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Course Description

Part 1: Fundamentals of Welded Connections

June 29, 2017

This session will consist of a review of applicable welding codes, the basics of welded joints and weld types, and required weld metal strength levels. Details for welded connection details will be discussed, including the basic criteria to be used to determine weld throat dimensions.



Learning Objectives

- Identify standards related to welding.
- List advantages and disadvantages of different weld details.
- Define variables essential to specifying a given weld detail.
- Identify preferred and unacceptable weld types and details for different connection geometries.



There's always a solution in steel.

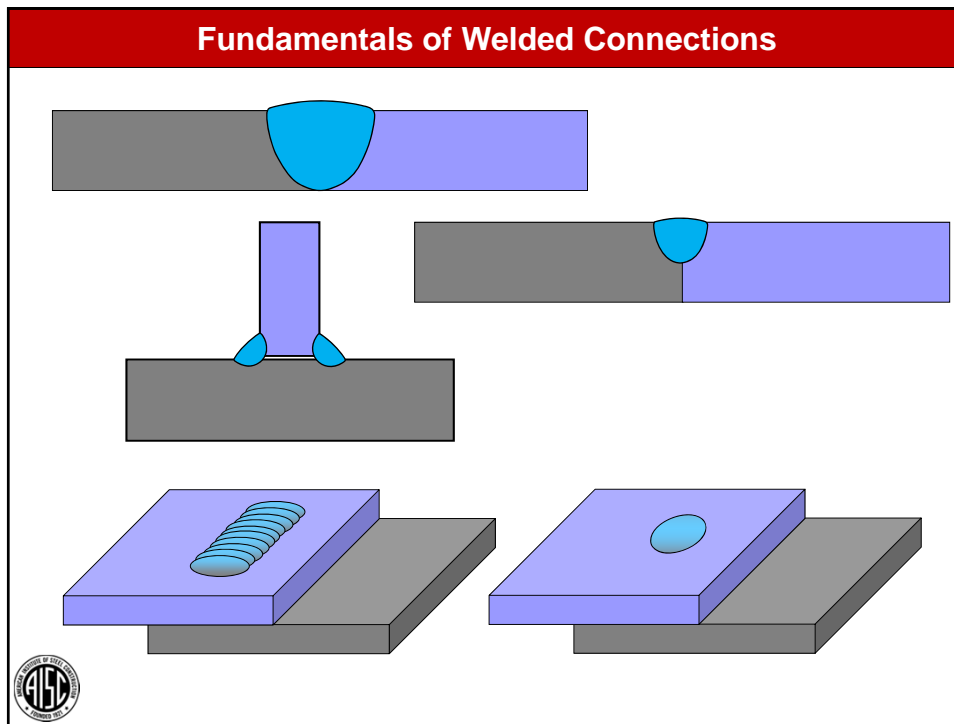
Welded Connections

Part 1: Fundamentals of Welded Connections
June 29, 2017




Presented by
Duane Miller, Sc.D., P.E.
Manager of Engineering Services and Welding
Design Consultant at The Lincoln Electric Company
Cleveland, OH






FRACTURE and FATIGUE CONTROL in STRUCTURES



“Failures in engineering structures occur predominately at component **connections**. ...For example, fatigue cracking in bridges, ships, offshore structures, pressure vessels, and buildings occurs, almost without exception, at the welded or bolted **connections** and attachments such as cover plate fillet weld terminations, stiffeners, backing bars, and seam and girth weld toes.”

Barsom and Rolfe




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Fundamentals of Welded Connections

Outline


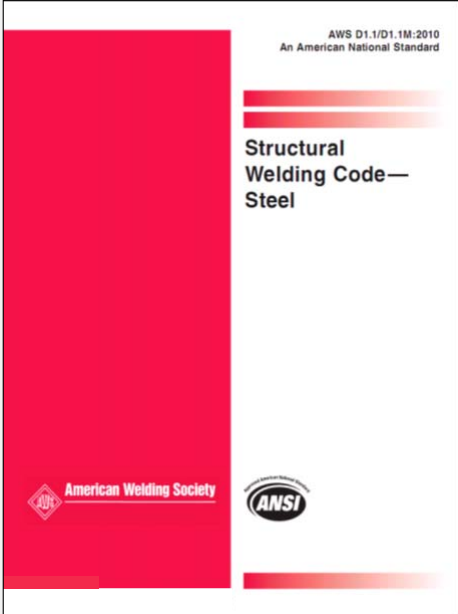
- ➔ • Applicable Codes
- Welding Processes
- Joints and Weld Types
- CJP Details
- PJP Details
- Fillet Weld Details

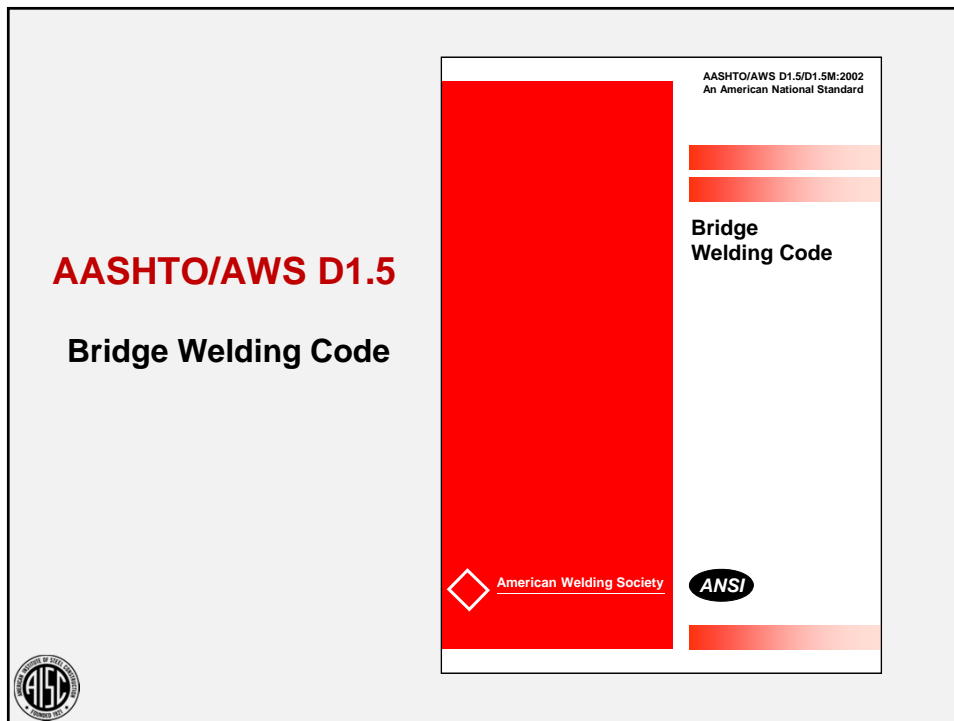
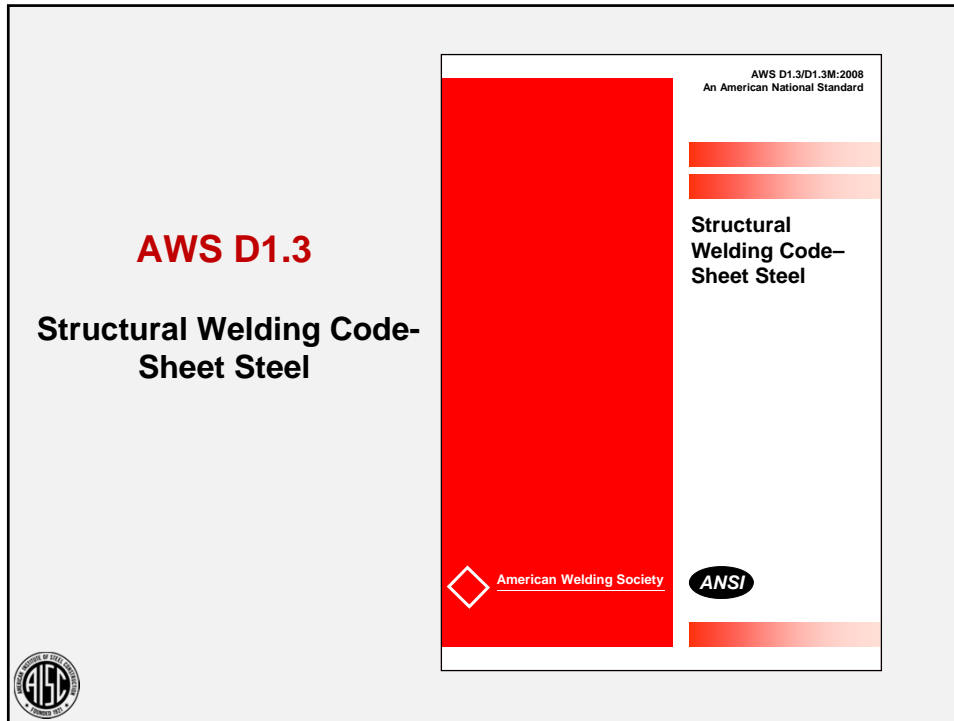


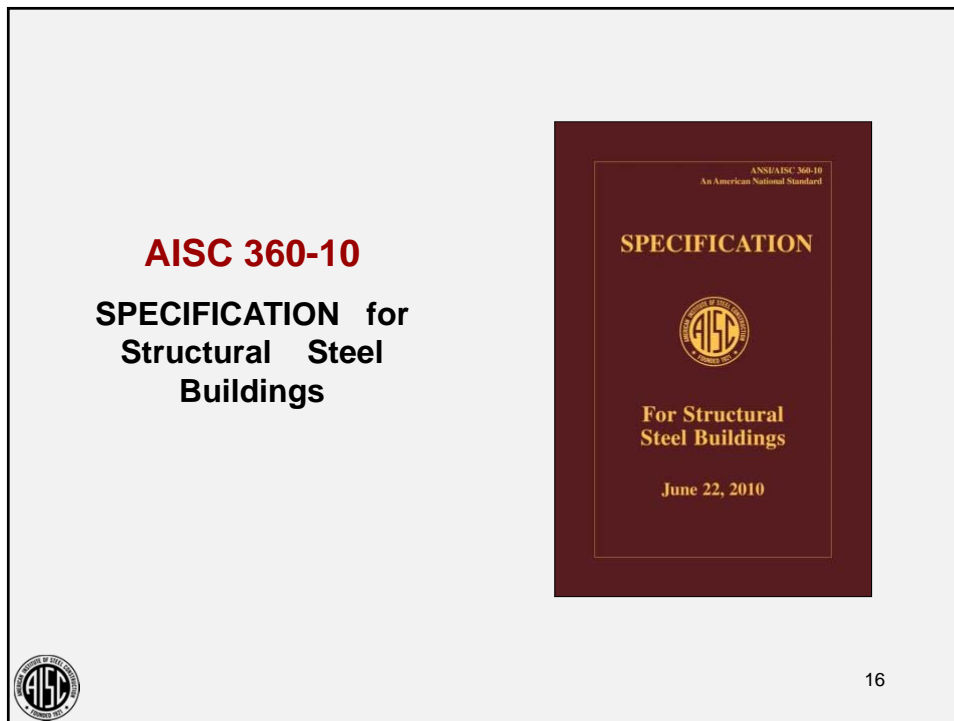
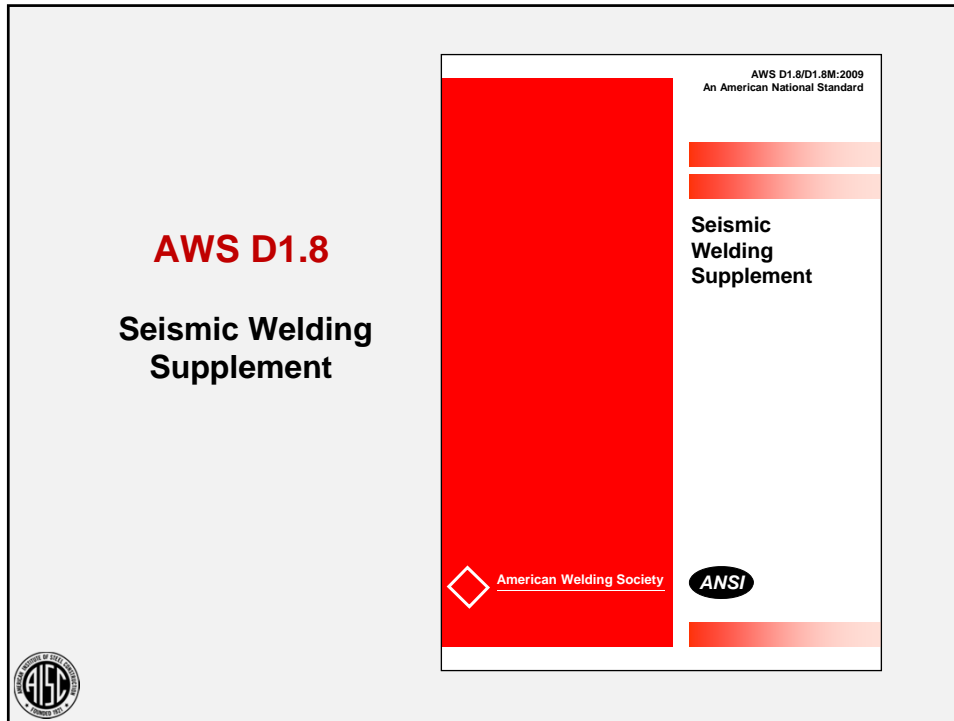
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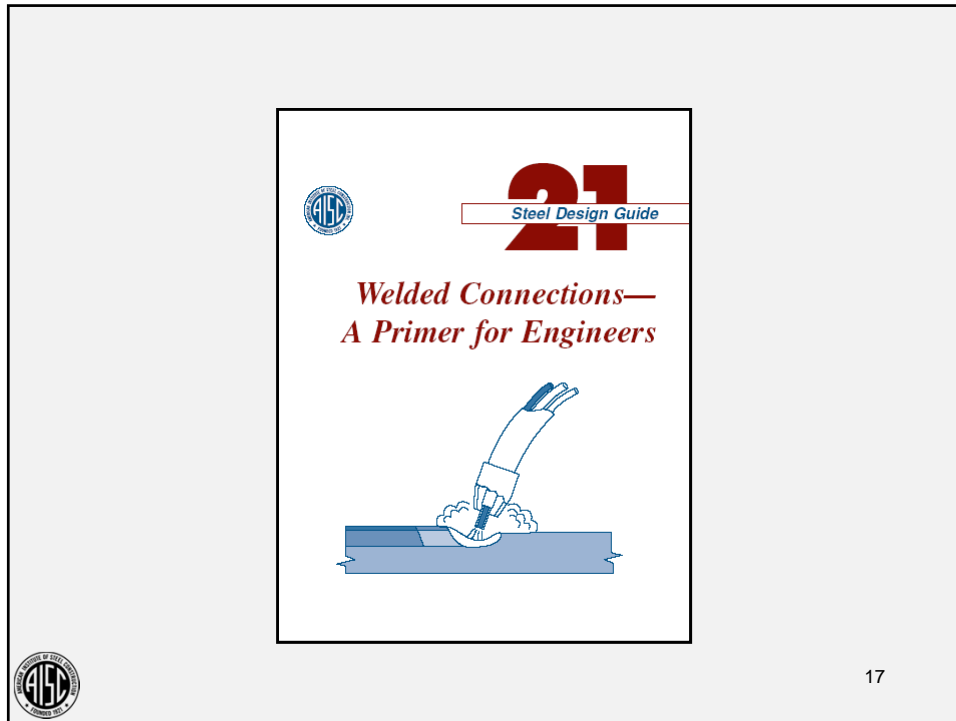
AWS D1.1

**Structural Welding Code—
Steel**









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Fundamentals of Welded Connections

Outline

- Applicable Codes
- ➔ • Welding Processes
- Joints and Weld Types
- CJP Details
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- Fillet Weld Details

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Arc Welding Processes

Major arc welding processes:

- Shielded Metal Arc Welding (SMAW)
- Flux Core Arc Welding (FCAW)
- Gas Metal Arc Welding (GMAW)
- Submerged Arc Welding (SAW)
- Electroslag Welding (ESW)
- Stud Welding (SW)
- Thermal Cutting



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AWS A3.0 Standard Welding Terms and Definitions

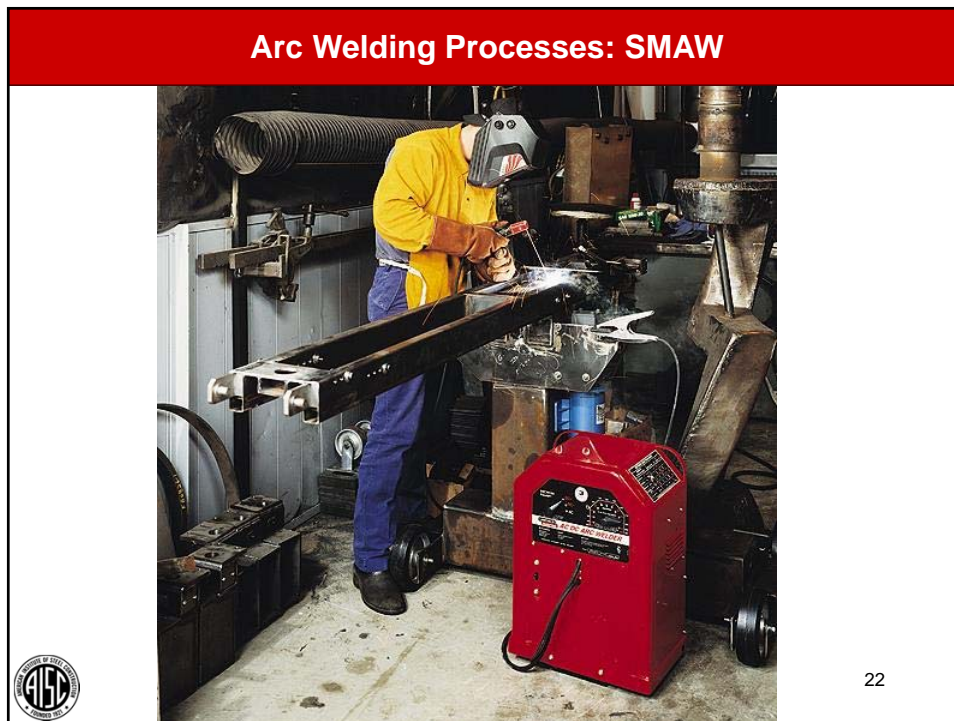
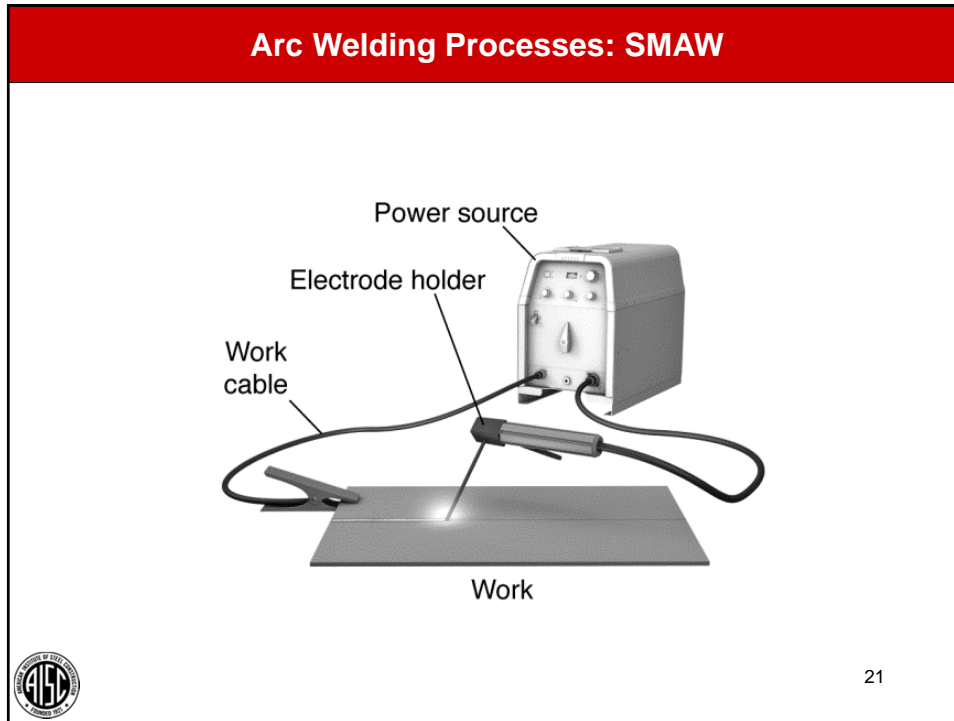


