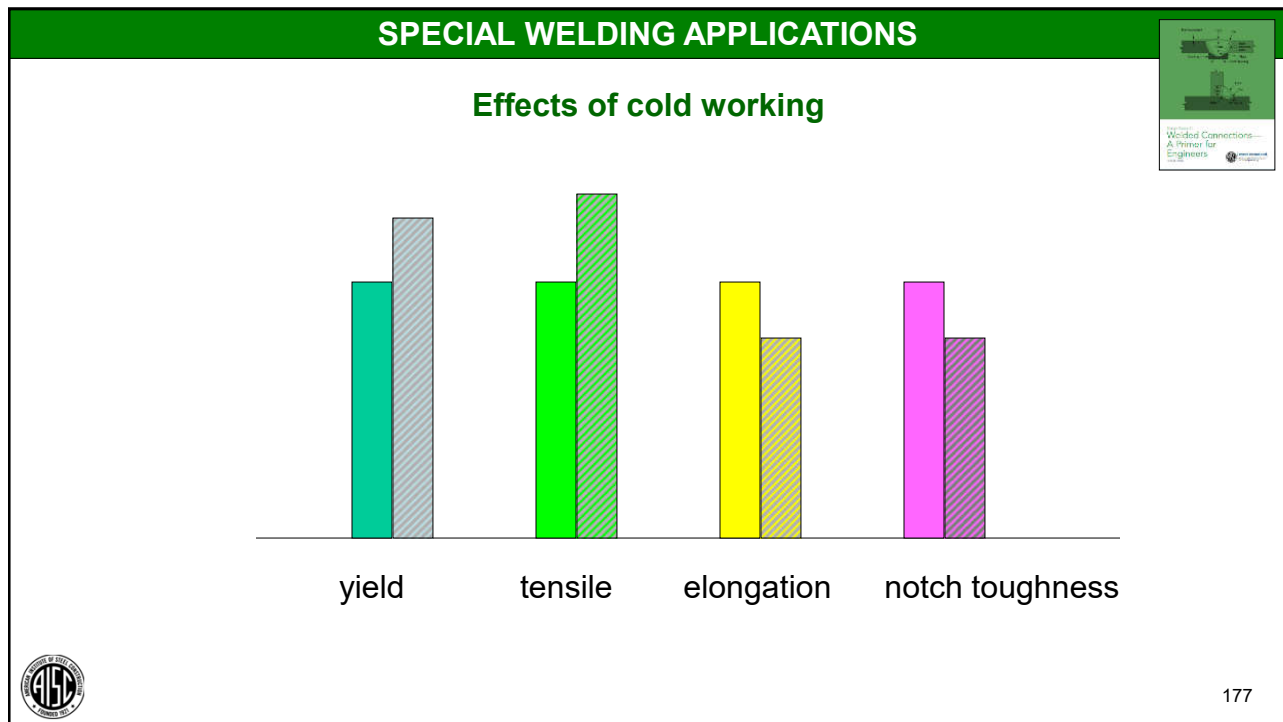
Welded Connections—
A Primer for
Engineers



As received hot rolled steel

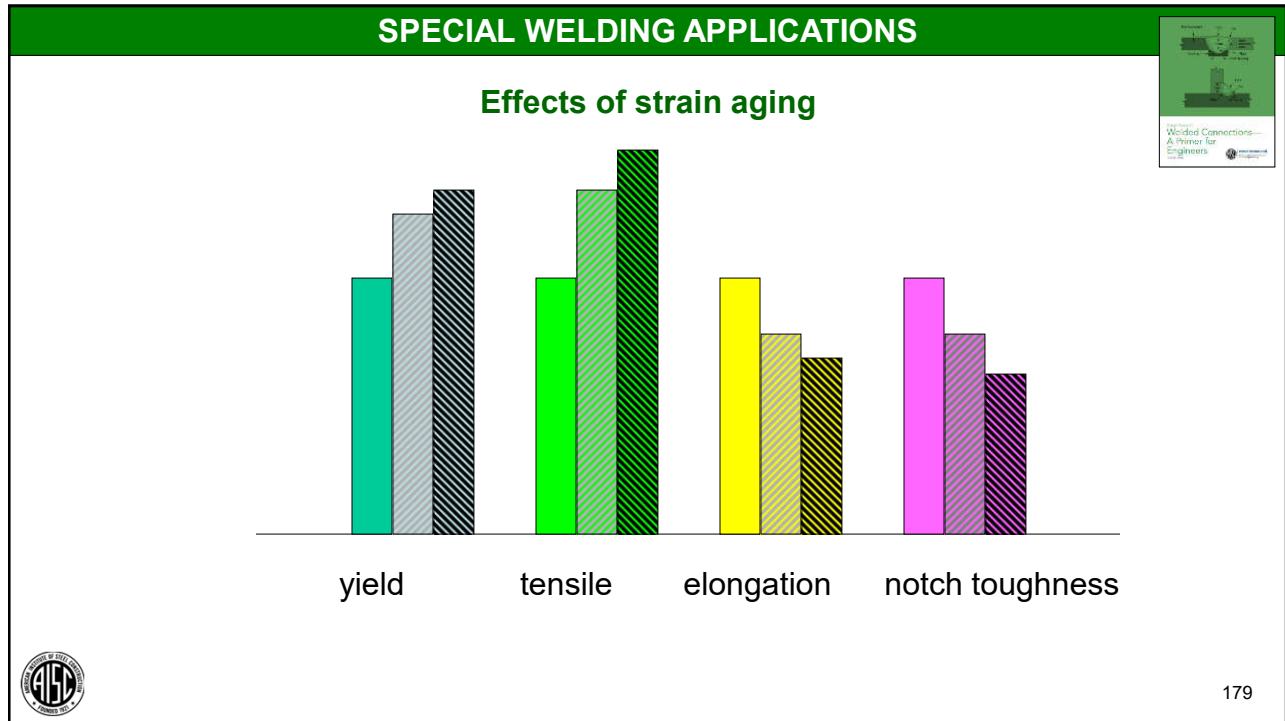




yield tensile elongation notch toughness

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- ### SPECIAL WELDING APPLICATIONS
- #### Strain Aging
- Occurs when steel is heated to 400-700 °F
 - Yield, tensile increase
 - Ductility, notch toughness decrease
 - Aggravated by presence of “free” nitrogen
 - Stress relief helps, but...
 - Typically impractical
 - Depending on alloy, may experience cracking (Cr, Mo, V, B)
- 
- 
- 178



- ### SPECIAL WELDING APPLICATIONS
- #### Welding on plastically deformed members
- Reduced notch toughness
 - Make sure material is crack and notch free
 - Reduced ductility
 - Minimize practices that increase ductility demand
- 
- 
- 180

AWS D1.1:2020 STRUCTURAL WELDING CODE



11. Strengthening and Repair of Existing Structures

11.1 Scope

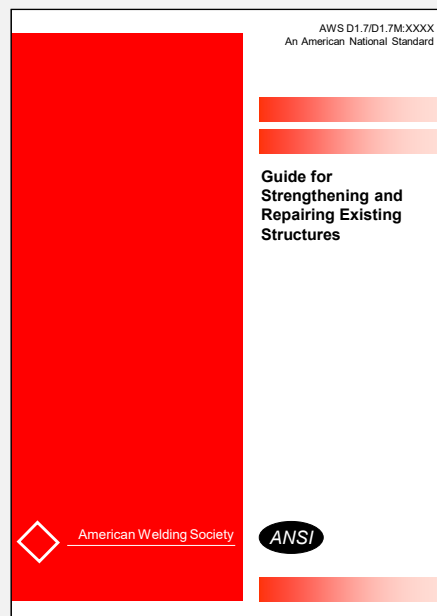
Strengthening or repair of an existing structure shall consist of modifications to meet design requirements, specified by the Engineer. This clause includes requirements for a comprehensive plan for the work, including design, workmanship, inspection, and documentation. The use of fatigue life enhancement methods is also described.



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AWS D1.7

Guide for Strengthening and Repairing Existing Structures



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SPECIAL WELDING APPLICATIONS



Welding on Existing Structures: Summary

- May involve historic steel: see DG 21 Chapter 4
- Welding on members under load: Caution
- Fire potential: sparks, resistance heating: Caution
- Welding on cold worked steel: local reduced ductility



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SPECIAL WELDING APPLICATIONS