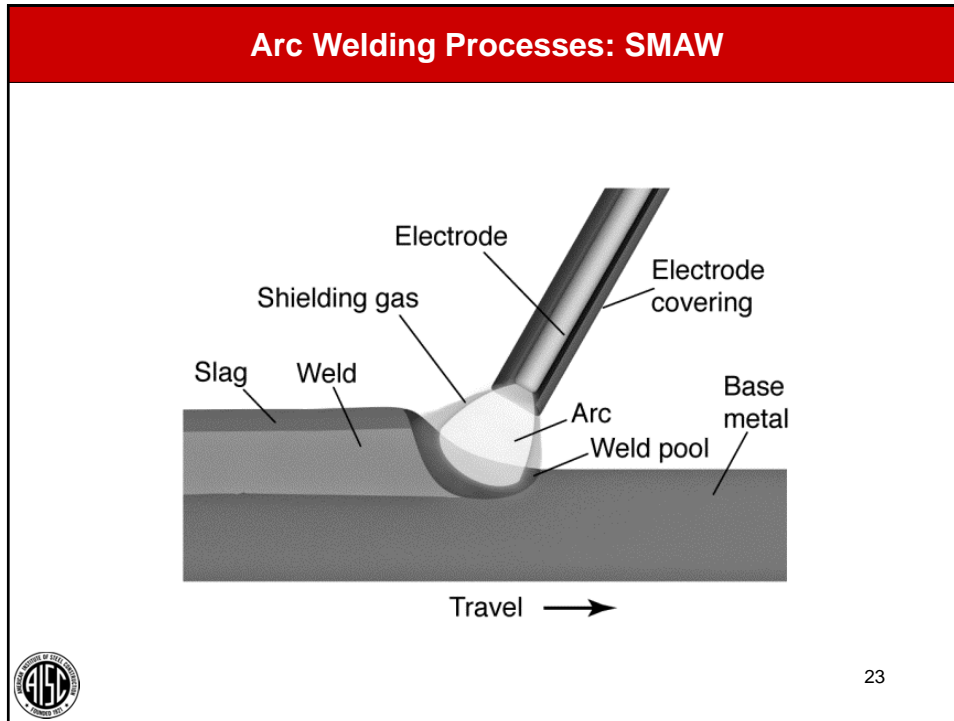
shielded metal arc welding (SMAW)

An arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode.



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ANSI Z49.1

**Safety in Welding, Cutting
and Allied Processes**

Available by free download
from AWS

aws.org

www.aws.org/technical/facts

ANSI Z49.1:2012
An American National Standard


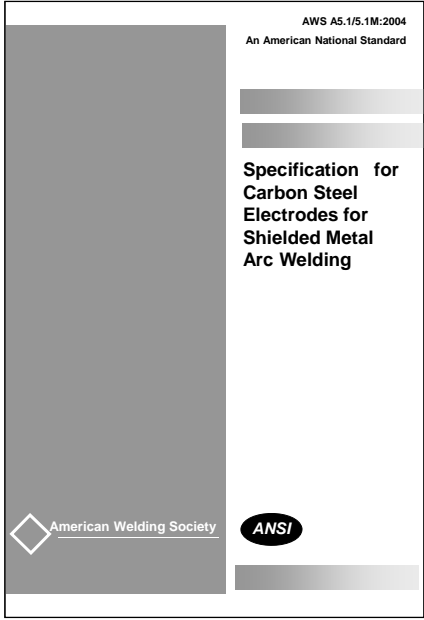
Safety in Welding,
Cutting, and
Allied Processes

American Welding Society®


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AWS A5.1

Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding



AWS A5 Filler Metal Specifications




E7018

E Electrode

70 ksi minimum specified tensile strength


1 = Position of welding

8 = Coating type, mechanical properties



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AWS A5 Filler Metal Specifications




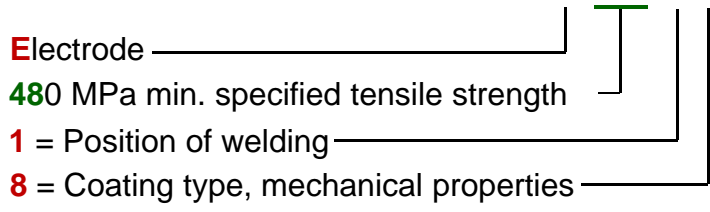
E4818

E Electrode

480 MPa min. specified tensile strength


1 = Position of welding

8 = Coating type, mechanical properties




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AWS A3.0 Standard Welding Terms and Definitions



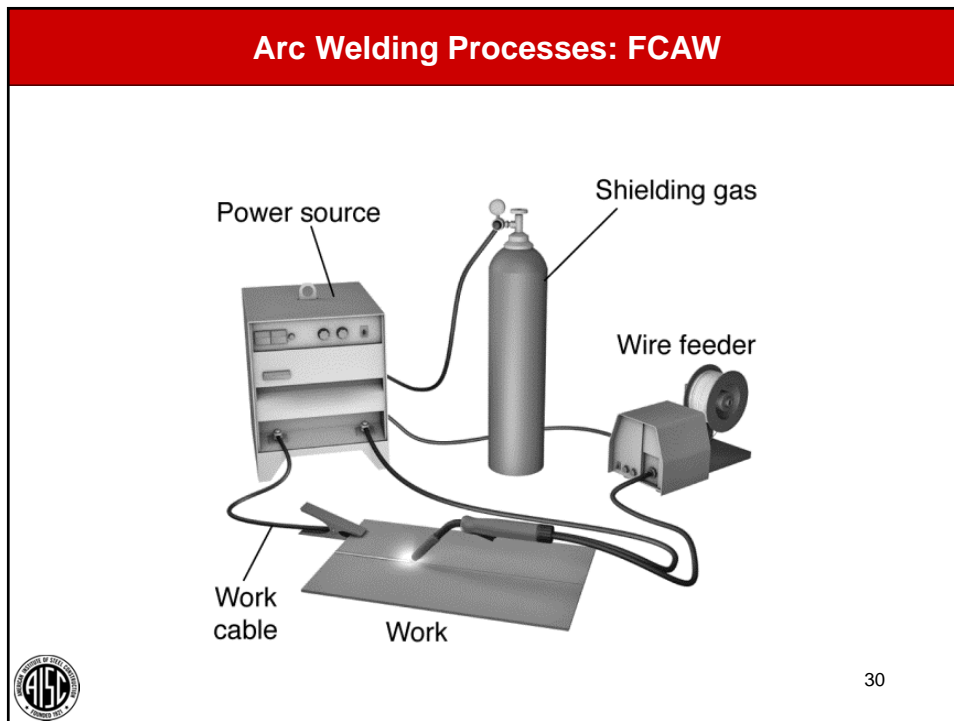
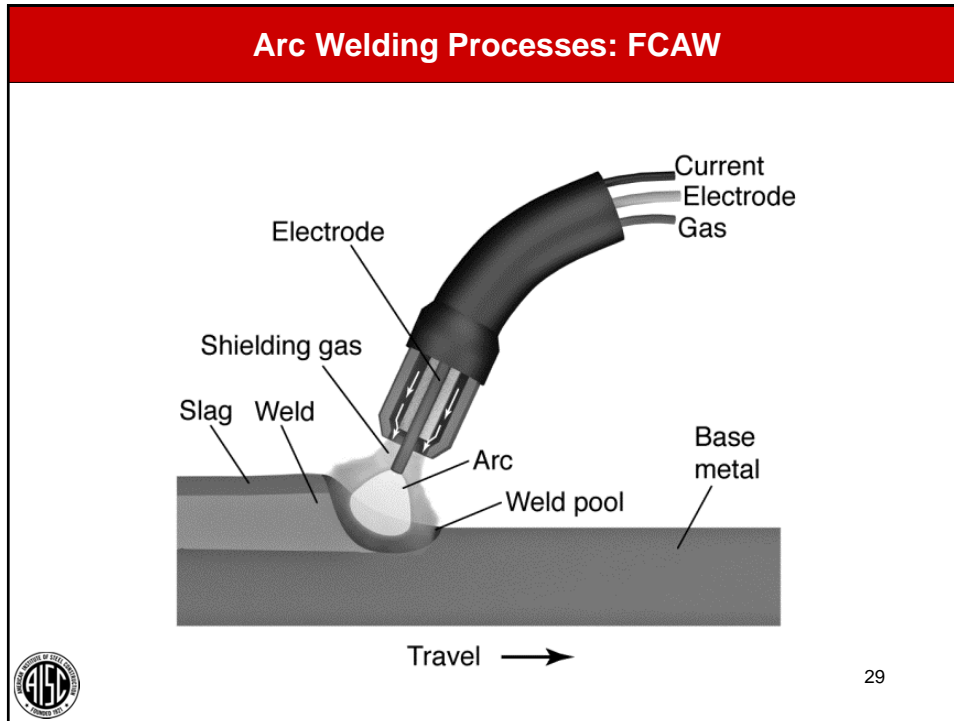
flux cored arc welding (FCAW).

An arc welding process using an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from a flux contained within the tubular electrode, with or without additional shielding gas, and without the application of pressure.



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AWS A3.0 Standard Welding Terms and Definitions



gas metal arc welding (GMAW).

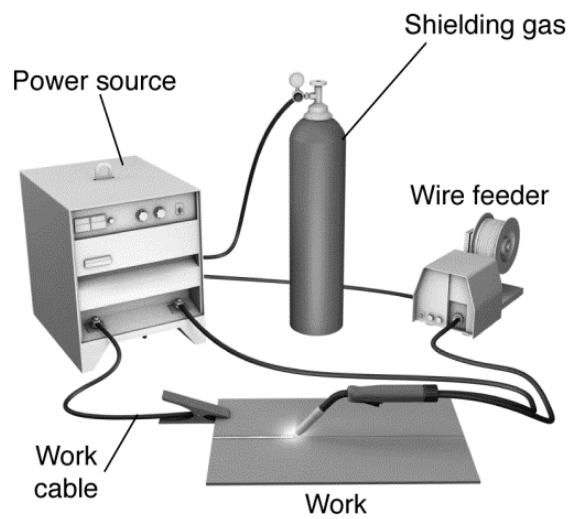
An arc welding process using an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

Note: may use solid electrode, or metal cored electrode.



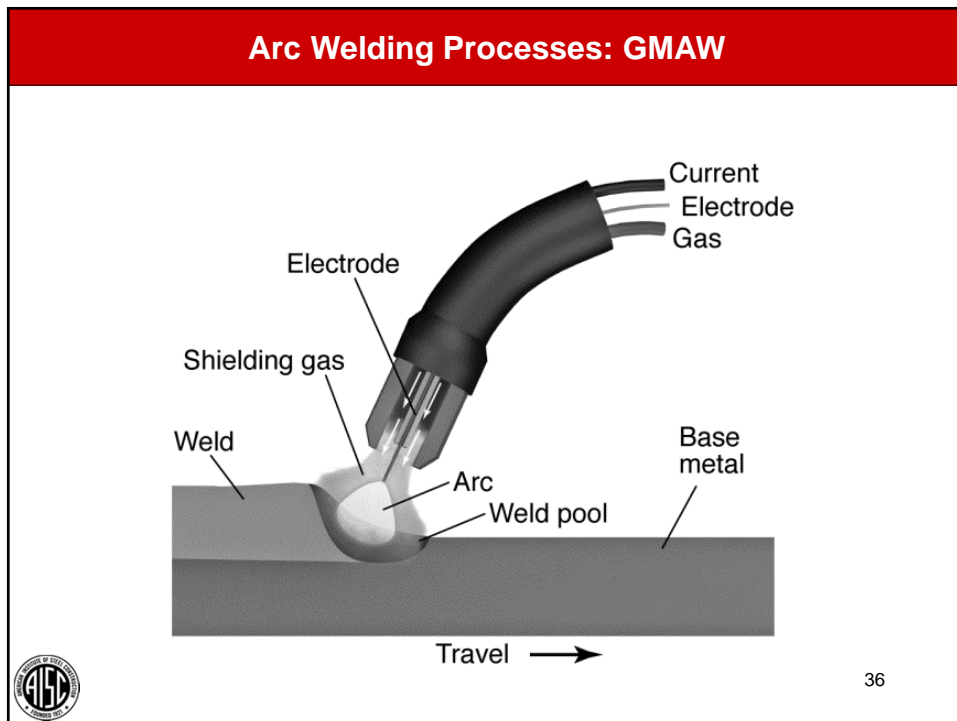
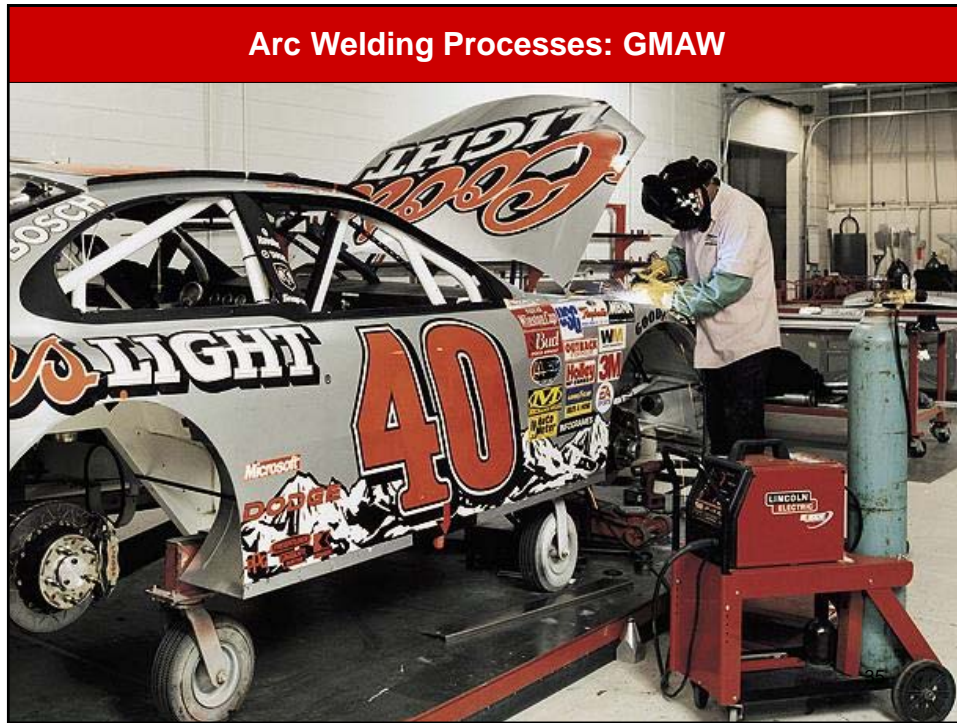
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Arc Welding Processes: GMAW



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AWS A3.0 Standard Welding Terms and Definitions



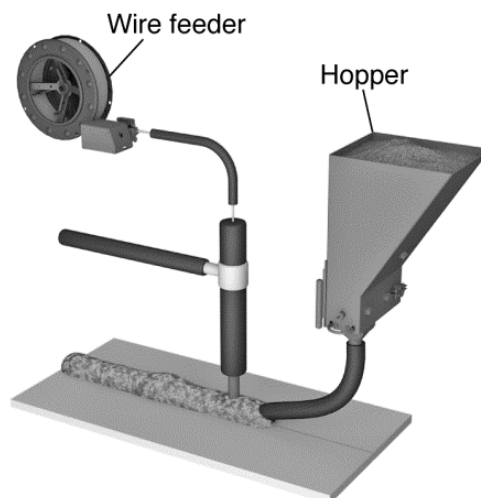
submerged arc welding (SAW).

An arc welding process using an arc or arcs between a bare metal electrode and the weld pool. The arc and molten metal are shielded by a blanket of granular flux on the workpieces. The process is used without pressure and with filler metal from the electrodes and sometimes from a supplemental source (welding rod, flux, or metal granules).