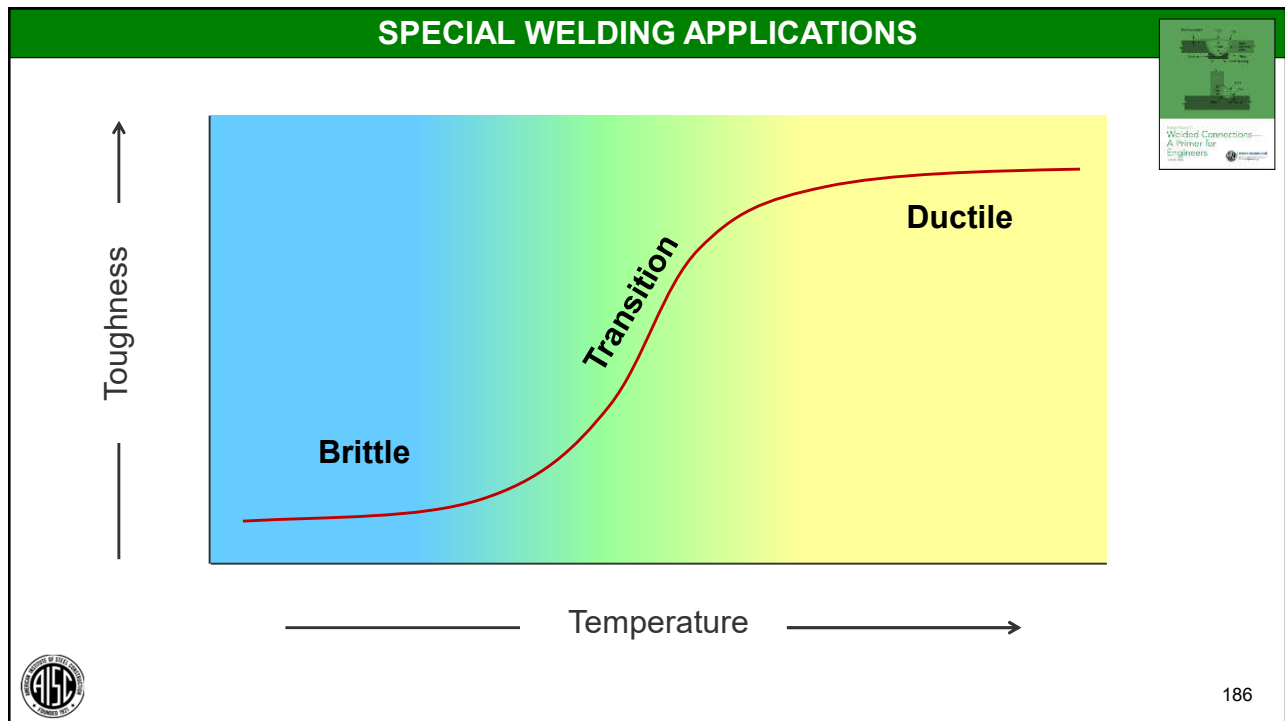
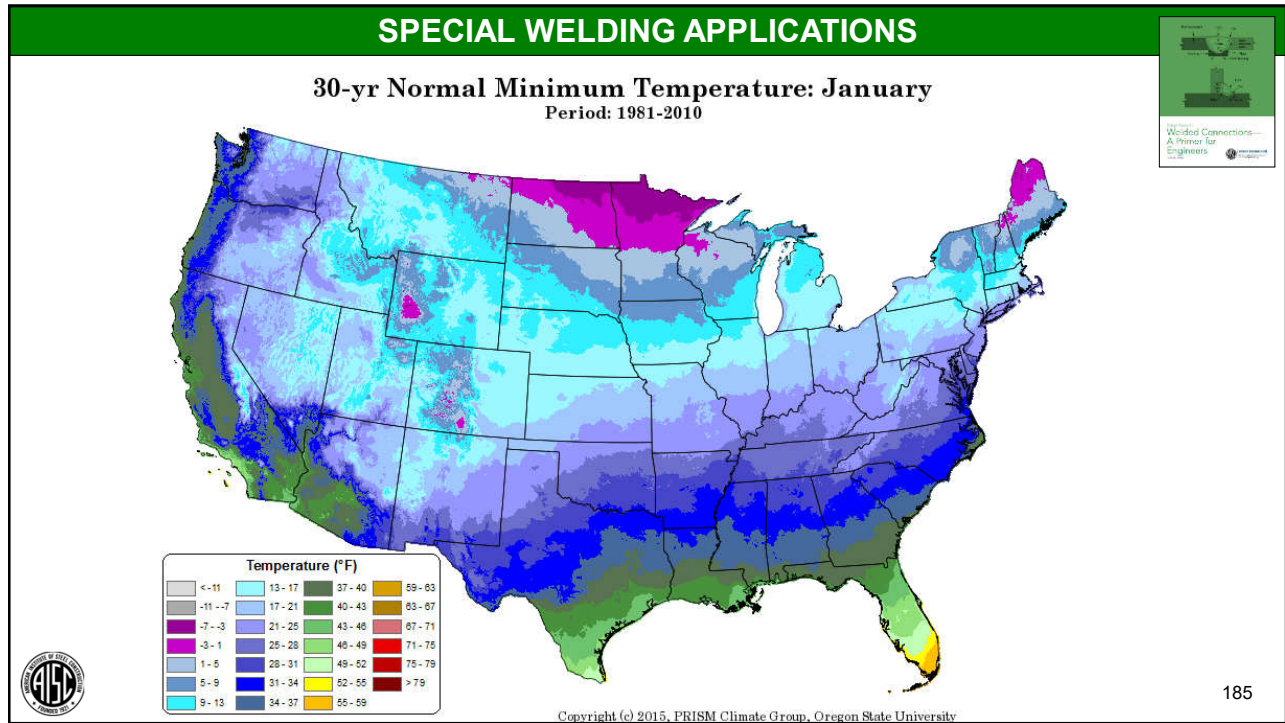


Today's Webinar

- 14.4 Welding on Heavy Shapes
- 14.6 Welding HSS
- 14.7 Welding AESS
- 14.8 Shop Versus Field Welding
- 14.9 Welding on Existing Structures
- ➔ 14.12 Cold Temperature Applications
- 14.15 Heat Shrinking
- 14.16 Buttering



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SPECIAL WELDING APPLICATIONS

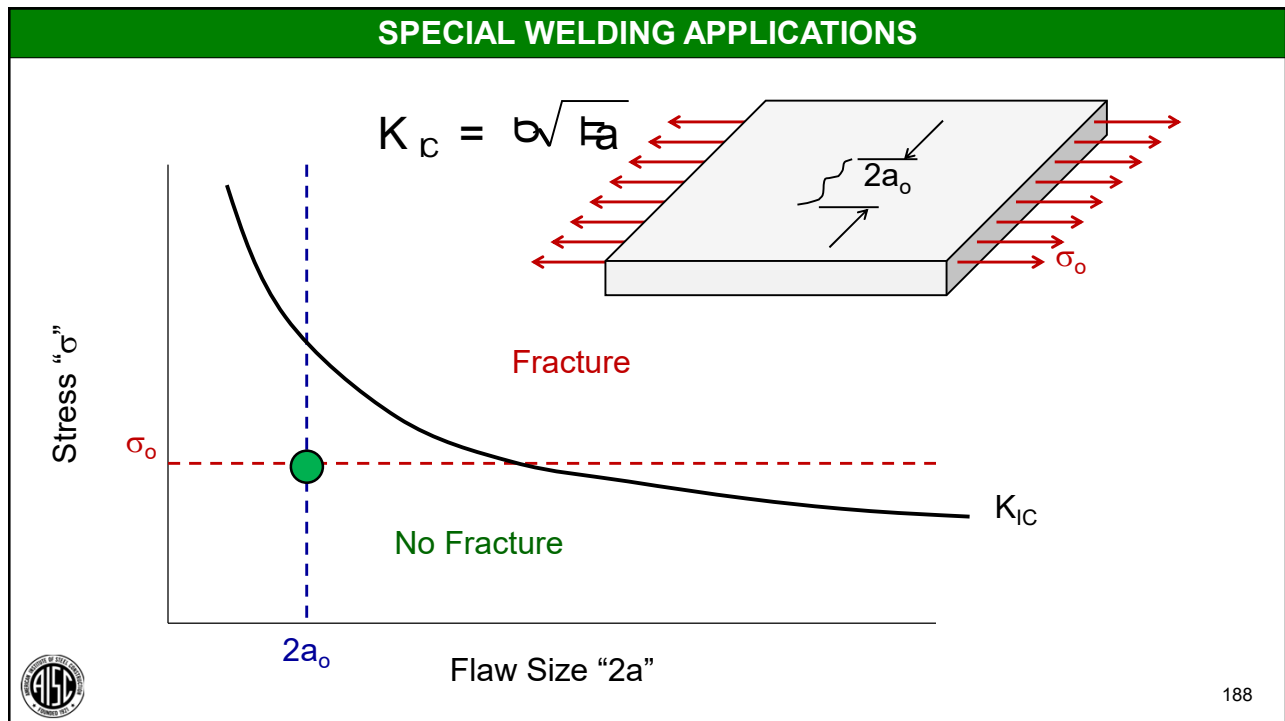
An infinite number of **correct** answers.

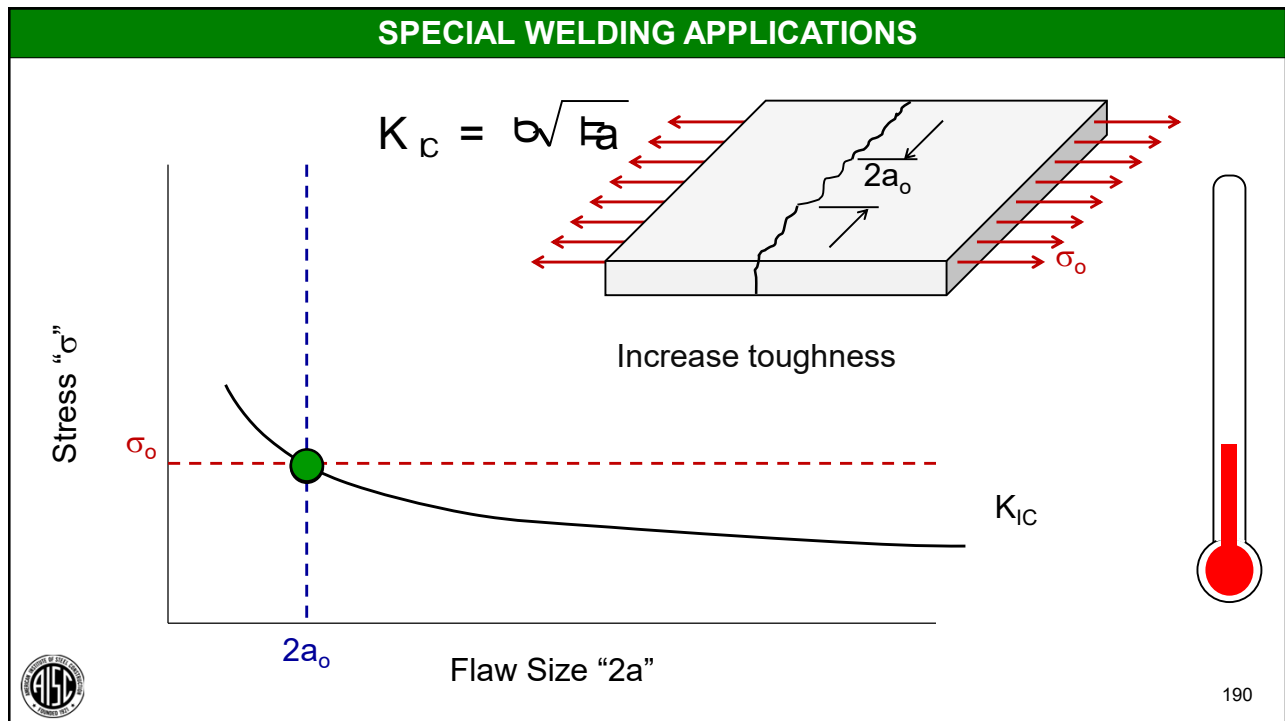
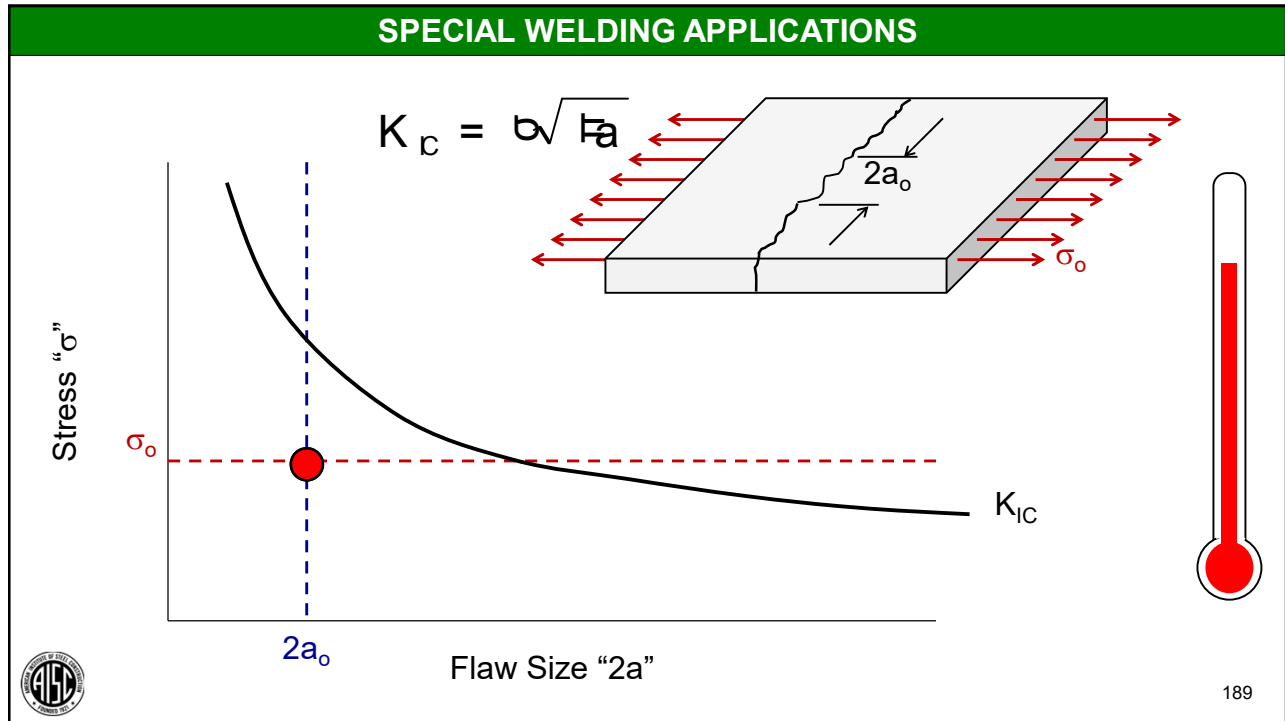
Toughness ← K_c > $b\sqrt{fa}$ → Stress

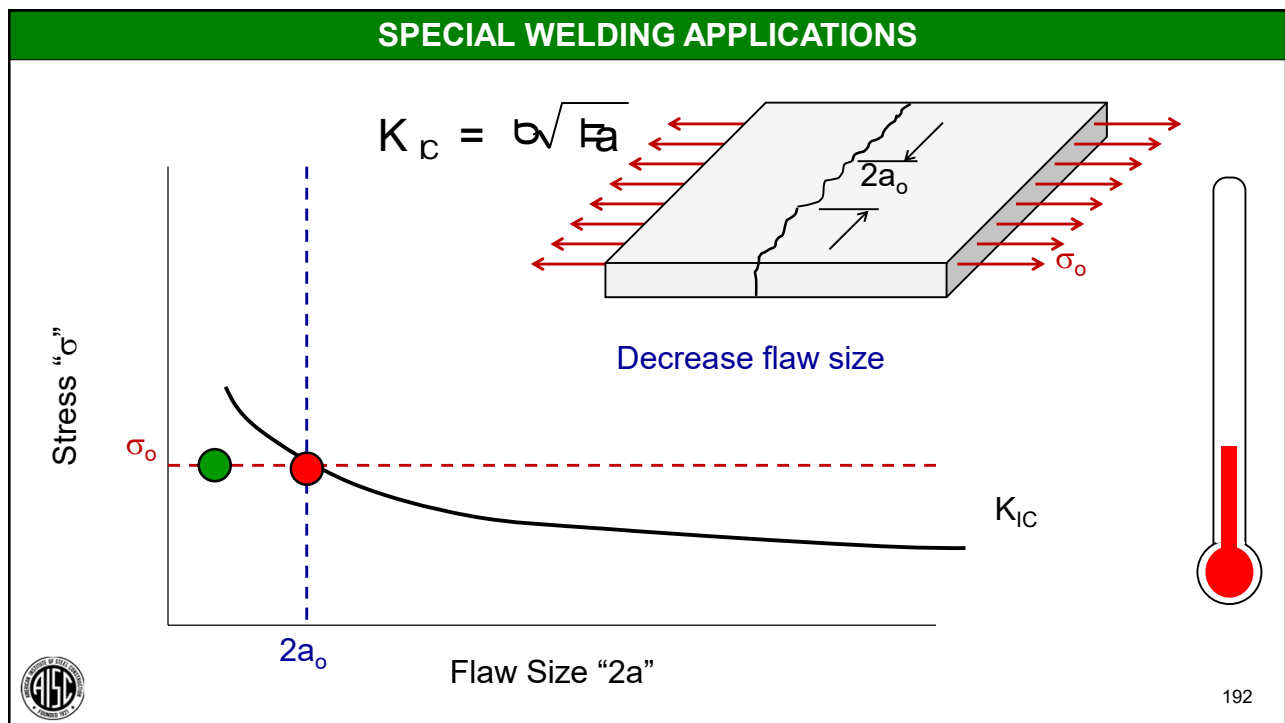
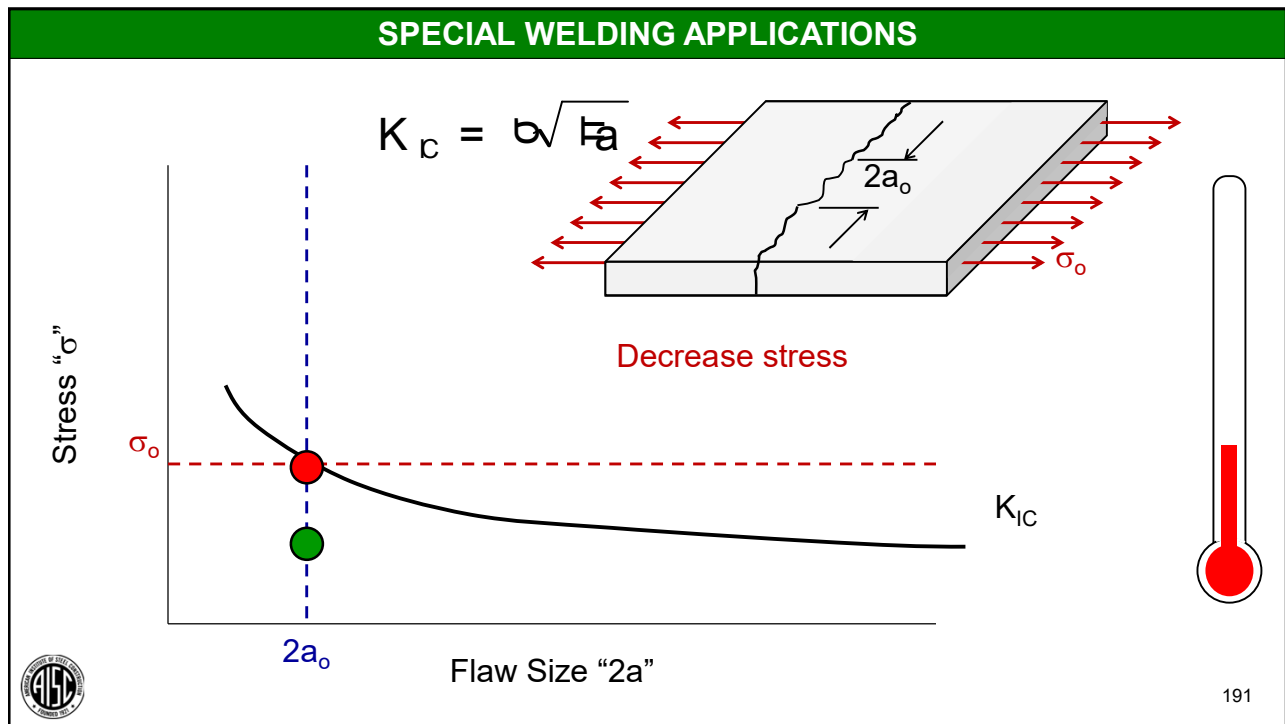
Flaw size