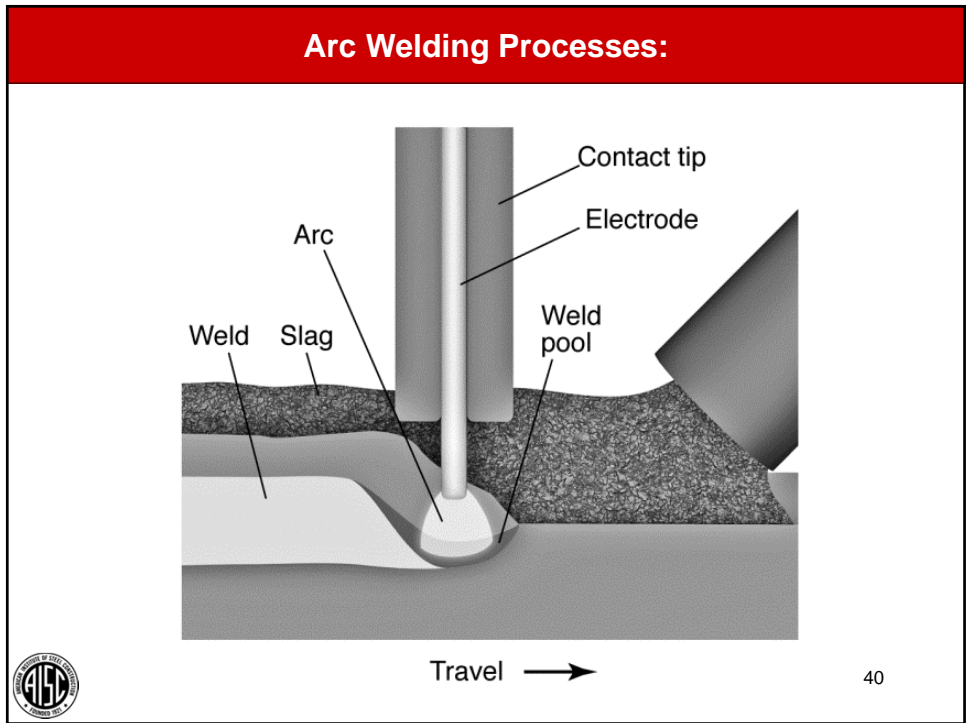
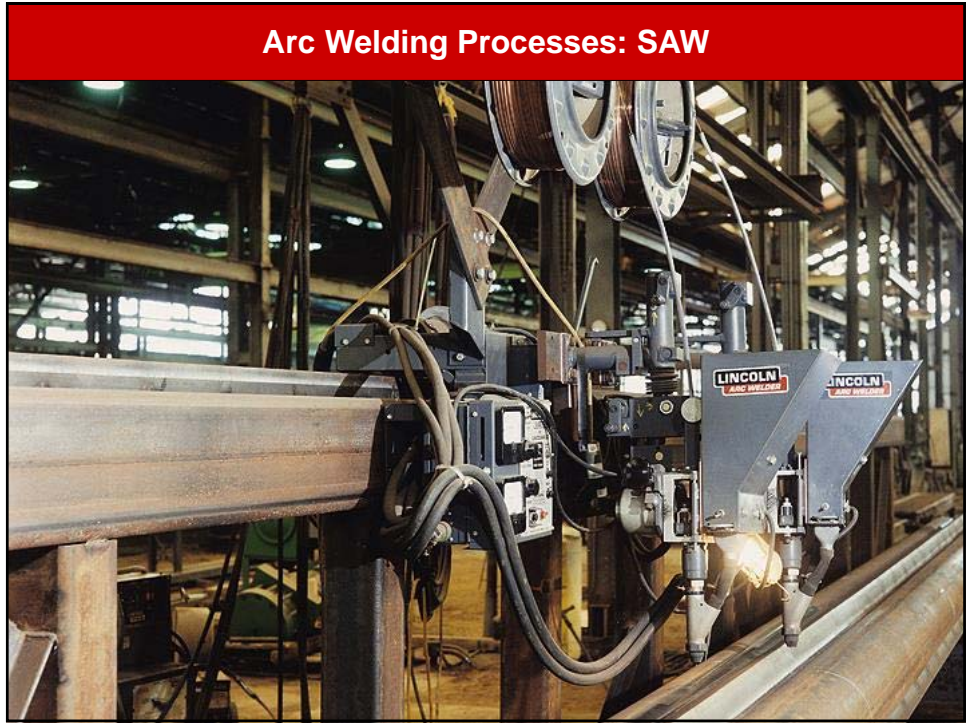


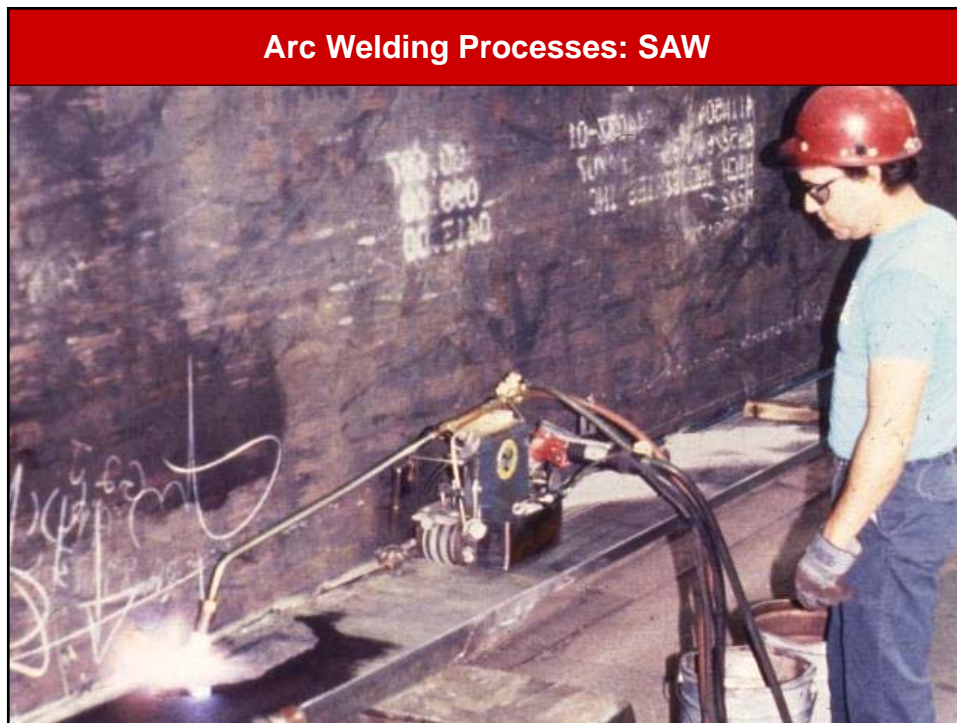
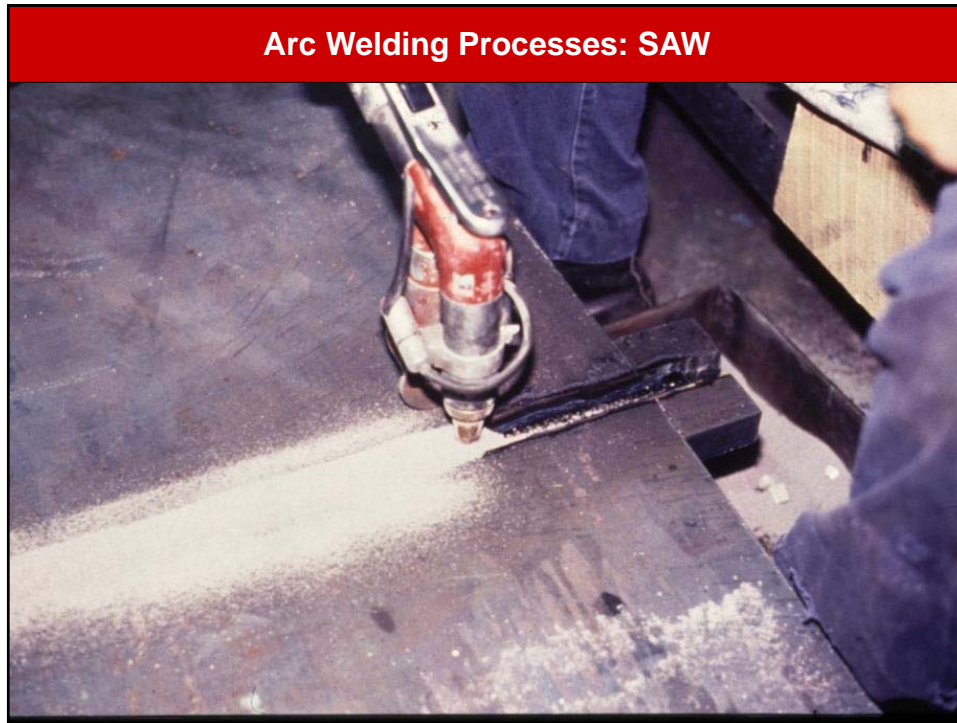
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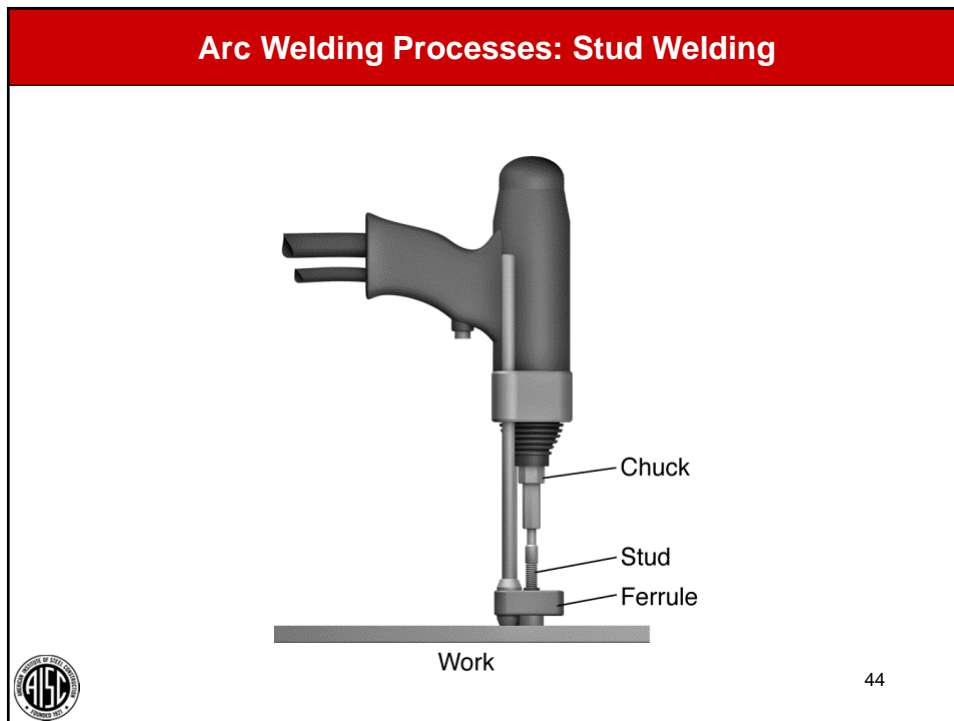
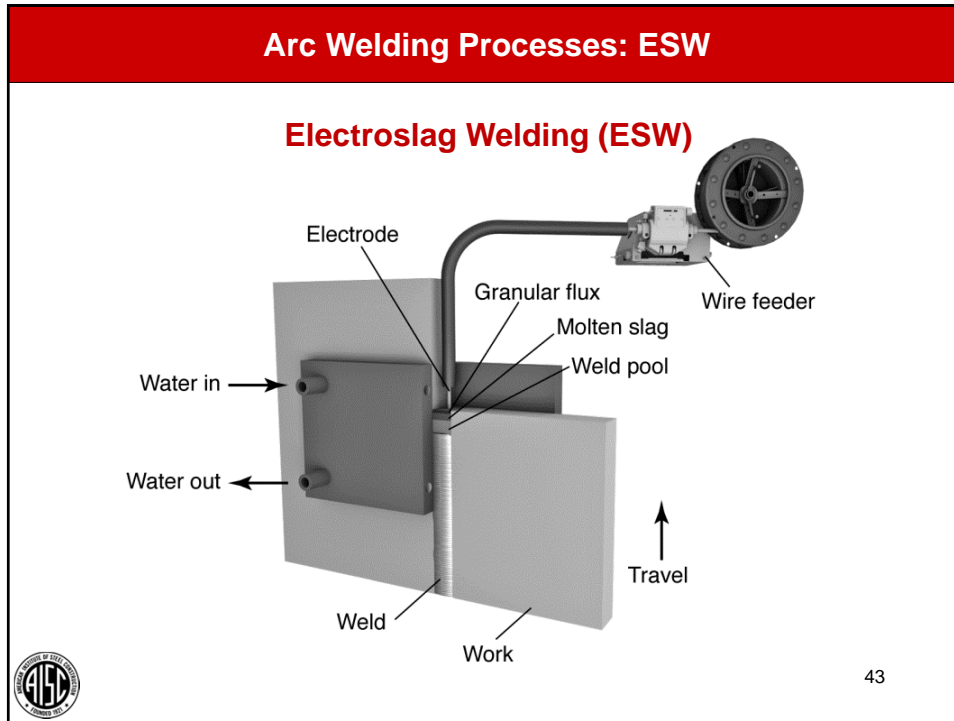
Arc Welding Processes: SAW

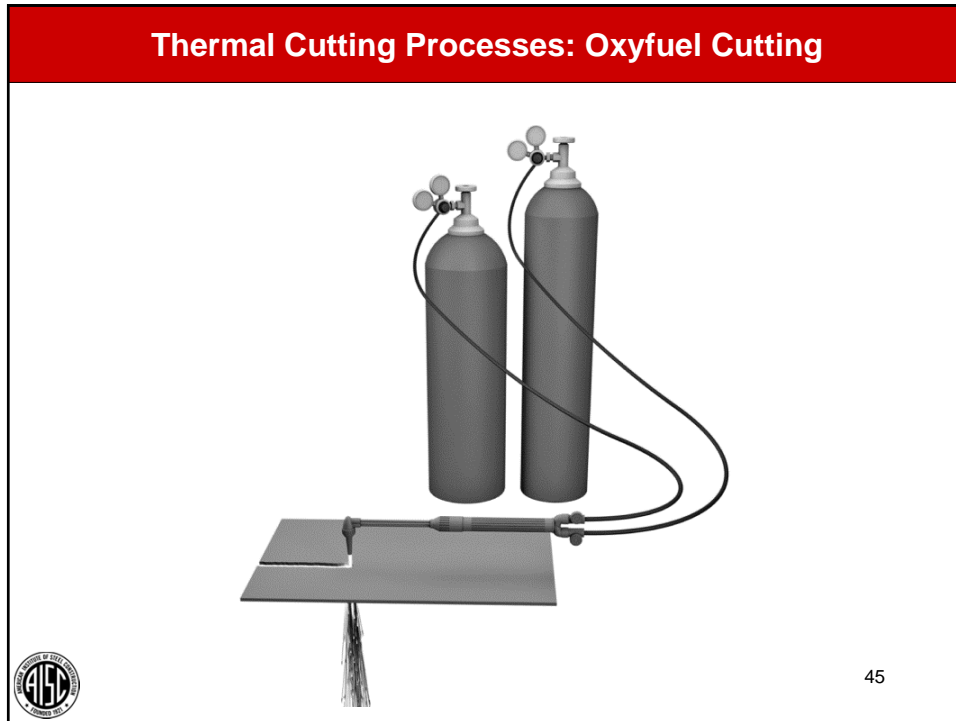


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Arc Welding Processes

The selection of which process to use is typically best left up to those doing the welding.

- Properly applied, all processes are capable of delivering quality welds
- Improperly applied, all processes may not deliver quality welds
- Mode of welding (manual, semiautomatic, automatic, robotic) will impact process selection



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Arc Welding Processes

Typical welding process applications:

- **GMAW:** for shop welding on clean parts; often the choice for robotic applications
- **FCAW-G:** for shop welding on dirtier parts
- **FCAW-S:** for field welding
- **SAW:** for big, long welds that lend themselves to automation
- **ESW:** flange splicing, stiffeners on box columns
- **SMAW:** maintenance welding, field welding, tack welding, repair welding, miscellaneous fabrication




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Fundamentals of Welded Connections

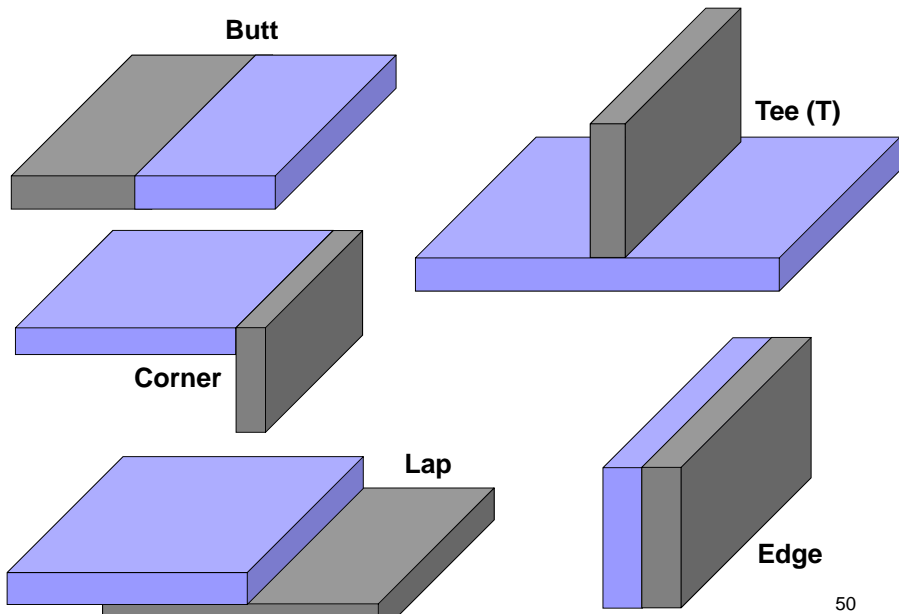
Outline

- Applicable Codes
- Welding Processes
- ➔ • Joints and Weld Types
- CJP Details
- PJP Details
- Fillet Weld Details



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JOINTS




The diagram illustrates five types of welded joints:

- Butt:** Two plates are joined end-to-end.
- Tee (T):** A vertical plate is welded to the center of a horizontal plate.
- Corner:** Two plates are joined at a 90-degree angle.
- Lap:** Two plates overlap and are welded together.
- Edge:** Two plates are joined along one edge.

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WELD TYPES

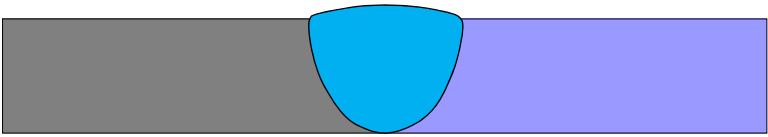
- **Complete Joint Penetration Groove Welds (CJP)**
 - “complete penetration welds”
 - “full pen welds”
 - “butt welds”
- **Partial Joint Penetration Groove Welds (PJP)**
 - “partial penetration”
 - “partial pen”
- **Fillet Welds**
- **Slot Welds**
- **Plug Welds**




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WELD TYPES

CJP Groove Weld in Butt Joint



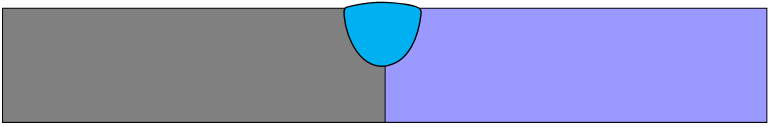
The diagram shows a cross-section of a butt joint between two steel plates. The left plate is shaded grey and the right plate is shaded light blue. A bright blue, semi-circular weld metal is shown filling the groove between the two plates, extending slightly above and below the original surface level of the plates, indicating complete penetration.




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WELD TYPES

PJP Groove Weld in Butt Joint



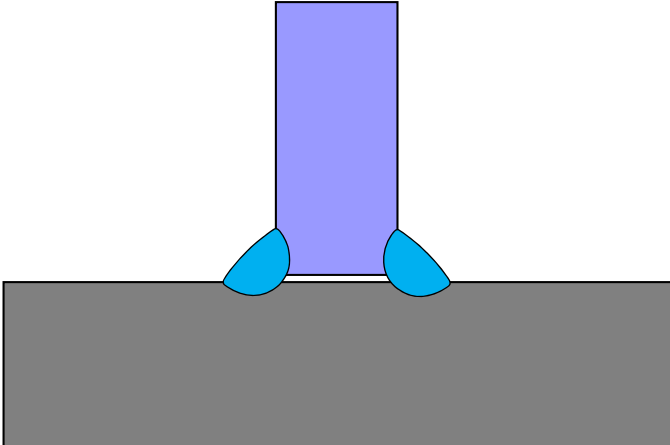
The diagram shows two horizontal rectangular plates, one grey on the left and one purple on the right, joined at their ends. A blue, semi-circular weld bead is shown at the joint, representing a groove weld. The weld bead is shaded blue to indicate its profile.