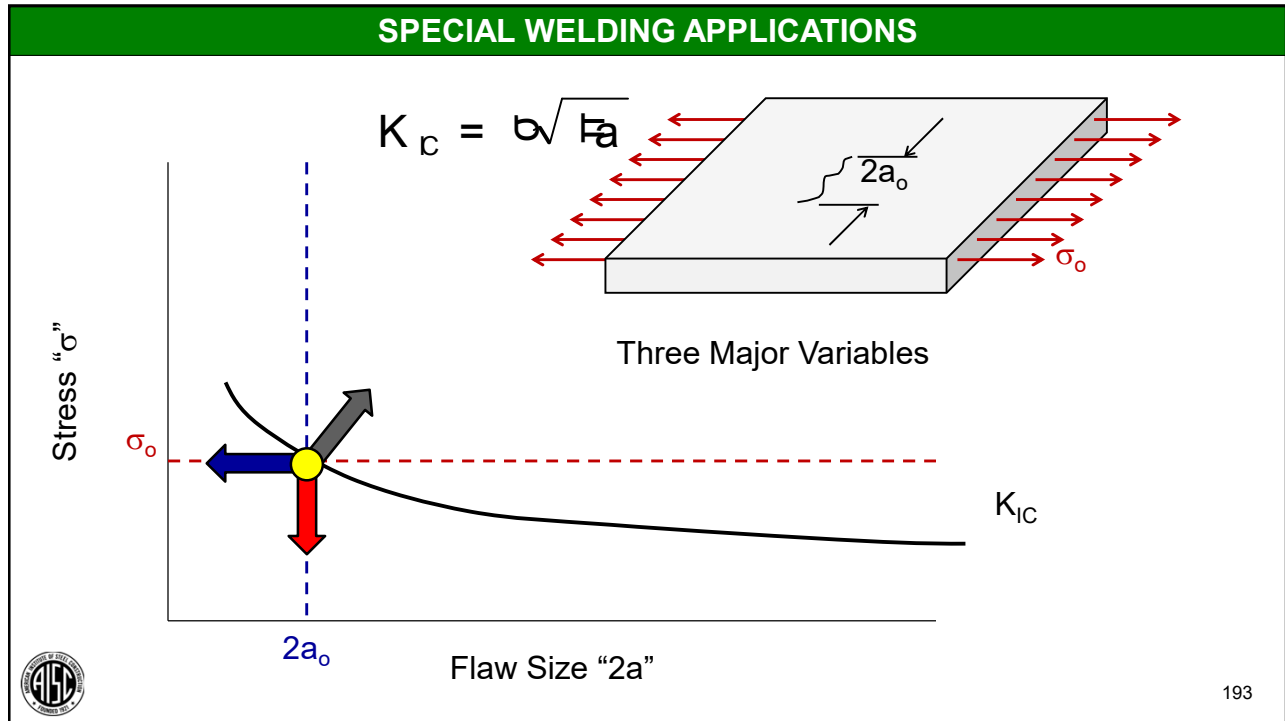
An infinite number of **incorrect** answers.


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AISC 360-16 Specification for Structural Steel Buildings

Commentary A3. MATERIAL


1a. ASTM Designations

“For especially demanding service conditions such as structures exposed to low temperatures, particularly those with impact loading, the specification of steels with superior notch toughness may be warranted.”

$K_{IC} > b\sqrt{Fa}$

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AISC 360-16 Specification for Structural Steel Buildings




Commentary A3. MATERIAL

1a. ASTM Designations


“Good workmanship and good design details incorporating joint geometry that avoids severe stress concentrations are generally the most effective means of providing fracture-resistant construction.”

$K_C > \sqrt{Fa}$ ↓



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SPECIAL WELDING APPLICATIONS



Cold Temperature Applications: Summary

Material Details Workmanship Inspection

For “good design details” and joint geometries that “avoid severe stress concentrations”, consider Appendix 3 Design for Fatigue.



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SPECIAL WELDING APPLICATIONS

Today's Webinar

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SPECIAL WELDING APPLICATIONS

Heat Shrinking

- Used to curve straight steel
- Used to straighten bent steel
- Used to correct for distortion
- Also known as “heat straightening”



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SPECIAL WELDING APPLICATIONS

The diagram illustrates a welded I-beam connection. On the left, a cross-section of an I-beam is shown with a vertical line labeled 'A-A' indicating the location of the weld. To the right, a longitudinal view of the beam shows a weld joint. The top flange of the I-beam is shaded gray, and the bottom flange is shaded light gray. The weld joint is shown as a dark gray line. A horizontal line with arrows at both ends, labeled 'A-A', indicates the location of the cross-section. Below the beam, two blue triangular supports are shown. Purple arrows pointing downwards represent a uniformly distributed load applied to the top flange of the beam. In the top right corner, there is a small inset image of a book cover titled 'Welded Connections - A Primer for Engineers'.

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SPECIAL WELDING APPLICATIONS

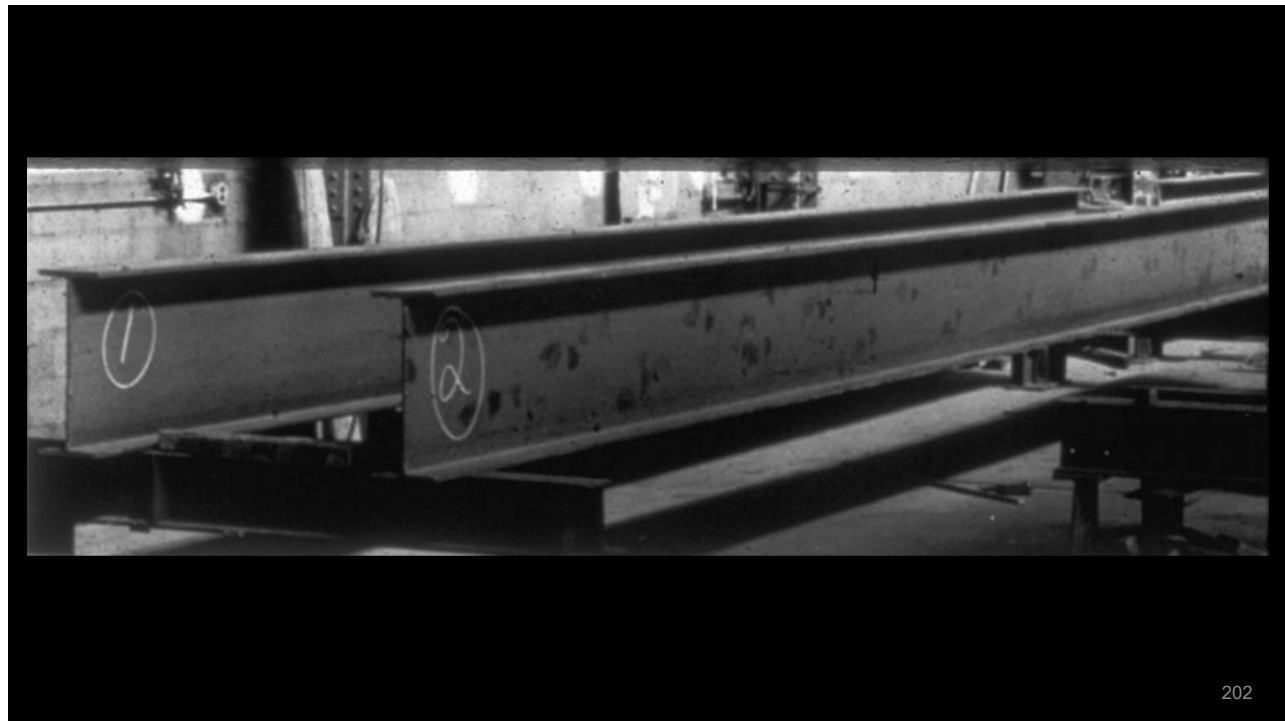
The diagram illustrates a welded I-beam connection under load, showing shear flow. On the left, a cross-section of an I-beam is shown with a vertical line labeled 'A-A'. To the right, a longitudinal view of the beam shows a weld joint. The top flange is shaded red, and the bottom flange is shaded brown. The weld joint is shown as a dark gray line. A horizontal line with arrows at both ends, labeled 'A-A', indicates the location of the cross-section. Below the beam, two blue triangular supports are shown. Purple arrows pointing downwards represent a uniformly distributed load applied to the top flange of the beam. Yellow arrows pointing outwards from the weld joint represent shear flow. In the top right corner, there is a small inset image of a book cover titled 'Welded Connections - A Primer for Engineers'.

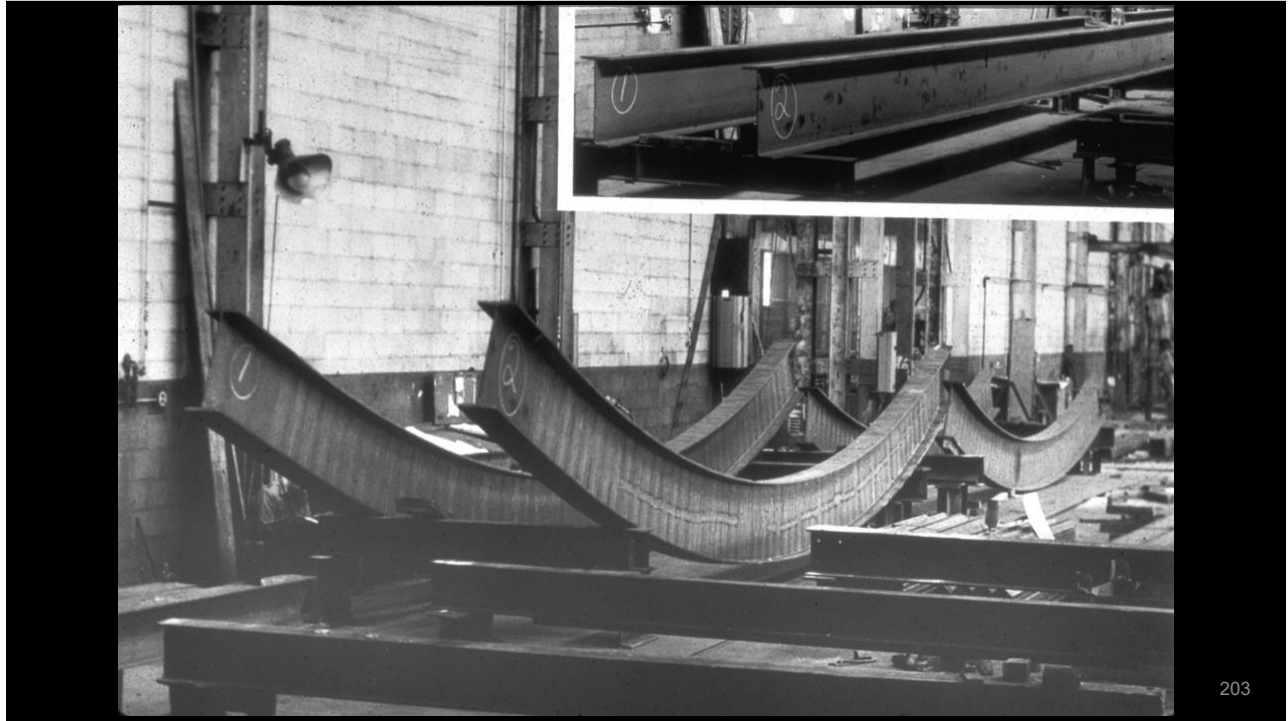
200

SPECIAL WELDING APPLICATIONS

The diagram illustrates two scenarios of special welding applications on a beam under a uniform load. The top scenario shows a beam with a single central weld joint, indicated by a shaded area. The bottom scenario shows a beam with multiple weld joints along its length, also indicated by shaded areas. Both diagrams include a cross-section of an I-beam and blue triangular supports.

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SPECIAL WELDING APPLICATIONS



Heat Shrinking

- 1200 °F temperature limit for hot rolled steels
- 1100 °F temperature limit for quenched and tempered steels
- New limits for QST steels
- Pre-stress of up to 50% of room temperature yield (Avent)



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AWS D1.1:2020 STRUCTURAL WELDING CODE



7.25.2 Localized Heat Repair Temperature Limitations.

Members distorted by welding shall be straightened by mechanical means or by application of a limited amount of localized heat. The temperature of heated areas as measured by approved methods shall not exceed 1100°F [600°C] for quenched and tempered steel nor 1200°F [650°C] for other steels. The part to be heated for straightening shall be substantially free of stress and from external forces, except those stresses resulting from the mechanical straightening method used in conjunction with the application of heat.



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SPECIAL WELDING APPLICATIONS

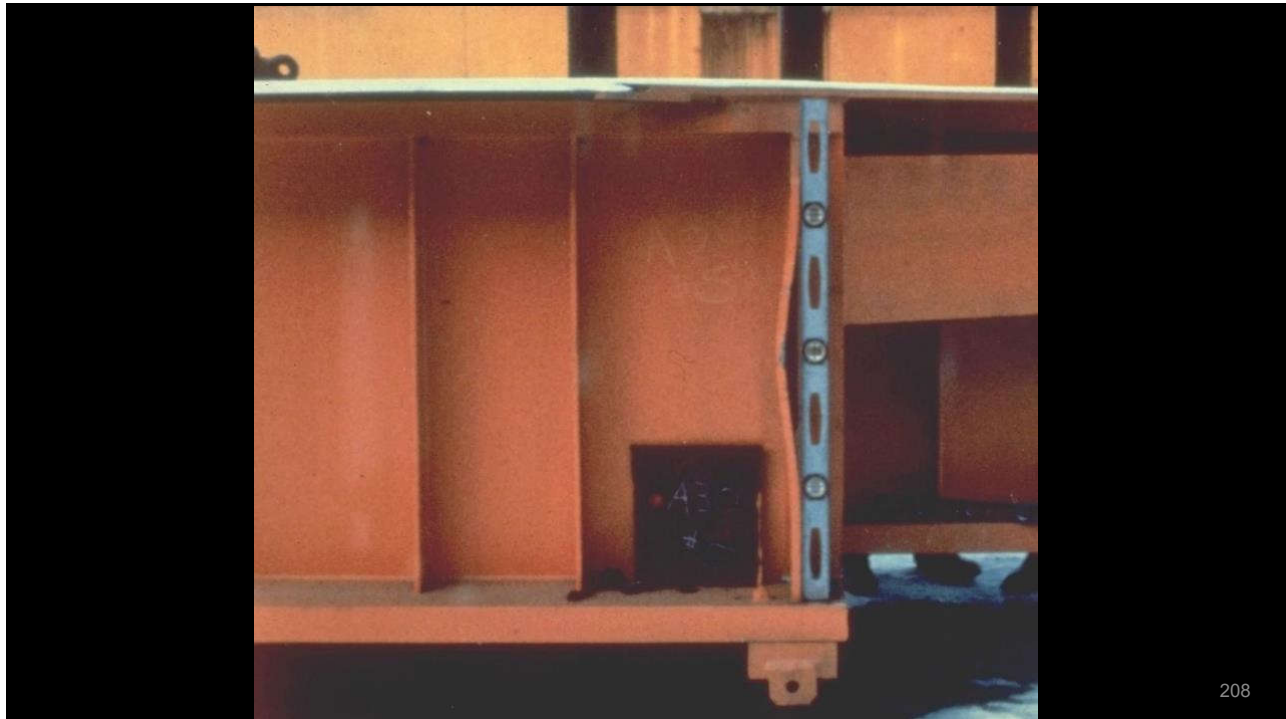


Heat Shrinking

- For new steel being curved
 - No change in modulus of elasticity (E)
 - Slight increase in yield and tensile strength
 - 10-25% increase in ductility
- For bent steel being straightened
 - Yield strength increases 10%
 - Tensile strength increases 4-6%