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WELD TYPES

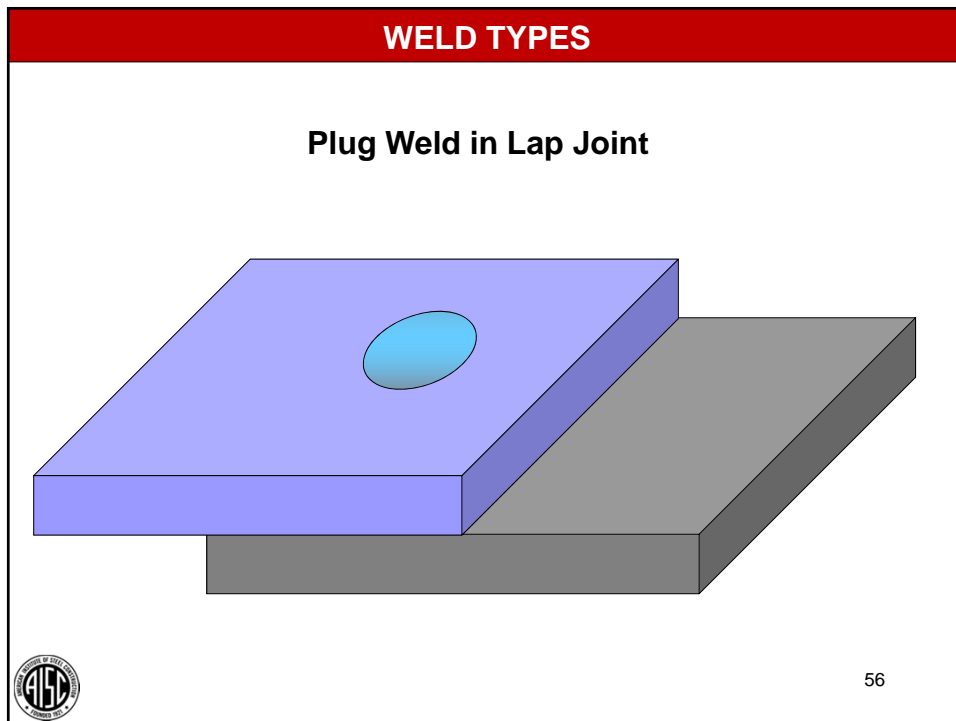
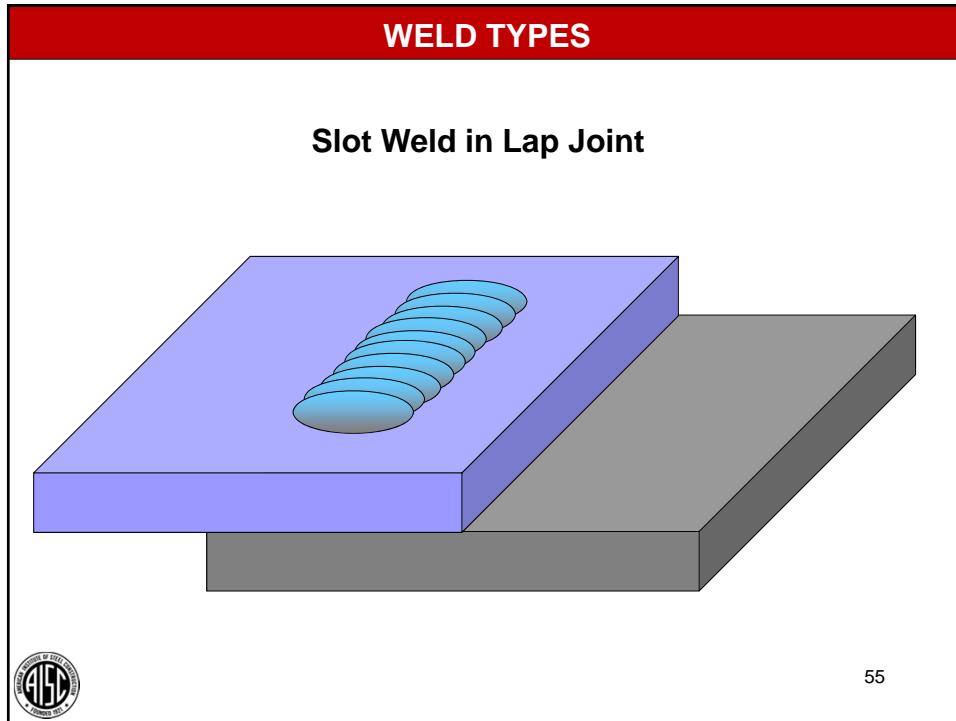
Fillet Welds in a Tee Joint

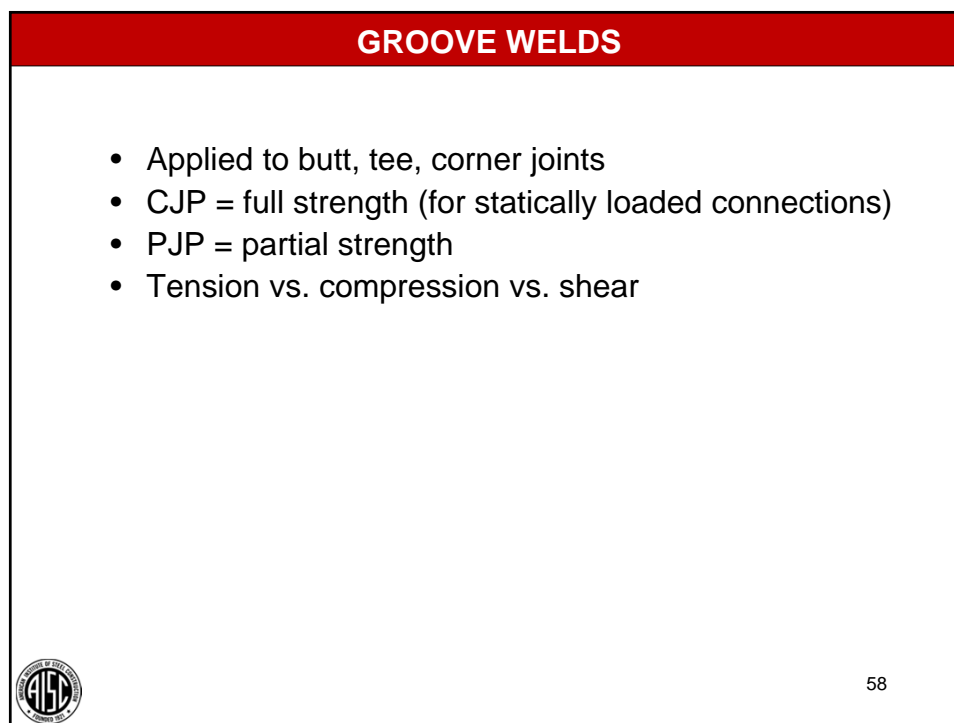
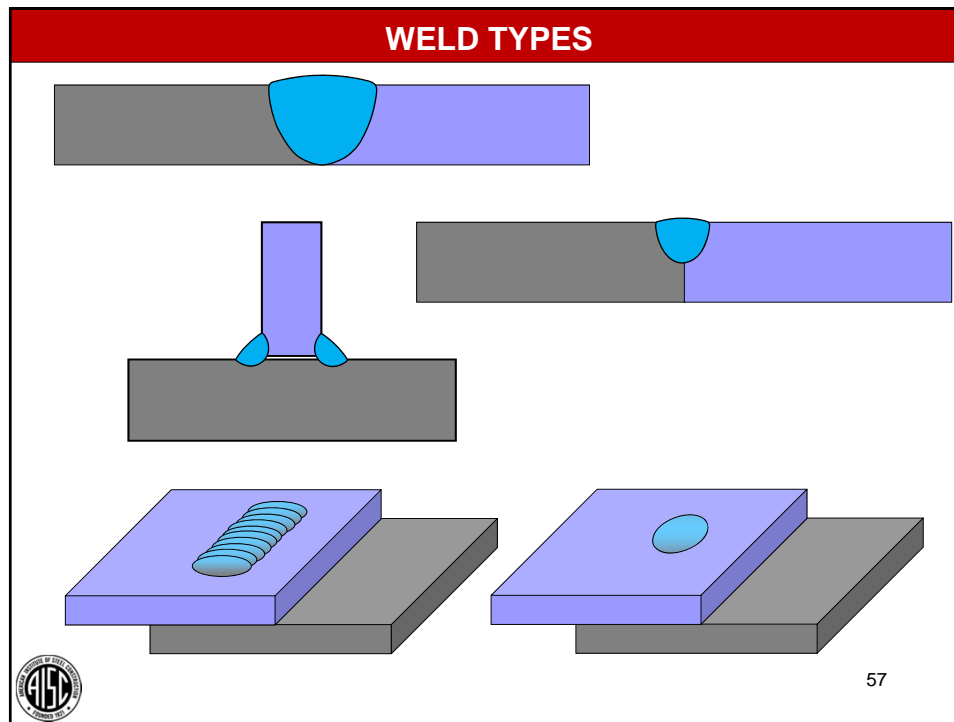


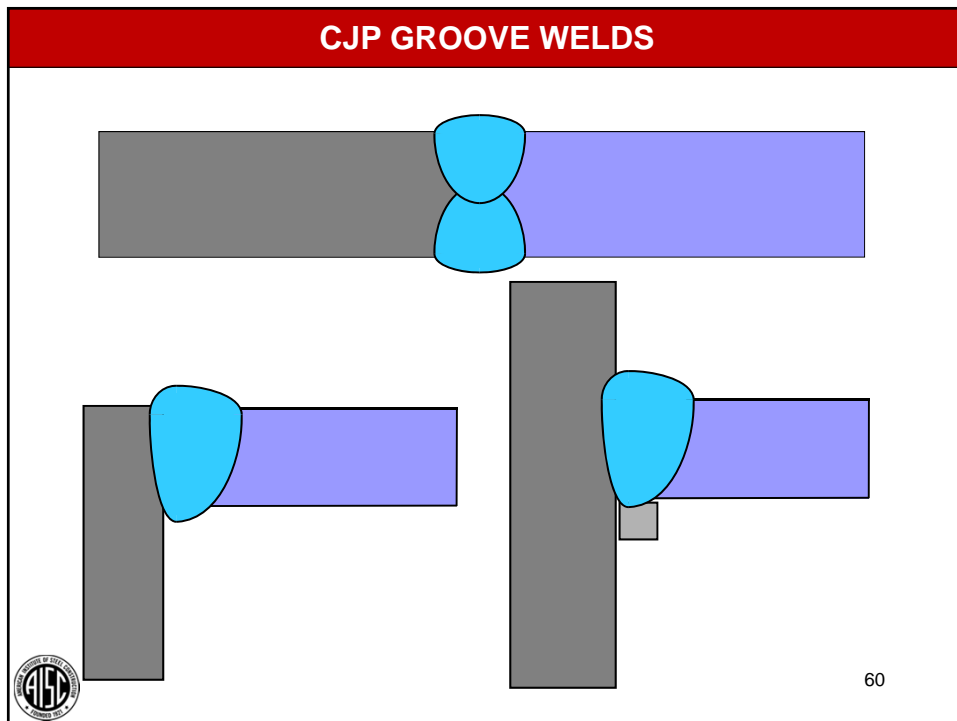
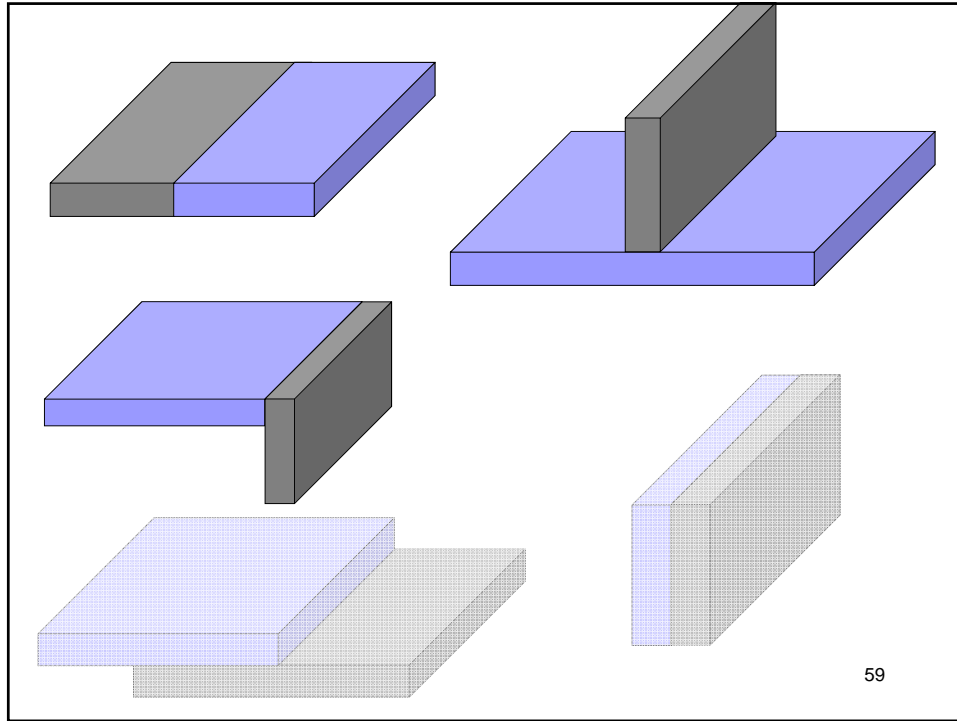
The diagram shows a vertical purple rectangular plate (stem) attached to a horizontal grey rectangular plate (base). Two blue, teardrop-shaped weld beads are shown at the junction, representing fillet welds. The weld beads are shaded blue to indicate their profile.



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CJP GROOVE WELDS

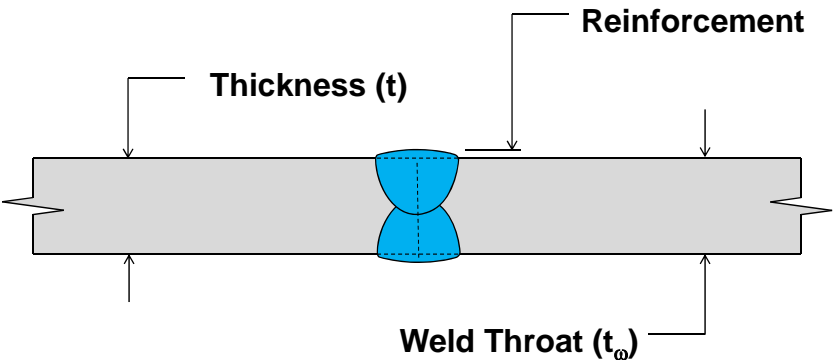
- Throat = plate thickness




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CJP GROOVE WELD

Weld Throat Dimension (t_w)



The diagram illustrates a cross-section of a CJP groove weld. Two gray plates of thickness t are joined by a blue groove weld. The weld throat dimension is labeled t_w . A reinforcement bar is shown above the weld. Arrows indicate the dimensions: Thickness (t), Reinforcement, and Weld Throat (t_w).



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CJP GROOVE WELDS

- Throat = plate thickness
- No design calculations are required for statically loaded connections, when “matching” filler metal is used.

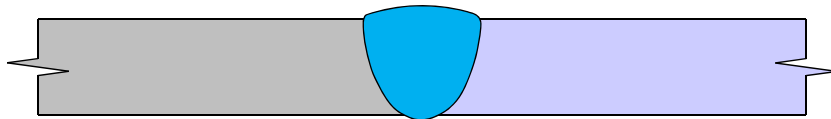


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CJP GROOVE WELDS

Complete Joint Penetration Groove Weld (CJP)

Single sided

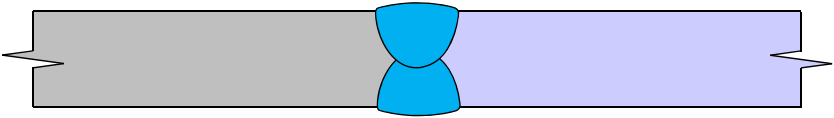


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CJP GROOVE WELDS

Complete Joint Penetration Groove Weld (CJP)

Double sided



The diagram shows two steel plates, one grey and one light blue, joined by a double-sided groove weld. The weld is represented by two blue, teardrop-shaped regions meeting at the center of the joint. The plates have jagged ends on the left and right sides, indicating they are part of a larger structure.