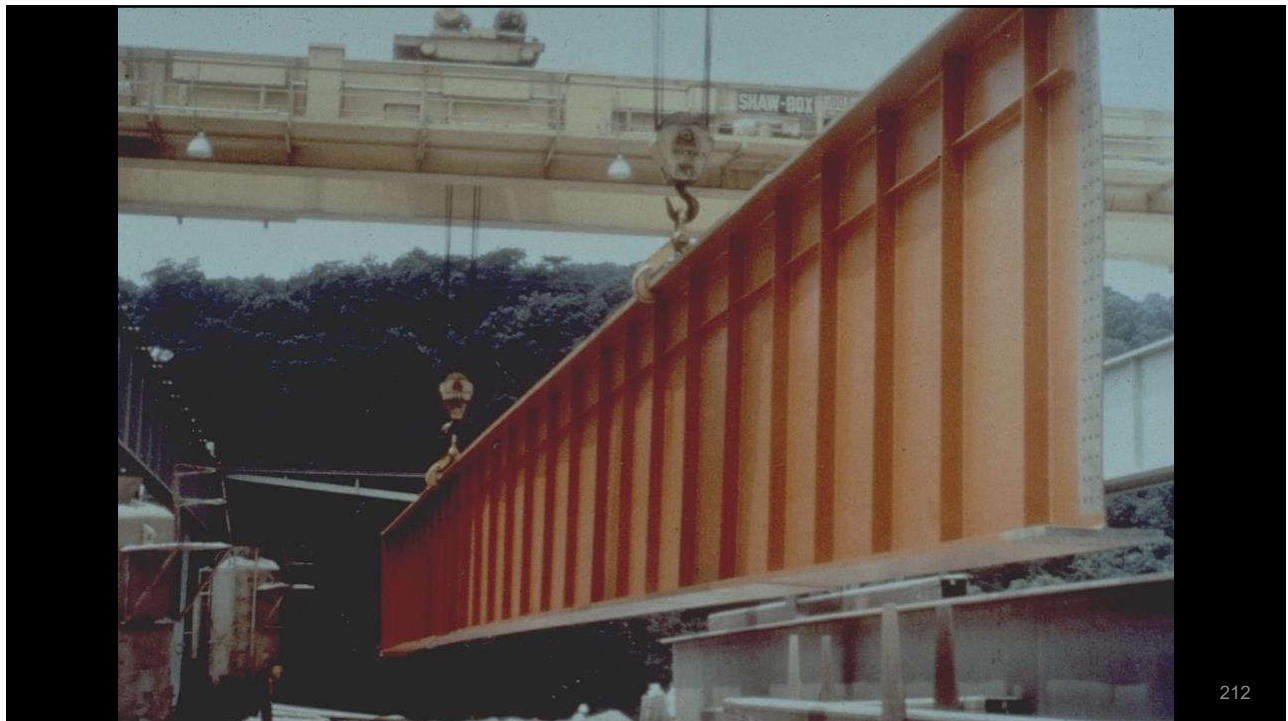


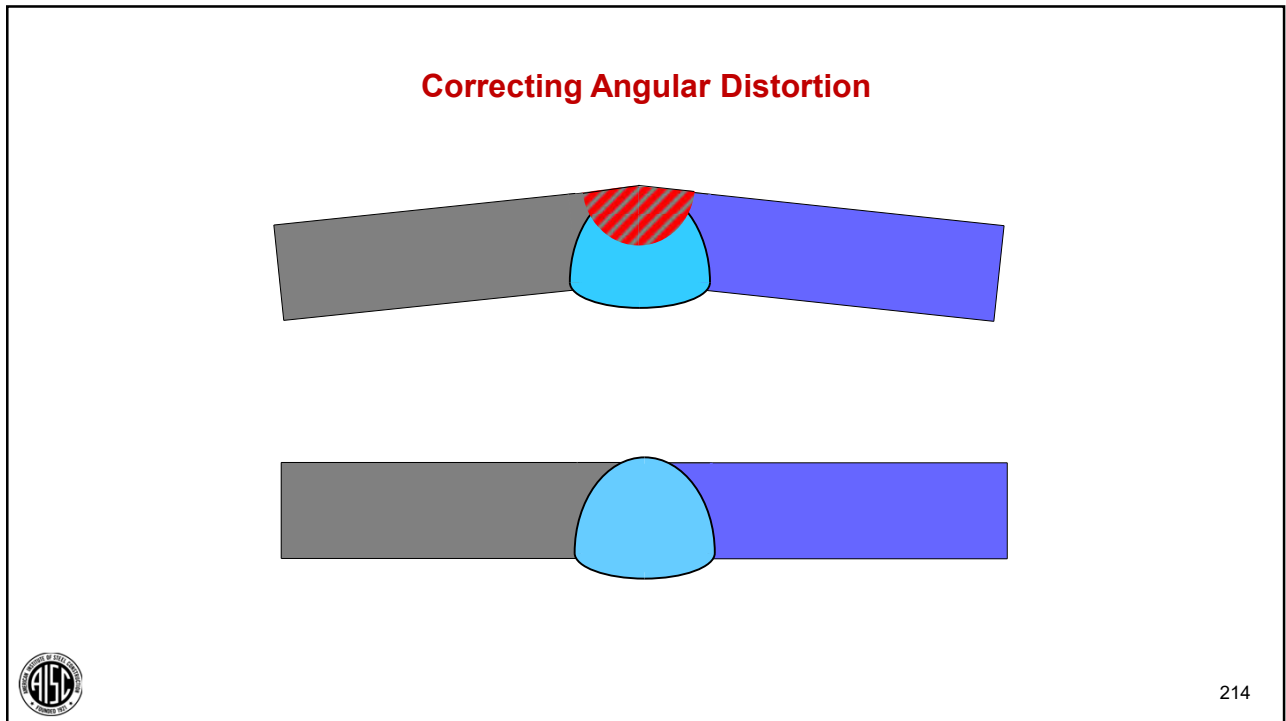
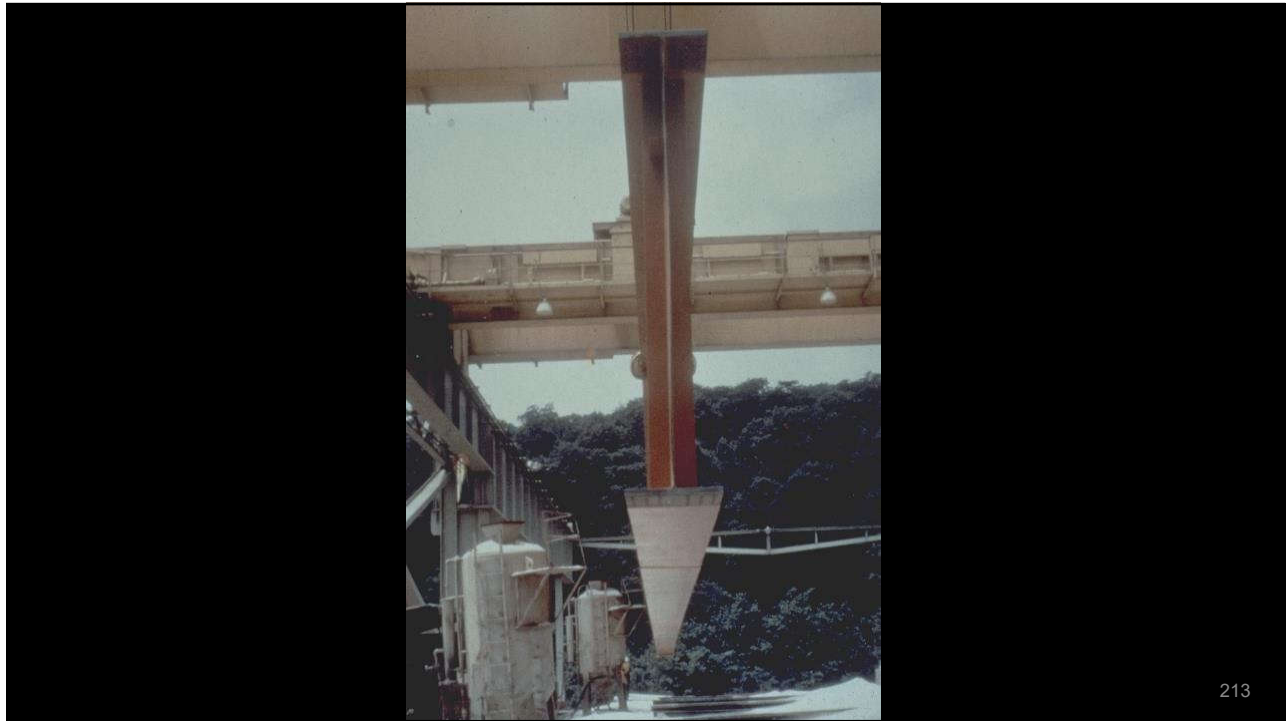
207



208








Correcting Panel Distortion


The diagram illustrates two methods for correcting panel distortion in a welded beam. The top row shows a beam with a central stiffener and a panel that is distorted (curved). The bottom row shows a beam with a central stiffener and a panel that is flat. The stiffener is shown in cross-section on the left.



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Correcting Panel Distortion

The diagram illustrates two methods for correcting panel distortion in a welded beam. The top row shows a beam with four stiffeners and a panel that is distorted (curved). The bottom row shows a beam with four stiffeners and a panel that is flat. The stiffeners are shown in cross-section on the left.



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SPECIAL WELDING APPLICATIONS



Heat Shrinking: Summary

- Used for shaping and straightening steel
- Code limits on temperatures
- Material is not damaged if properly done



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SPECIAL WELDING APPLICATIONS



Today's Webinar

- 14.4 Welding on Heavy Shapes
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SPECIAL WELDING APPLICATIONS

BUTTERING



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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2020)

buttering

A surfacing variation primarily use to provide metallurgically compatible weld metal for the subsequent completion of the weld.

See also buildup, cladding, and hardfacing.



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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2020)

surfacing weld

A weld applied to a surface, as opposed to making a joint, to obtain desired properties or dimensions. See Figures B15(C) and B30(C).