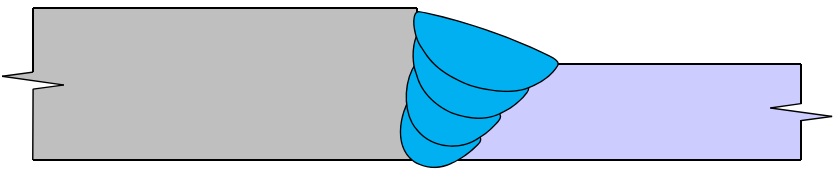


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CJP GROOVE WELDS

Complete Joint Penetration Groove Weld (CJP)

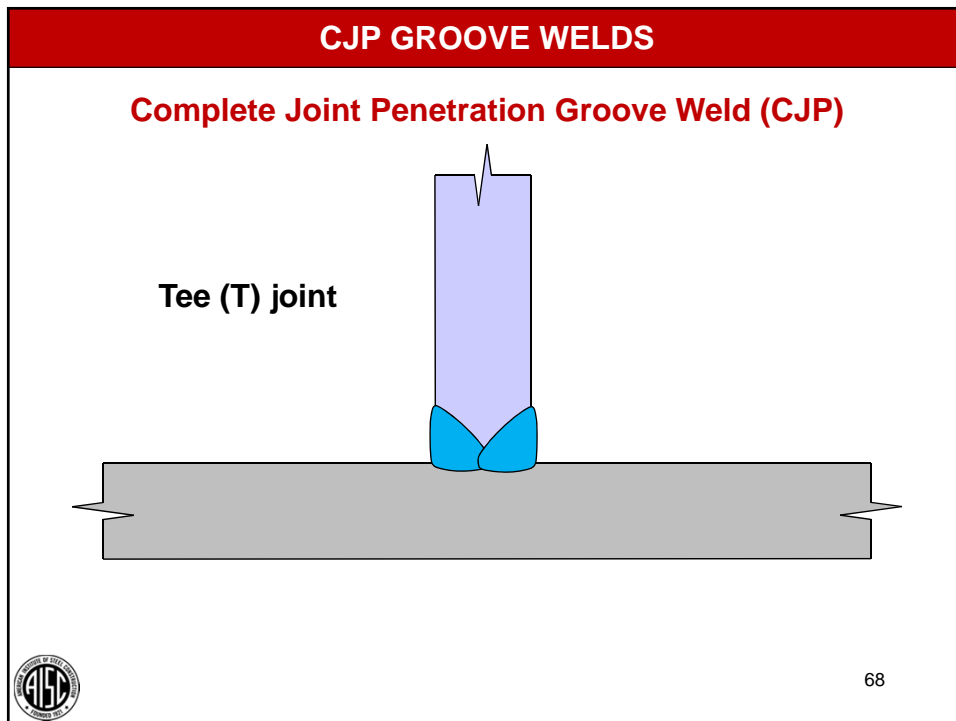
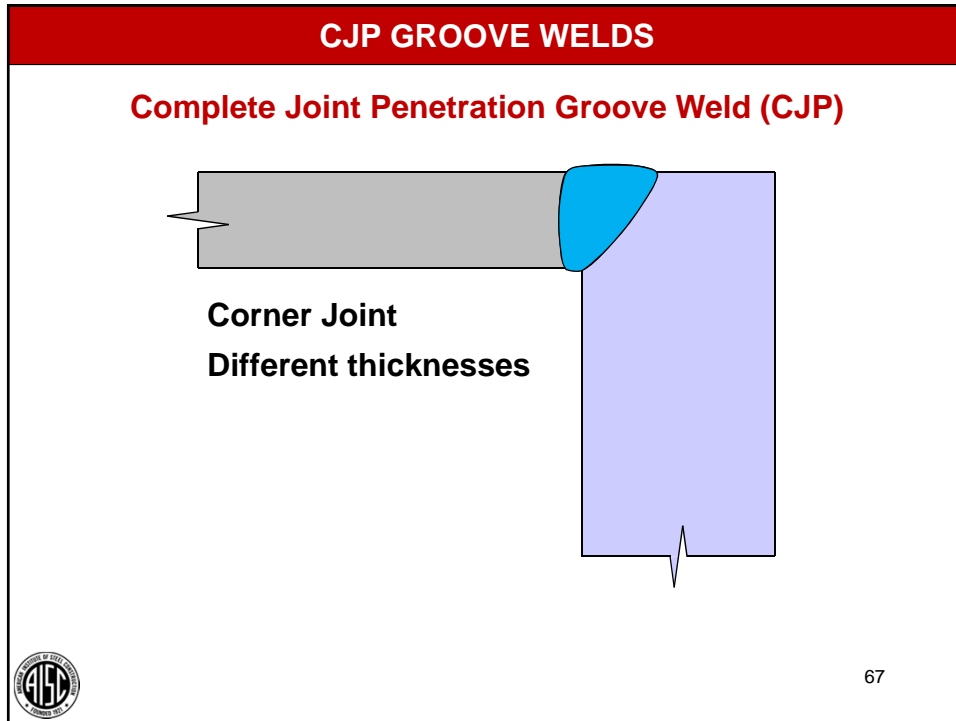
Two thicknesses

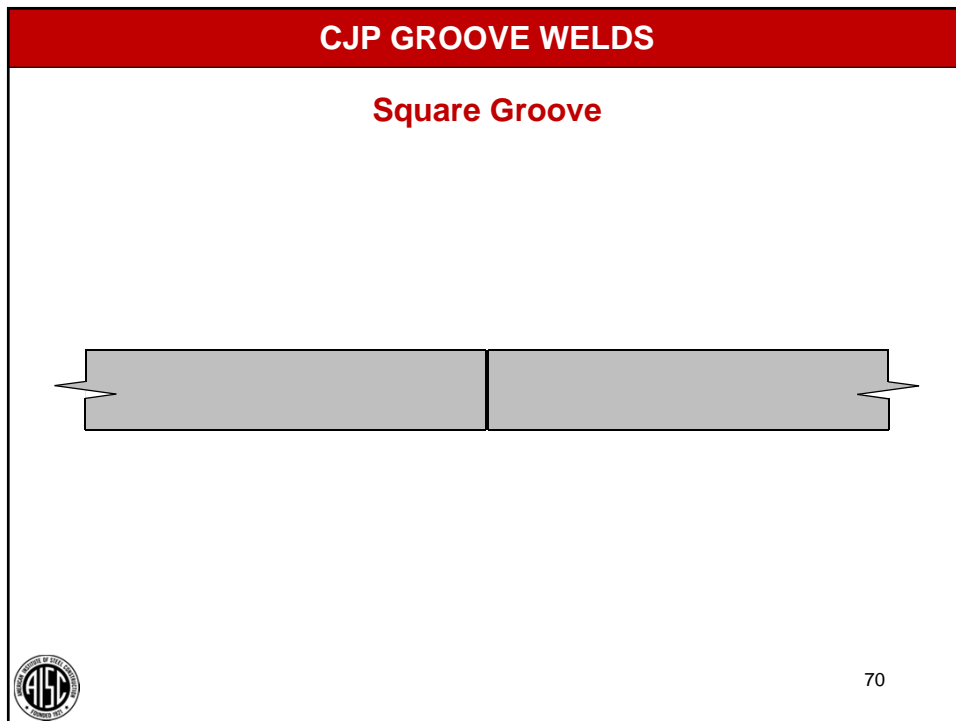
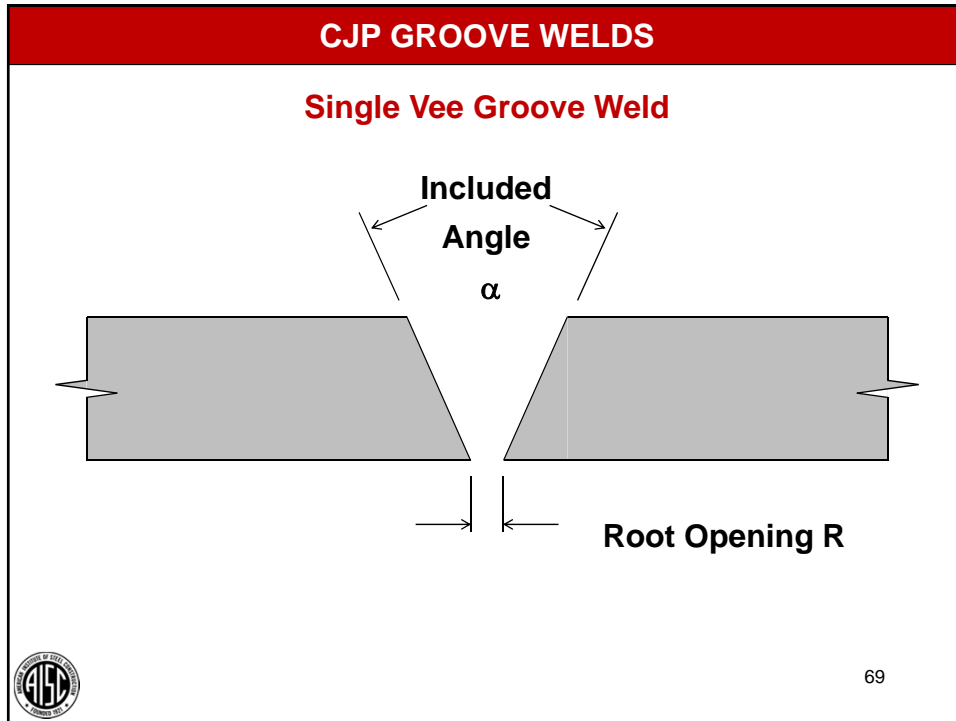


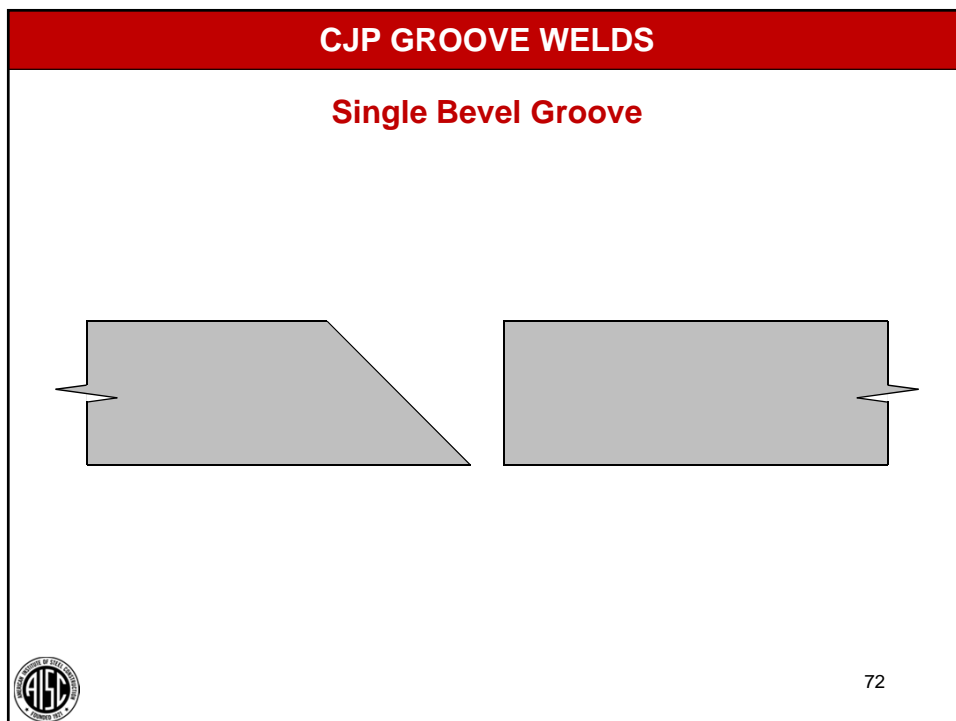
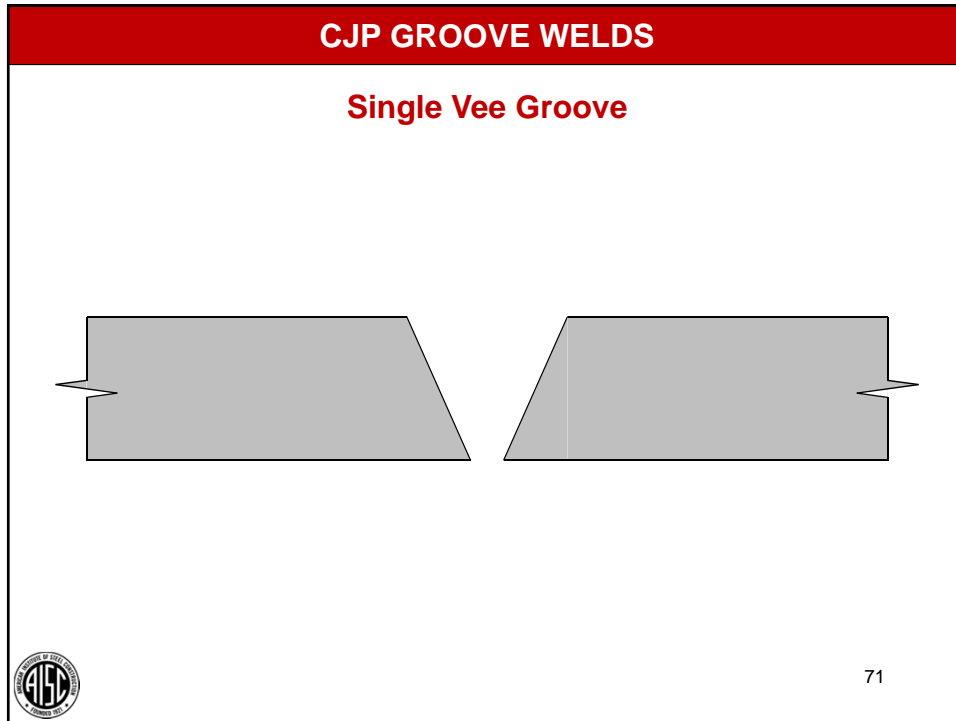
The diagram shows two steel plates, one grey and one light blue, joined by a two-thickness groove weld. The weld is represented by three blue, teardrop-shaped regions stacked on top of each other at the center of the joint. The plates have jagged ends on the left and right sides, indicating they are part of a larger structure.

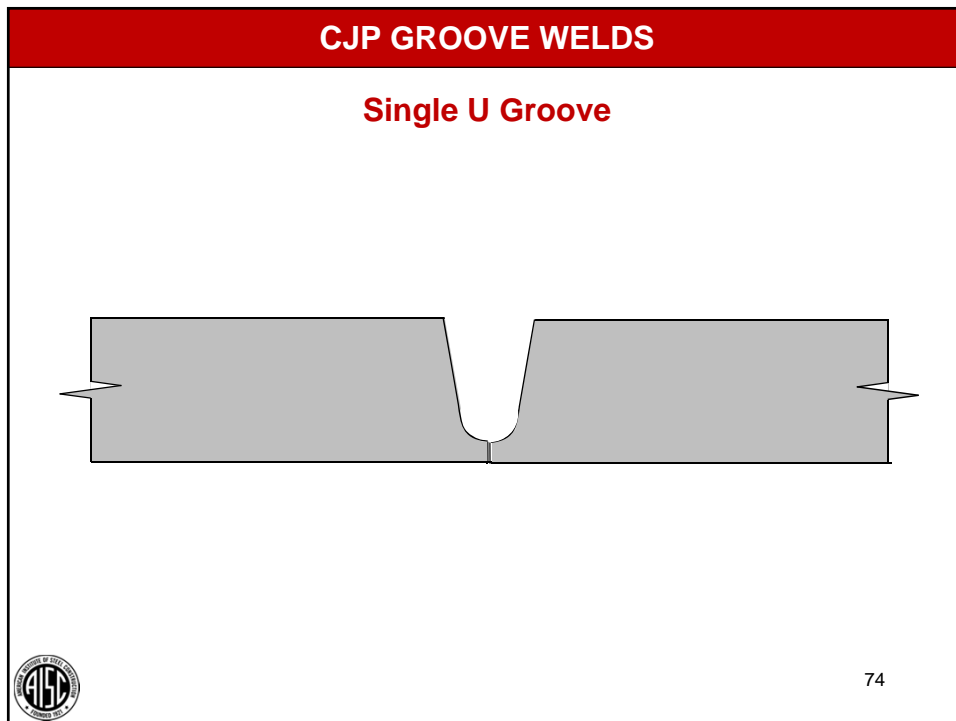
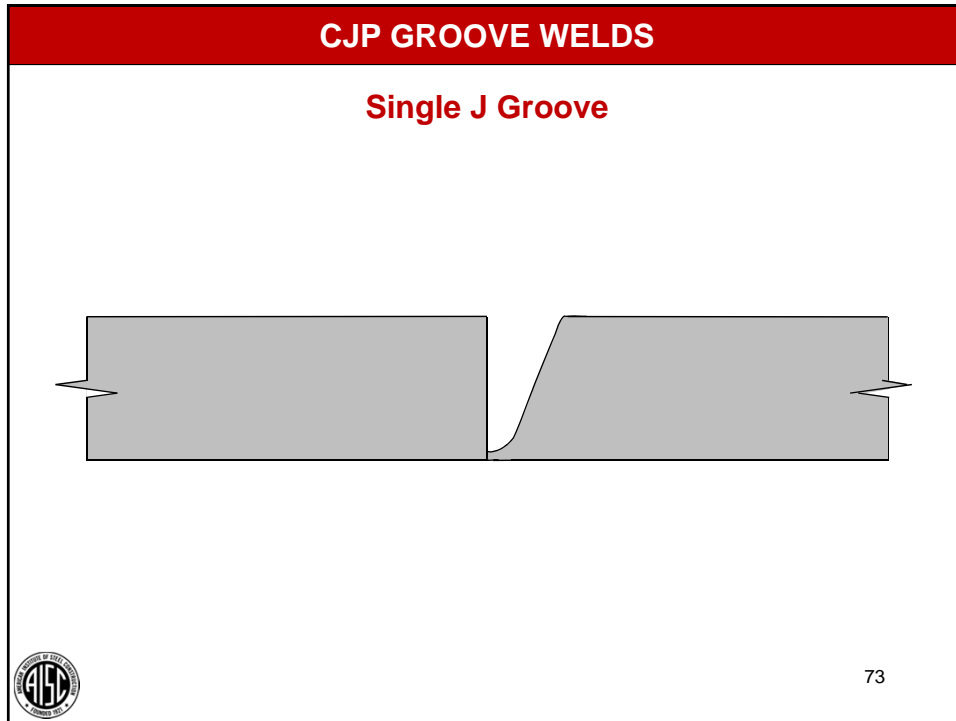