(C) SURFACING WELD
Figure B15(C)

(C) SURFACING WELD
Figure B30(C)

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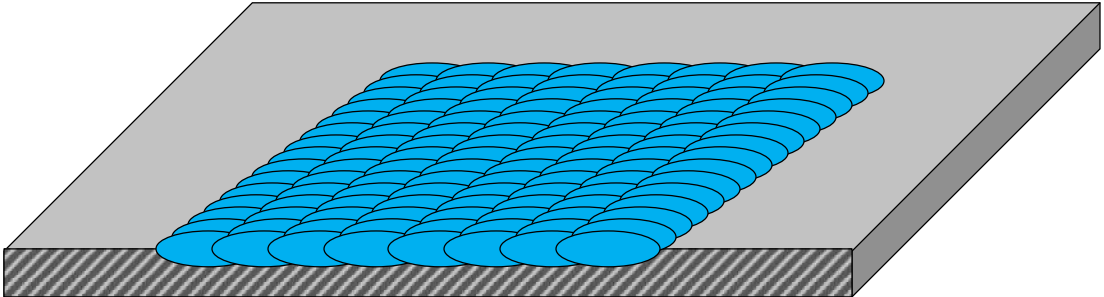
SPECIAL WELDING APPLICATIONS

Buttering is used to:


- Mitigate lamellar tearing tendencies
- Build up the faces of groove weld joint cavities where root openings are excessive
- Restore material from steel that was damaged by corrosion
- Enable welding on “hard to weld” steels

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SPECIAL WELDING APPLICATIONS



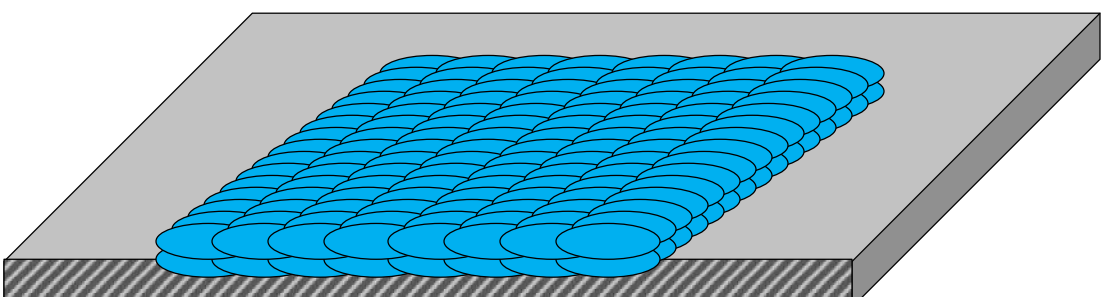
Welded Connections—
A Primer for
Engineers




223

This diagram illustrates a special welding application on a flat surface. It shows a grid of blue weld ripples, representing a specific welding pattern. The surface is shown in a 3D perspective, with a hatched area indicating the base material. A small inset image in the top right corner shows a book cover titled "Welded Connections—A Primer for Engineers". The AISC logo is located in the bottom left corner, and the number 223 is in the bottom right corner.

SPECIAL WELDING APPLICATIONS

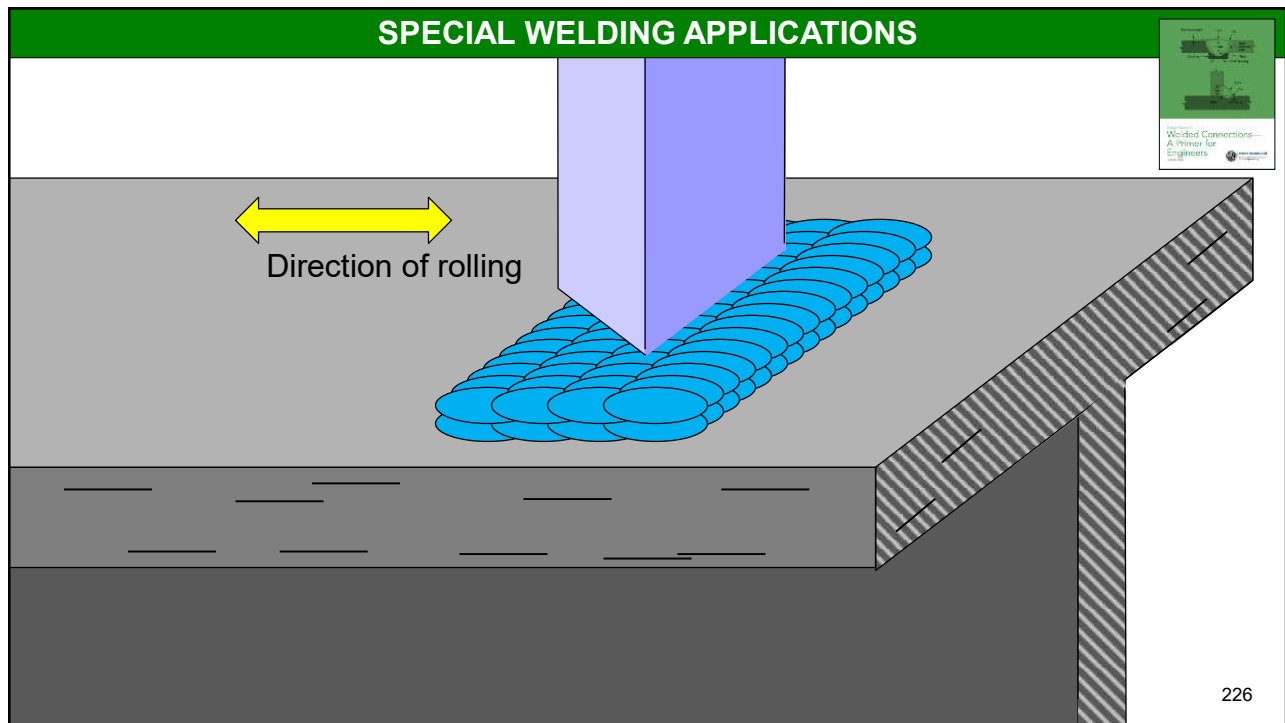
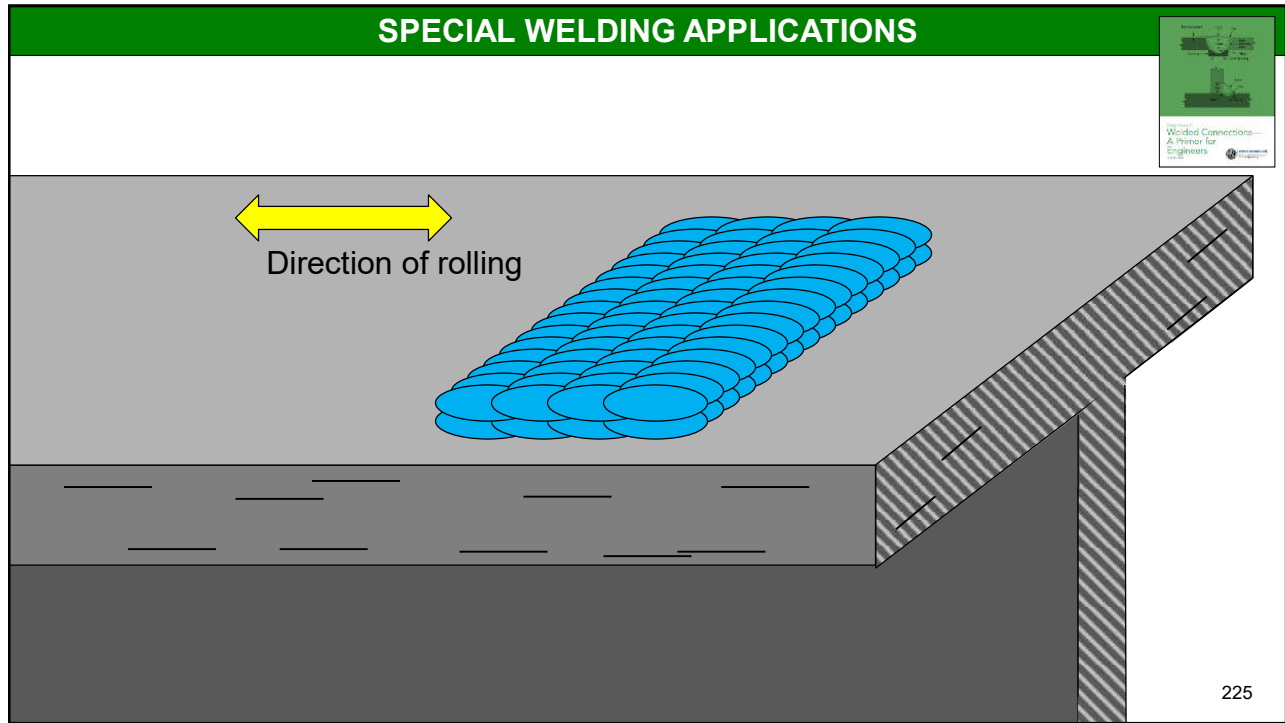


Welded Connections—
A Primer for
Engineers



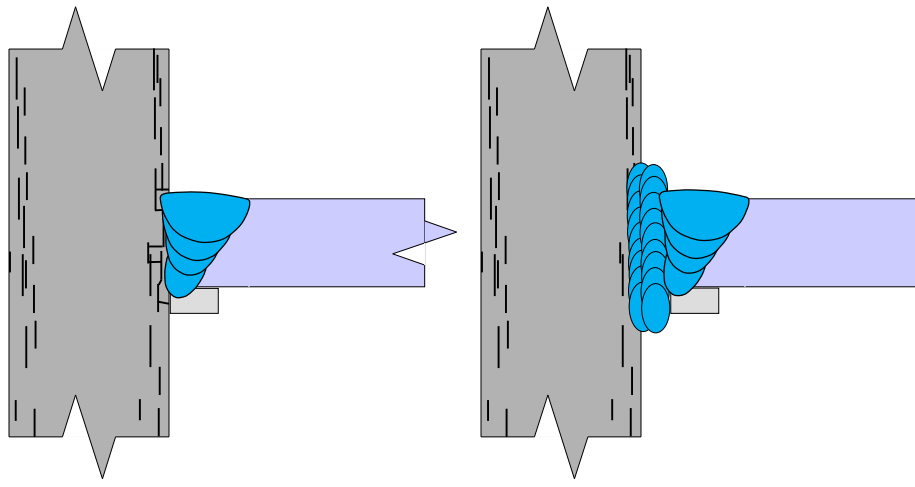
224

This diagram illustrates a special welding application on a flat surface, similar to the one above. It shows a grid of blue weld ripples. The surface is shown in a 3D perspective, with a hatched area indicating the base material. A small inset image in the top right corner shows a book cover titled "Welded Connections—A Primer for Engineers". The AISC logo is located in the bottom left corner, and the number 224 is in the bottom right corner.



SPECIAL WELDING APPLICATIONS

Buttering Solution



Sensitive Detail Buttered Detail

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SPECIAL WELDING APPLICATIONS

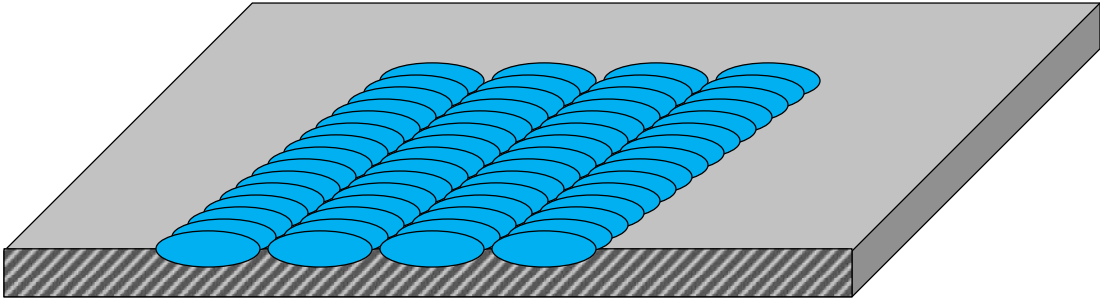
Buttering Guidelines

- Deposit butter layers with the same care and controls used for joining welds (WPSs, qualified welders, in process visual inspection, etc.)
- Overlap bead by approximately 50%

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SPECIAL WELDING APPLICATIONS

Non-preferred: no overlap



The diagram illustrates a non-preferred welding application. It shows a 3D perspective of a grey rectangular plate with a hatched bottom surface. On top of the plate, there are two parallel rows of blue, semi-circular weld ripples. The ripples in the two rows are positioned such that they do not overlap, leaving a distinct gap between the end of one ripple and the start of the next in the adjacent row.

Welded Connections—
A Primer for
Engineers

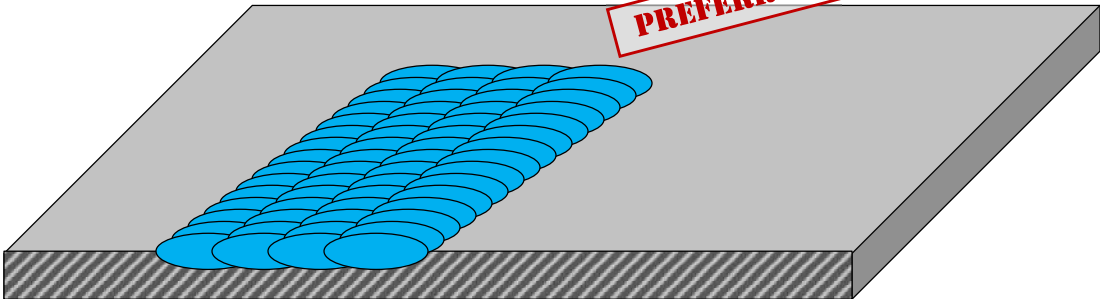


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SPECIAL WELDING APPLICATIONS


Approximately 50% overlap

PREFERRED



The diagram illustrates a preferred welding application. It shows a 3D perspective of a grey rectangular plate with a hatched bottom surface. On top of the plate, there are two parallel rows of blue, semi-circular weld ripples. The ripples in the two rows overlap by approximately 50%, meaning the end of one ripple in one row is positioned halfway under the start of the next ripple in the adjacent row.

Welded Connections—
A Primer for
Engineers



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SPECIAL WELDING APPLICATIONS



Buttering Guidelines

- Deposit butter layers with the same care and controls used for joining welds (WPSs. Qualified welders, in process visual inspection, etc.)
- Overlap bead by approximately 50%.
- If NDT of the weld to be made to the butter layer is required, the butter layer should also receive NDT.



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SPECIAL WELDING APPLICATIONS



Buttering: Summary

- Build up out-of-tolerance joints
- One method to mitigate lamellar tearing
- Buttering procedures should be consistent with the applicable code, including final quality requirements



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SPECIAL WELDING APPLICATIONS

Today's Webinar

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- 14.16 Buttering



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SPECIAL WELDING APPLICATIONS



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Thank you!

AISC | Questions



Individual Session Registrants

PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- All individuals attending at your connection: you will receive an email on how to report their attendance from: registration@aisc.org.
 - Be on the lookout: Check your spam filter! Check your junk folder!
 - Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

8-Session Registrants

PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.

8-Session Registrants

Access to the quiz

Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

Posted Friday mornings. www.aisc.org/nightschool -- Click on Current Course Details.

Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

Note: If you attend the live presentation, you do not have to take the quizzes to receive PDHs

8-Session Registrants

Access to the recording

Information for accessing the recording will be emailed to you by Wednesday. The recording will be available for four weeks. (For 8-session registrants only.) EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for PDHs.

8-Session Registrants

Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



Login

If you're an existing customer, please enter your username and password.

<p>USERNAME</p> <input type="text" value="Enter your username"/>	<p>DON'T HAVE AN ACCOUNT?</p> <p>My AISC allows you to access Engineering Journal articles and Design Guides you have downloaded from the bookstore.</p> <p>REGISTER NOW</p>
<p>PASSWORD</p> <input type="password" value="Enter your password"/>	
<input type="checkbox"/> Remember Me	

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.

The image shows the 'MyAISC' user profile page. On the left is a sidebar titled 'IN THIS SECTION' with a list of links: Edit Profile, My Downloads, My Pending Quizzes, My Events, Order History, Course History, and Course Resources. The 'Course Resources' link is circled in red. The main content area has a header 'MyAISC' and a 'MY PROFILE' section with an 'EDIT PROFILE' button. Below that is a 'MY PURCHASED DOWNLOADS' section with a 'VIEW DOWNLOADS' button. At the bottom is a 'MY COURSE RESOURCES' section with a 'VIEW RESOURCES' button, which is also circled in red. The text in the 'MY COURSE RESOURCES' section reads: 'View online resources for Night School and Live Webinar package registrat'.

8-Session Registrants

Night School Resources



Course Resources

Event	Start Date
NS 33 8-Session Package-Night School 33 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 34 8-Session Package-Night School 34 - Fundamentals of Stability	6/5/2017 7:00:00 PM

8-Session Registrants

Night School Resources



Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13D5N	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending

8-Session Registrants

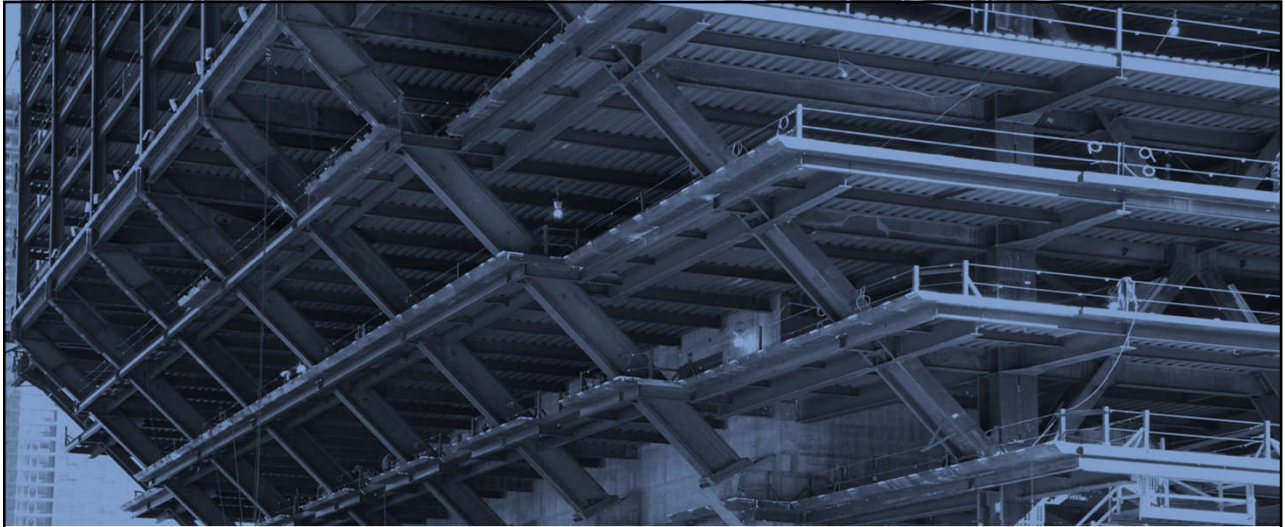
Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool27. Scroll down to Quiz and Attendance records.
 - Updated on Friday mornings.

8-Session Registrants

Night School Resources

- Webinar connection information
 - Reminder email sent out Monday mornings
- Links to handouts also found here



AISC | Thank you



**Smarter.
Stronger.
Steel.**