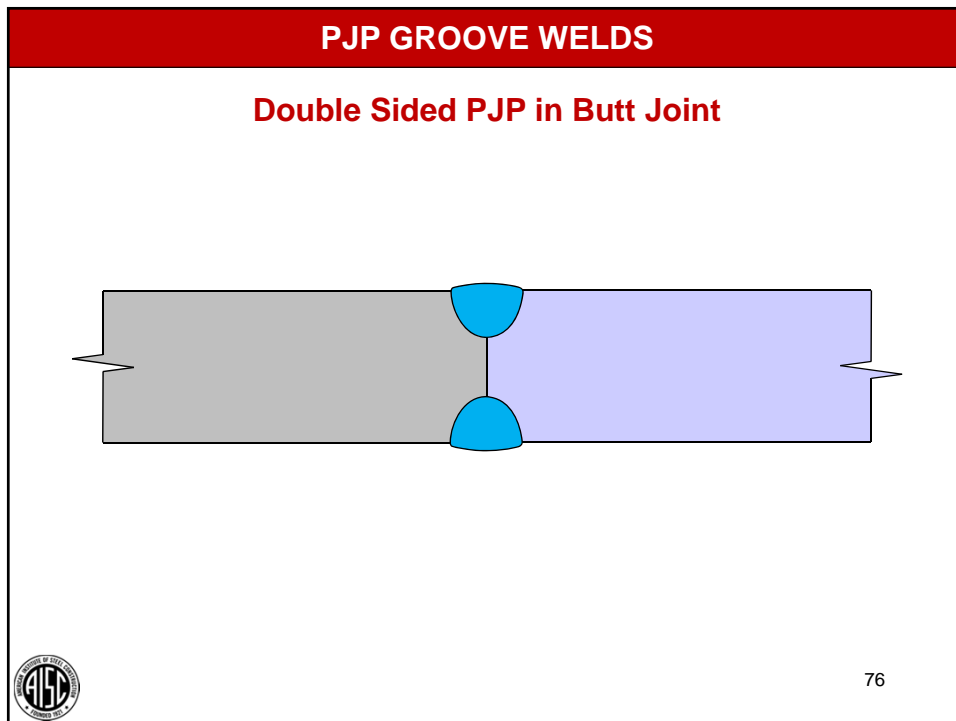
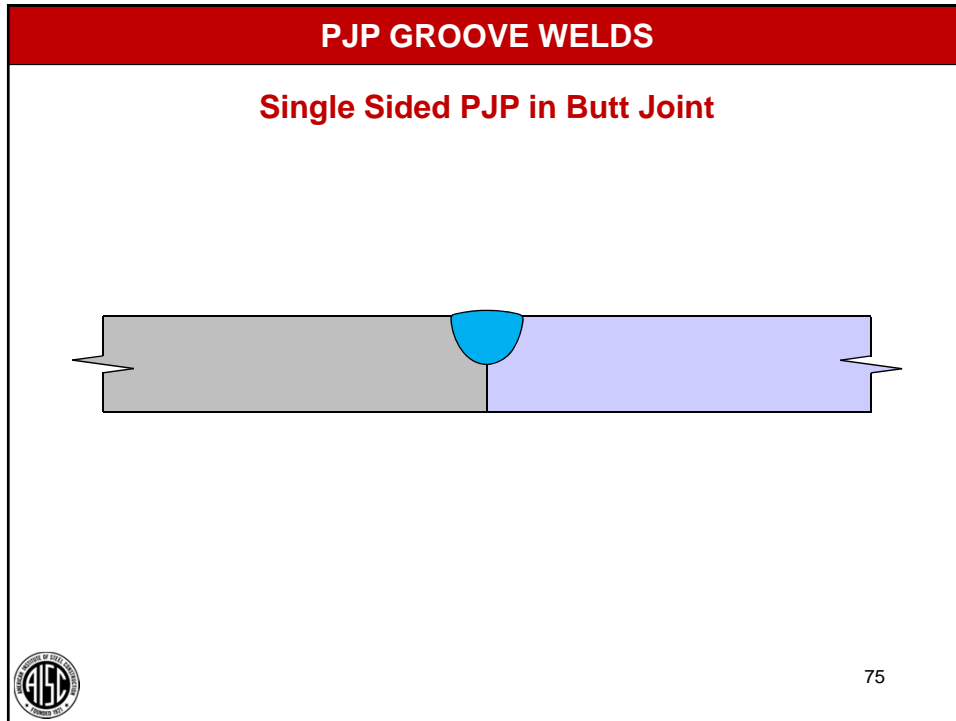
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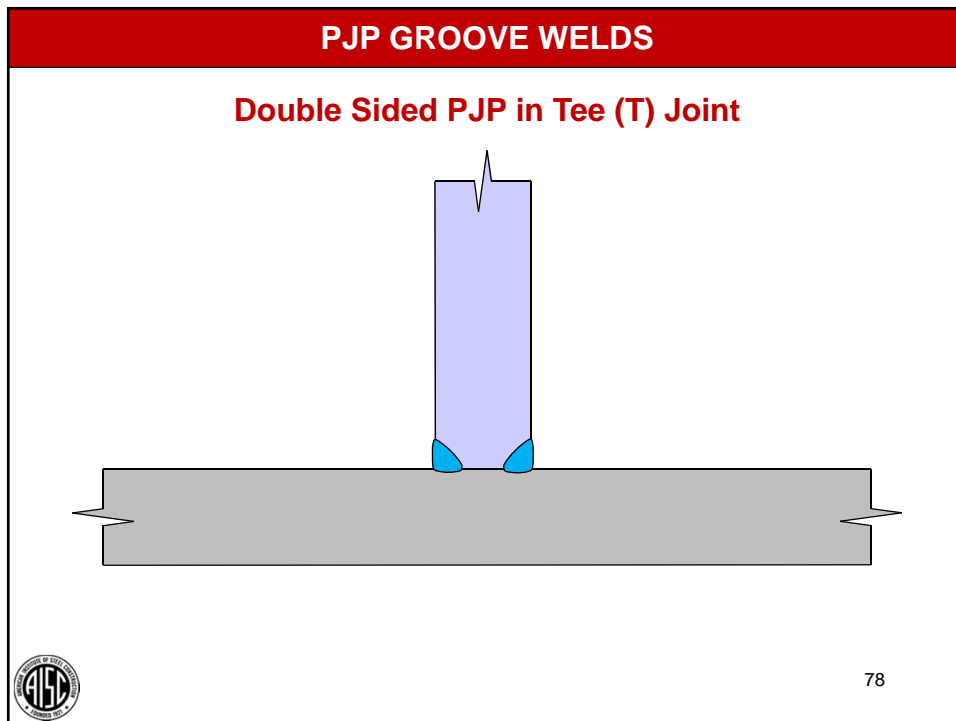
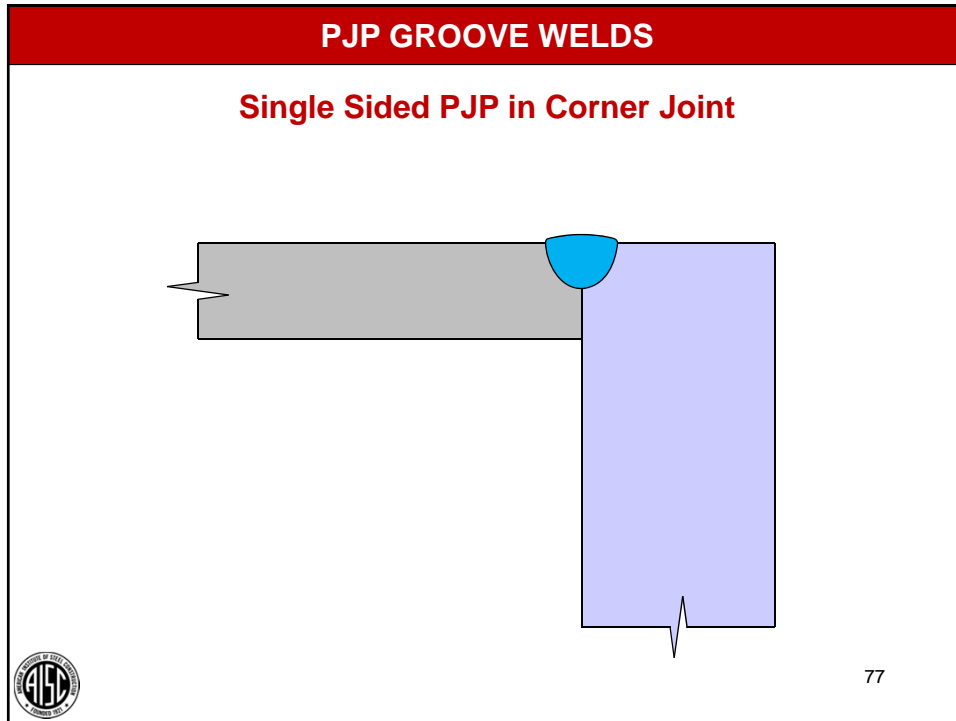


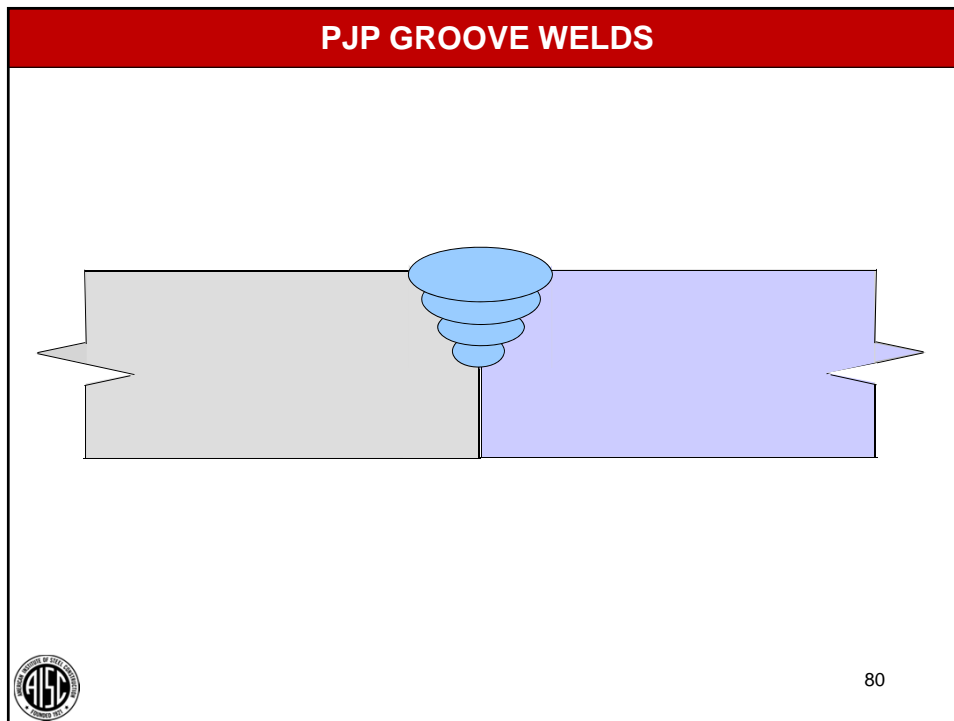
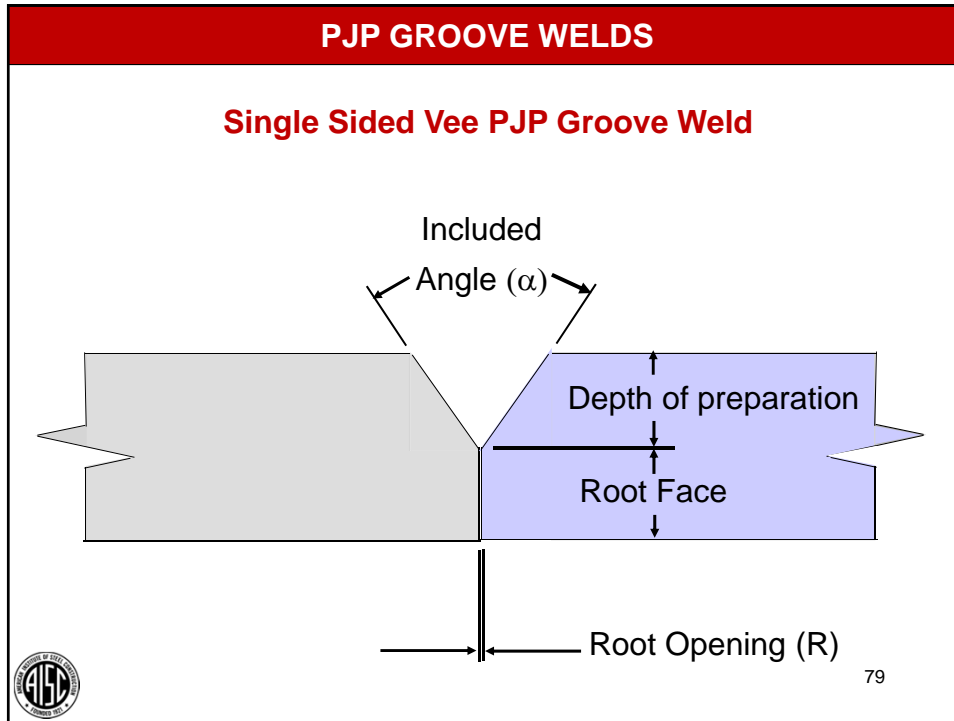


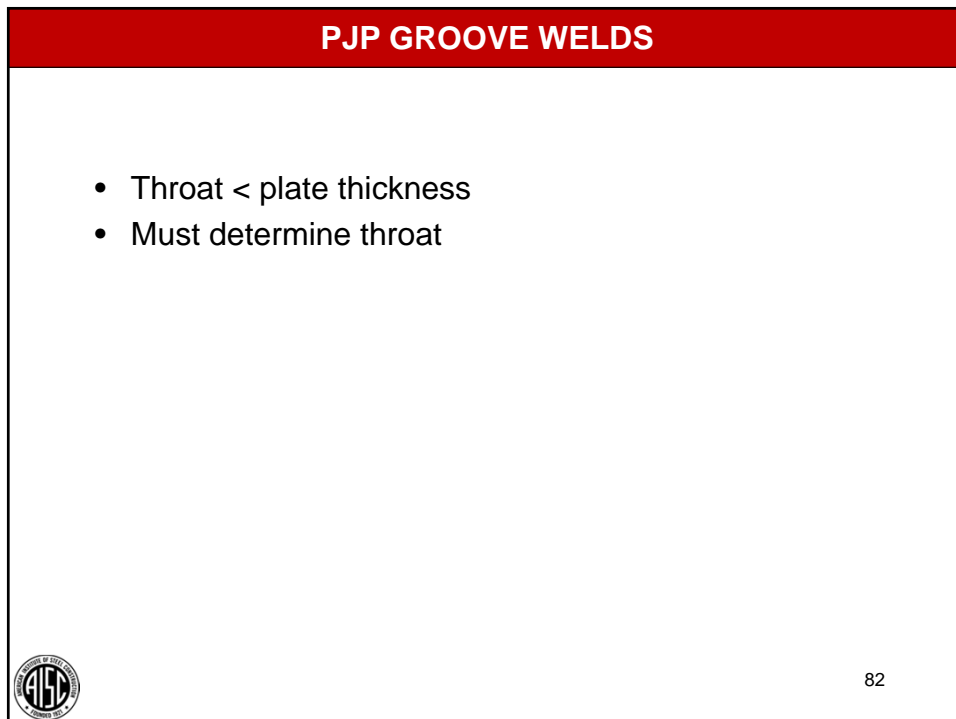
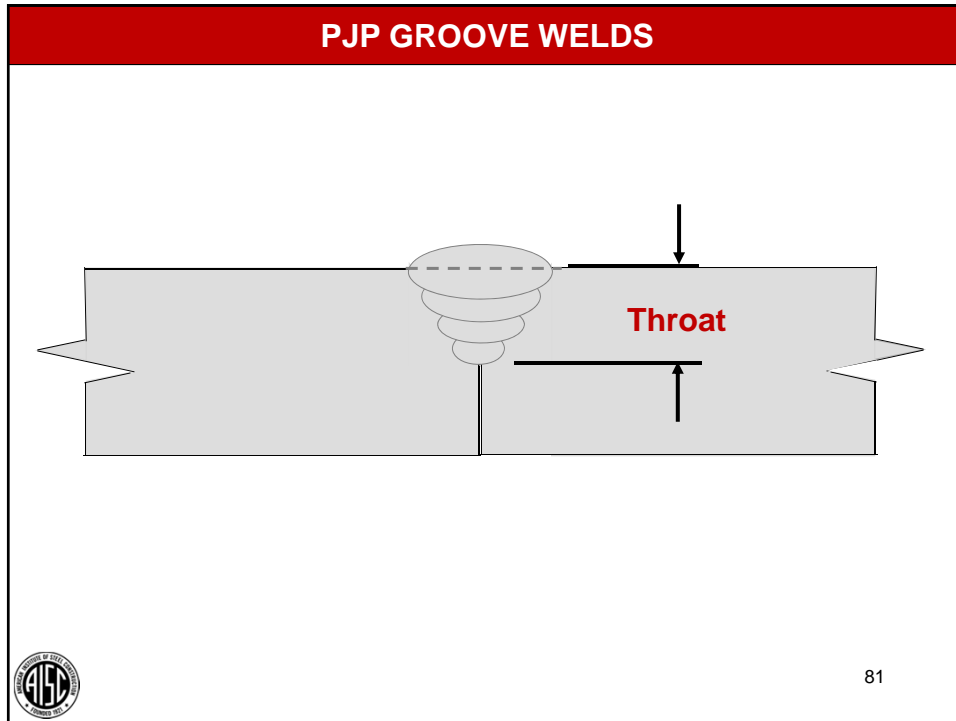


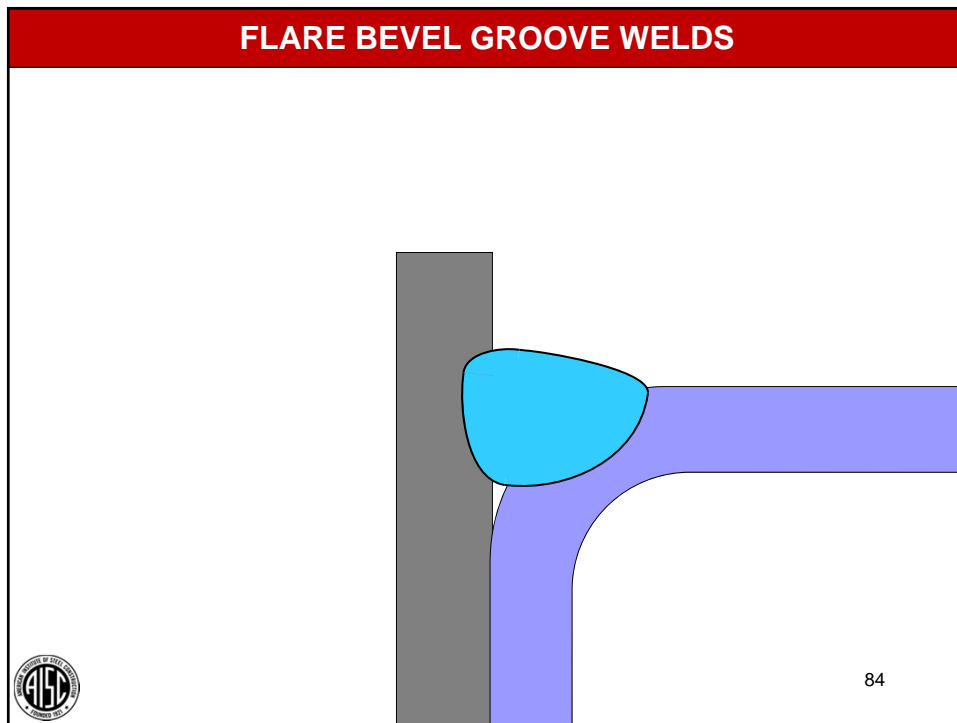
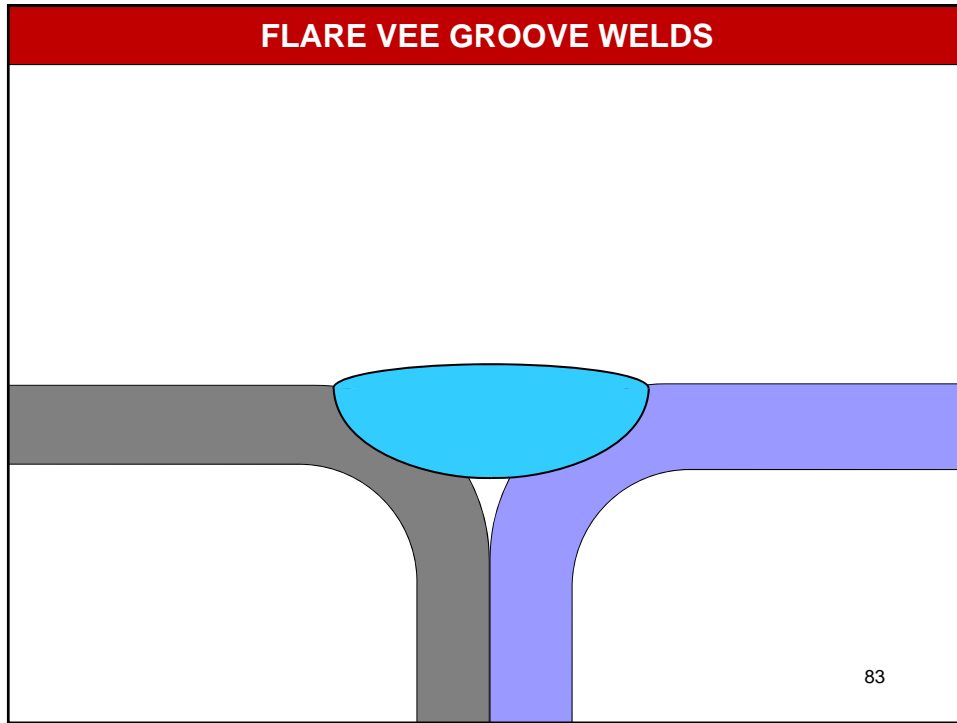


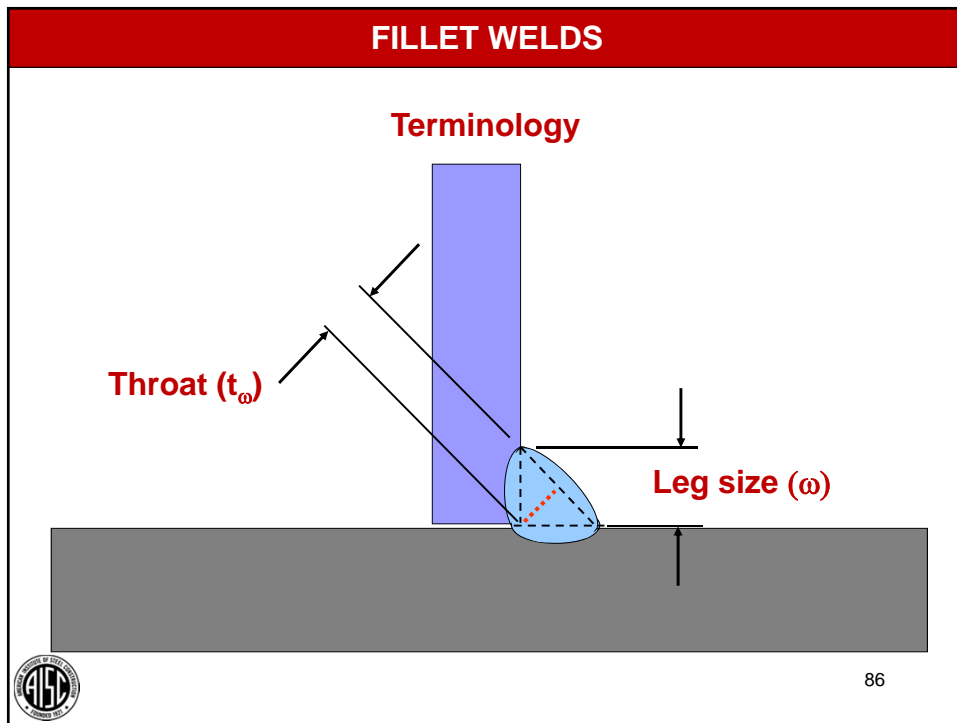
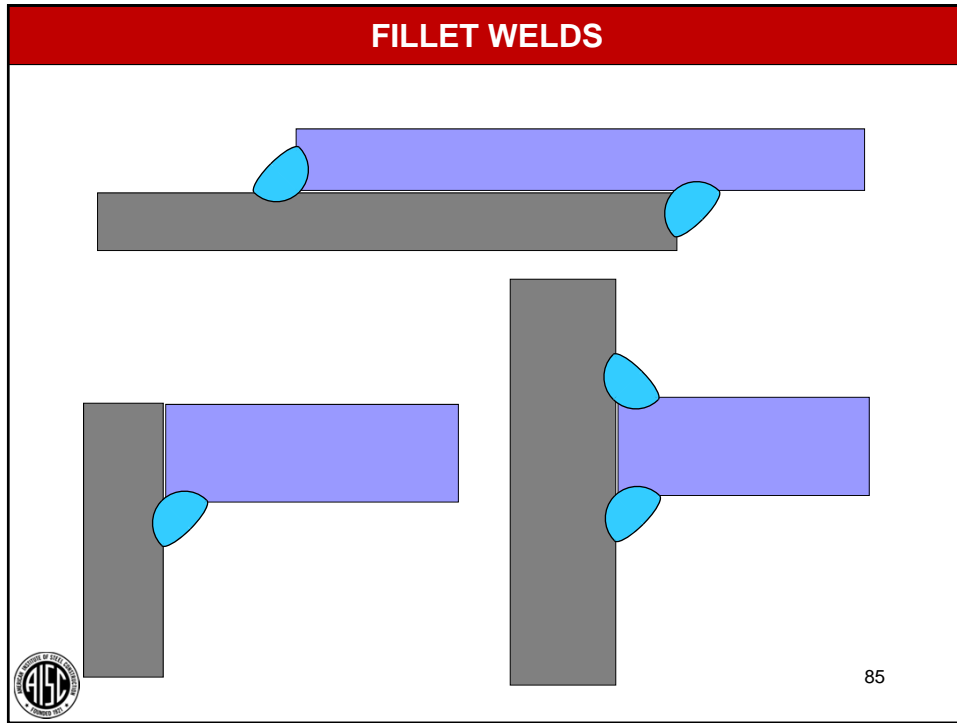


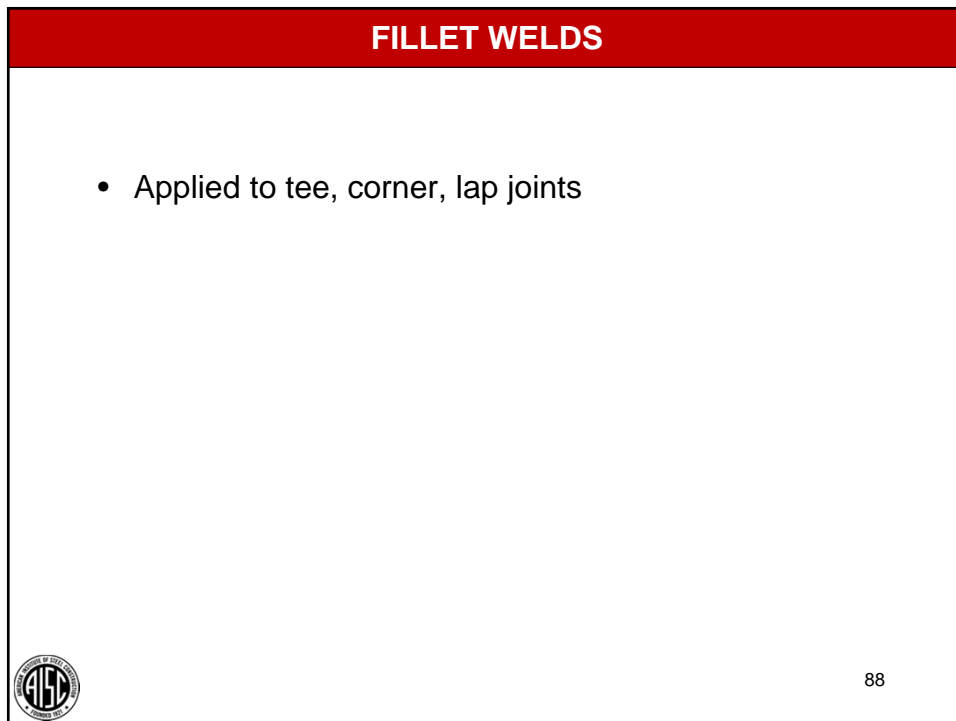
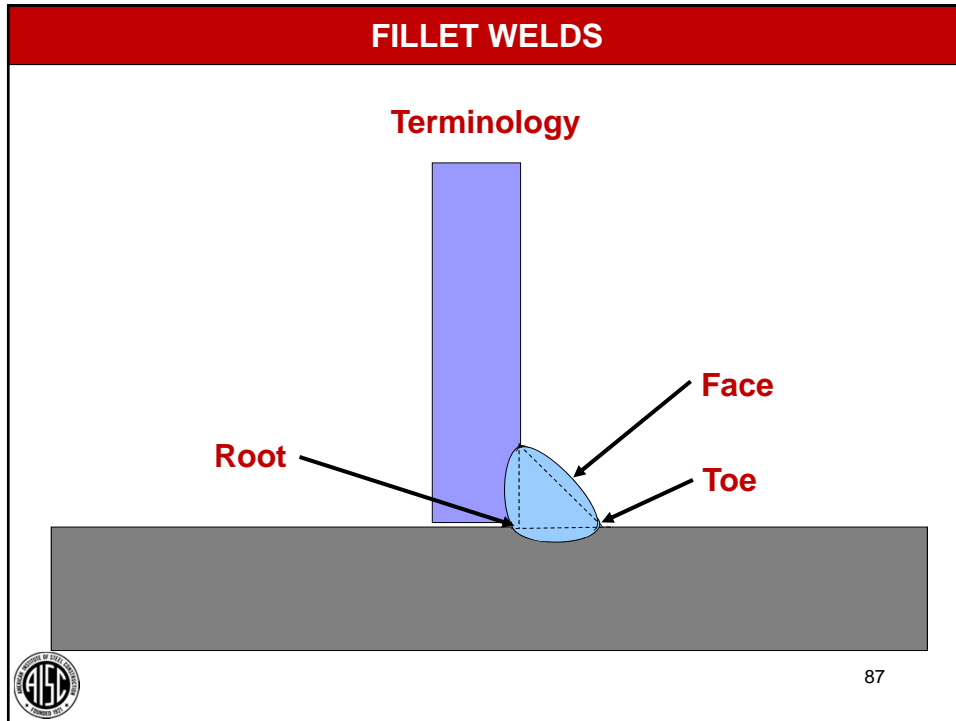


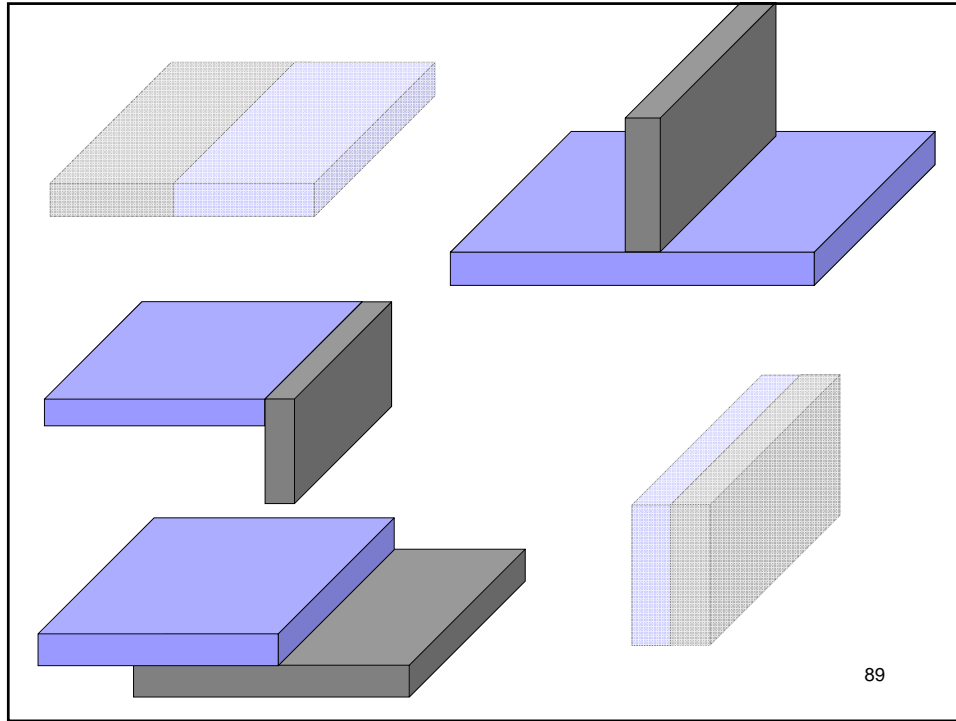










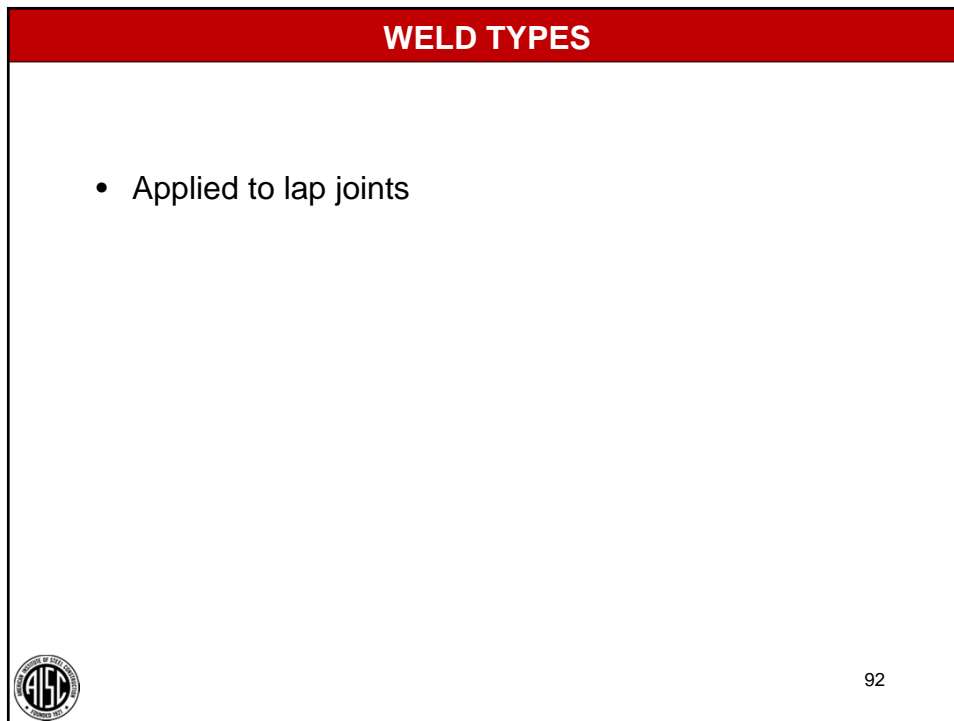
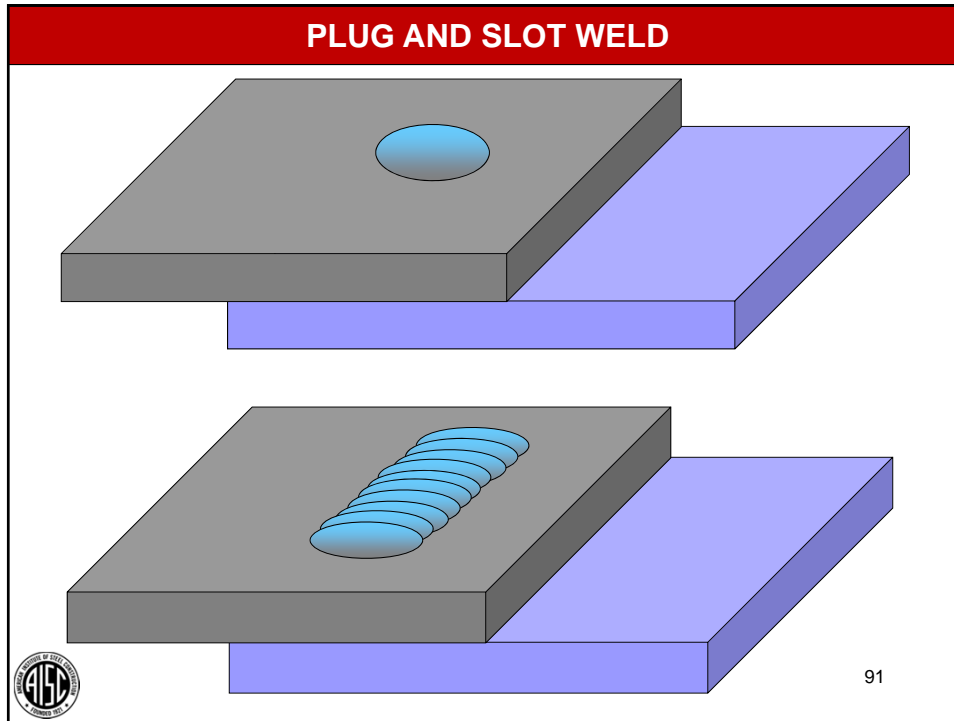


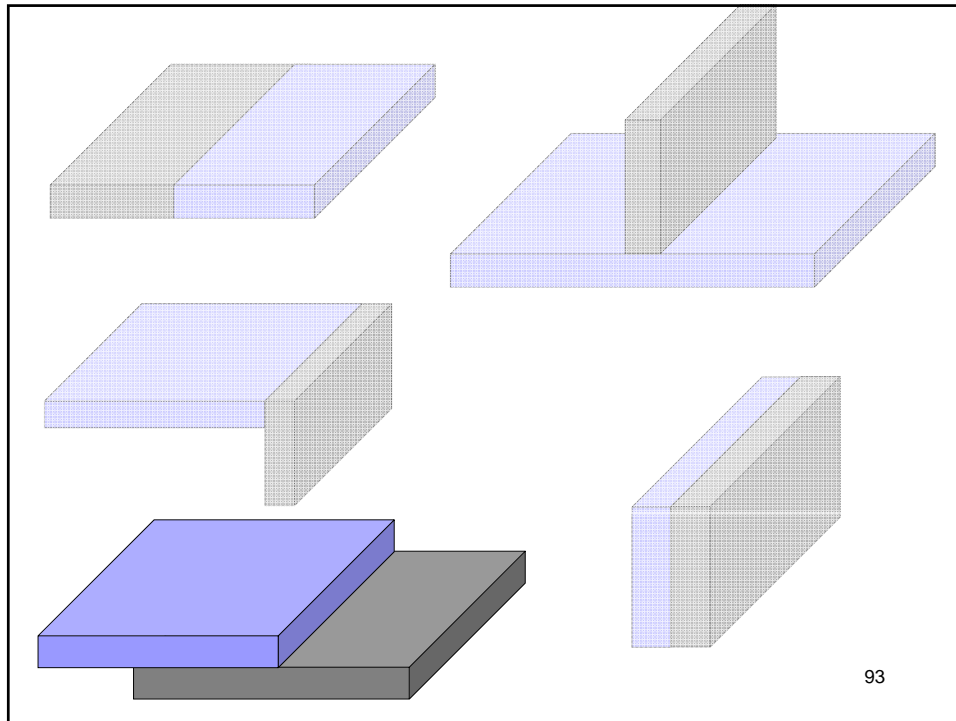
FILLET WELDS

- Applied to tee, corner, lap joints
- Specify leg (throat) dimension
- Specify length



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WELD TYPES

- Applied to lap joints
- Not often applied in structures
- Restricted capacity in cyclically loaded structures




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Fundamentals of Welded Connections

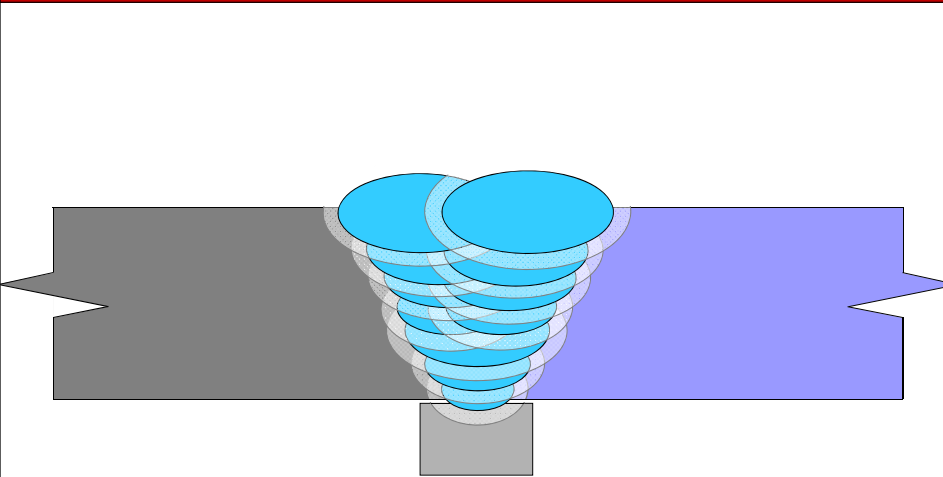
Outline

- Applicable Codes
- Welding Processes
- Joints and Weld Types
- ➔ • CJP Details
- PJP Details
- Fillet Weld Details




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Details of CJP Groove Welds



The diagram illustrates a cross-section of a groove weld joint. Two steel plates, one shaded grey and the other light blue, are joined by a groove weld. The weld is shown as a series of overlapping blue semi-circular weld ripples. A grey rectangular block is positioned below the joint, representing a backing bar or support. The plates have jagged ends on the left and right, indicating they are part of a larger structure.




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Details of CJP Groove Welds

AWS D1.1 Prequalified CJP Groove Weld Details

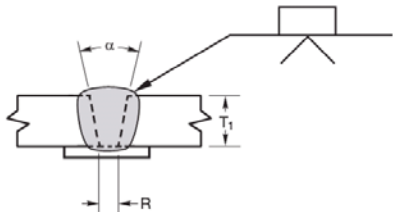
- An essential part of a prequalified Welding Procedure Specification (WPS)
- Incorporates geometric features conducive to consistent through thickness fusion and overall weld quality
- Includes root conditions that encourage fusion and proper width-to-depth profiles to discourage solidification cracking
- In some cases, but not all, reflects welding economics


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

Single V Groove Weld: CJP

Single-V-groove weld (2)
Butt joint (B)



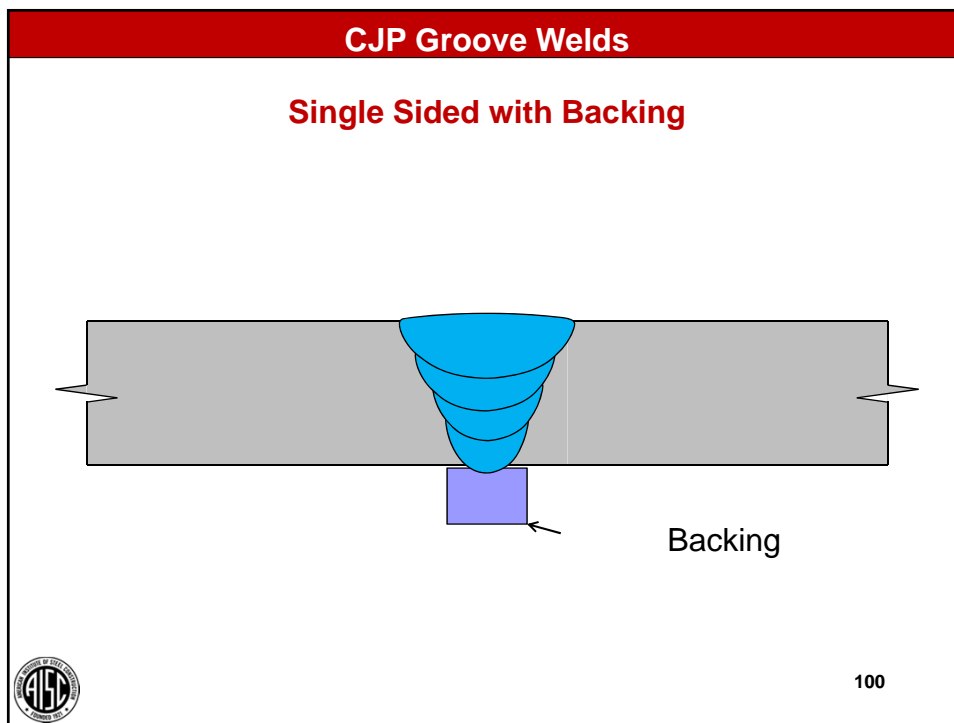
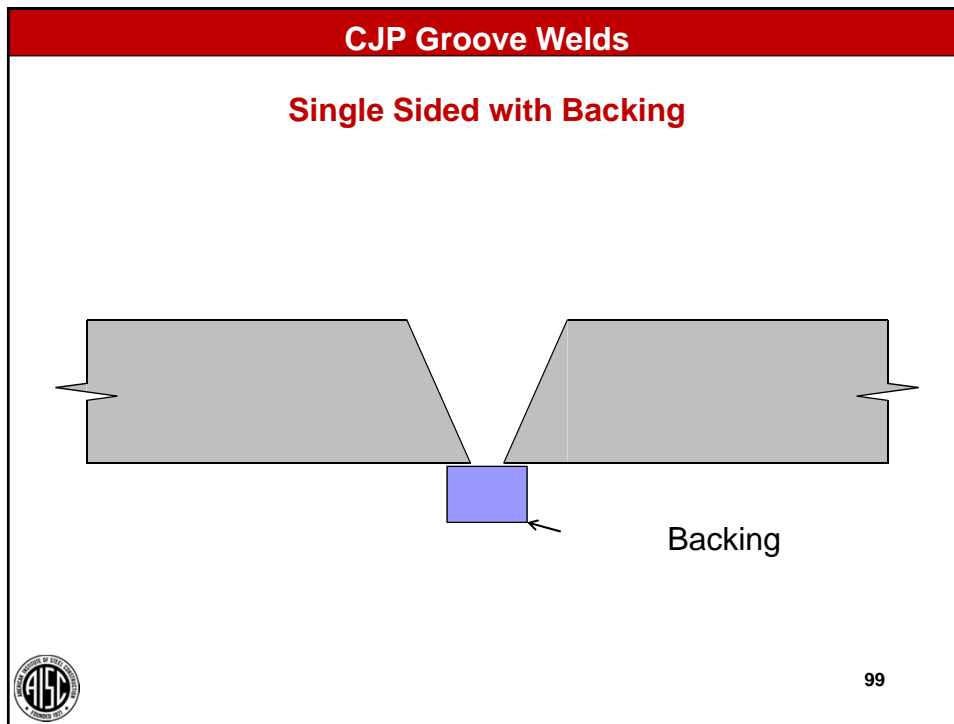
Tolerances

As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
R = +1/16, -0	+1/4, -1/16
$\alpha = +10^\circ, -0^\circ$	+10°, -5°

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Groove Angle			
SMAW	B-U2a	U	—	R = 1/4	$\alpha = 45^\circ$	All	—	e, j
				R = 3/8	$\alpha = 30^\circ$	F, V, OH	—	e, j
				R = 1/2	$\alpha = 20^\circ$	F, V, OH	—	e, j
GMAW FCAW	B-U2a-GF	U	—	R = 3/16	$\alpha = 30^\circ$	F, V, OH	Required	a, j
				R = 3/8	$\alpha = 30^\circ$	F, V, OH	Not req.	a, j
				R = 1/4	$\alpha = 45^\circ$	F, V, OH	Not req.	a, j
SAW	B-L2a-S	2 max.	—	R = 1/4	$\alpha = 30^\circ$	F	—	j
SAW	B-U2-S	U	—	R = 5/8	$\alpha = 20^\circ$	F	—	j

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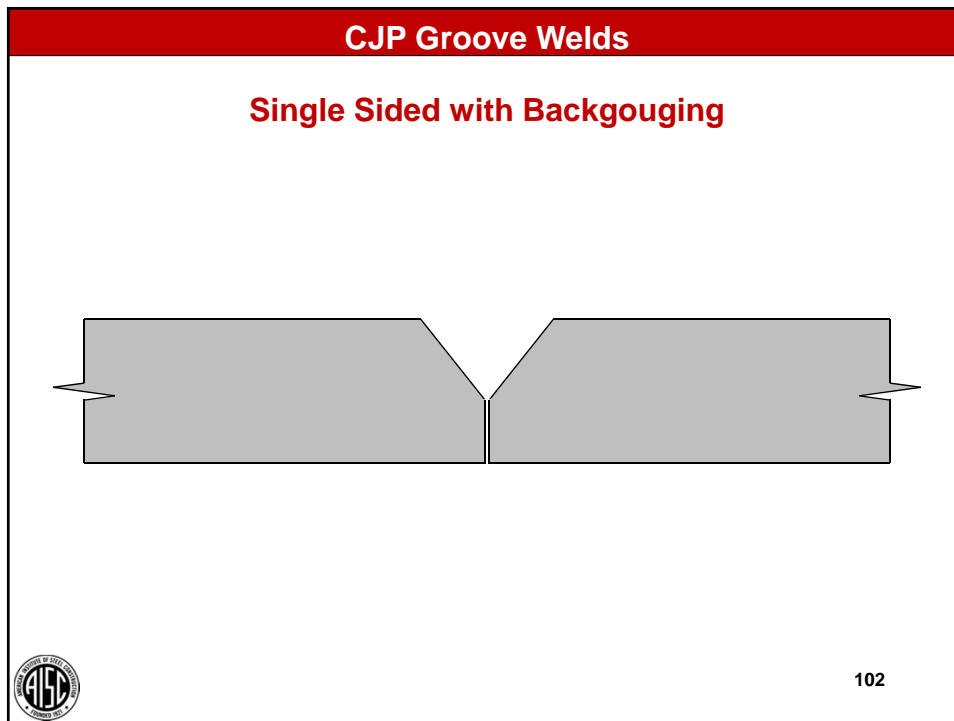


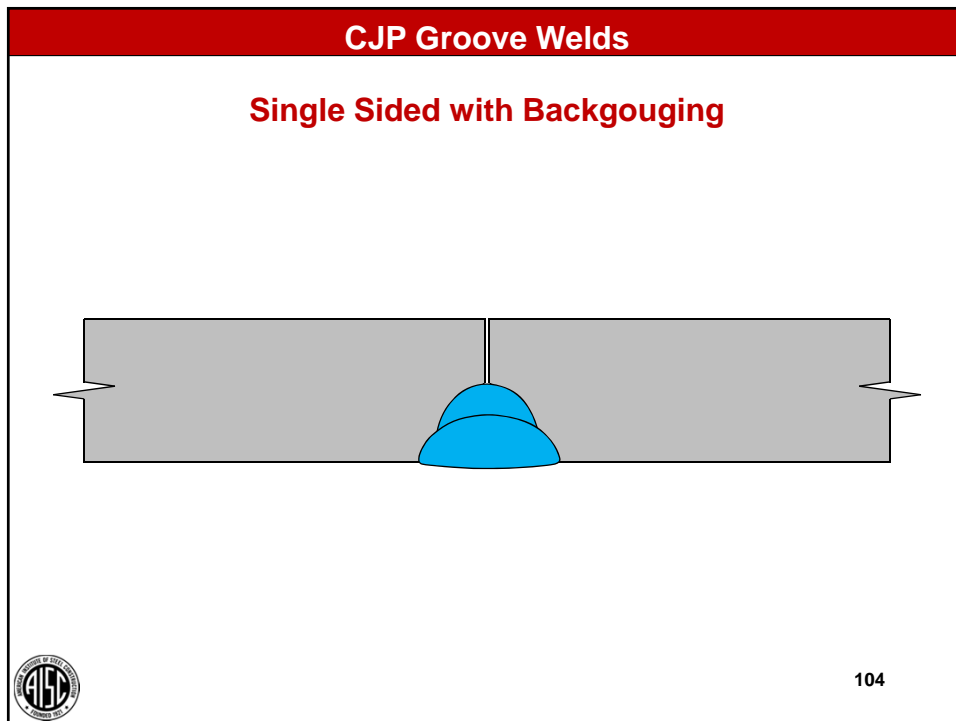
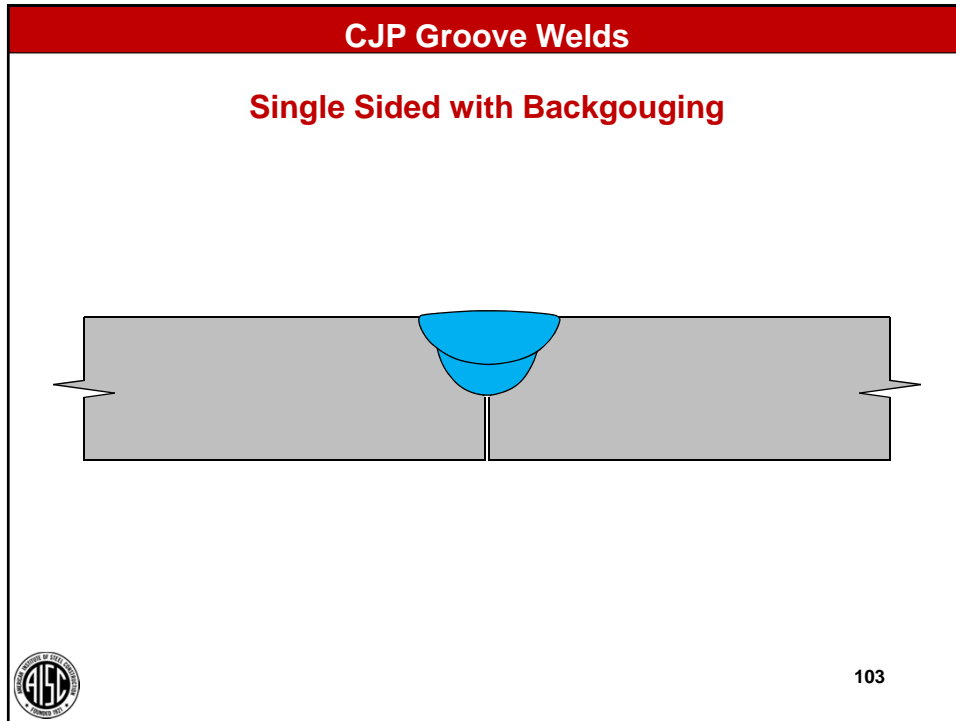
AWS D1.1:2010 Structural Welding Code--Steel

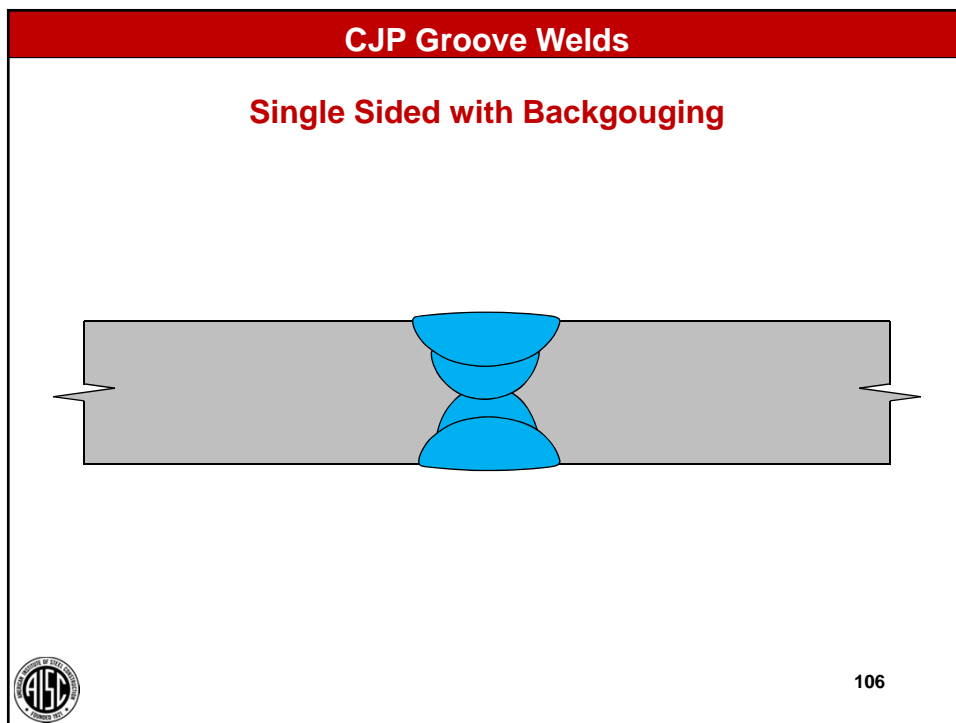
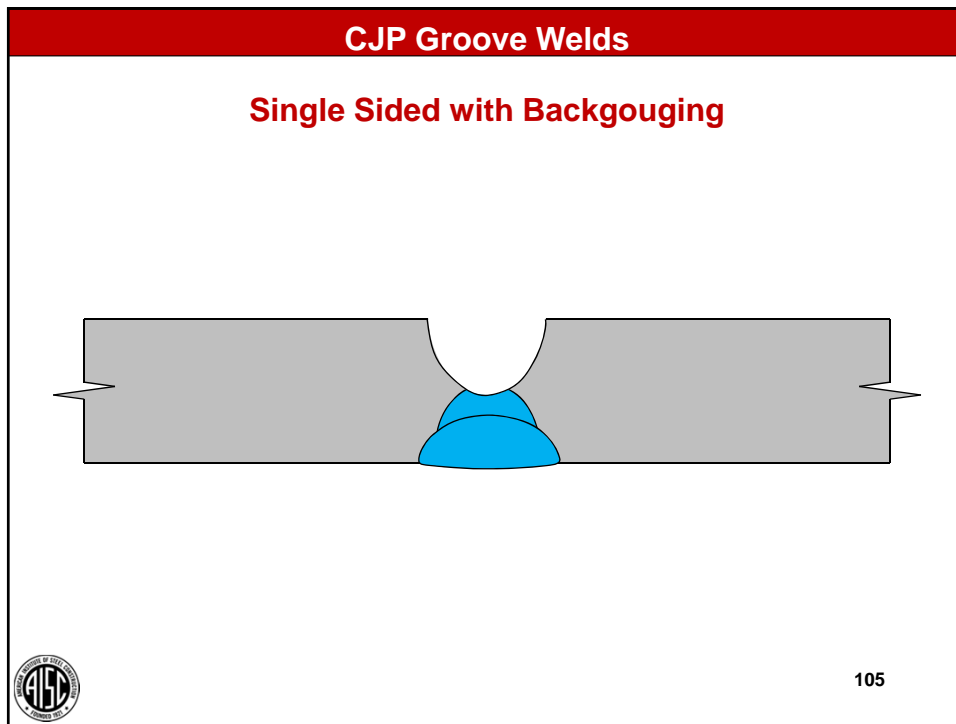
Single V Groove Weld: CJP

Single-V-groove weld (2)
Butt joint (B)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes	
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 3.13.1)				As Fit-Up (see 3.13.1)
SMAW	B-U2	U	—	R = 0 to 1/8 f = 0 to 1/8 $\alpha = 60^\circ$	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	—	d, e, j
GMAW FCAW	B-U2-GF	U	—	R = 0 to 1/8 f = 0 to 1/8 $\alpha = 60^\circ$	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	Not required	a, d, j
SAW	B-L2c-S	Over 1/2 to 1	—	R = 0 f = 1/4 max. $\alpha = 60^\circ$	R = ± 0 f = +0, -f $\alpha = +10^\circ, -0^\circ$	+1/16, -0 $\pm 1/16$ +10°, -5°	F	—	d, j
		Over 1 to 1-1/2	—	R = 0 f = 1/2 max. $\alpha = 60^\circ$					
		Over 1-1/2 to 2	—	R = 0 f = 5/8 max. $\alpha = 60^\circ$					







CJP Groove Welds: Backing

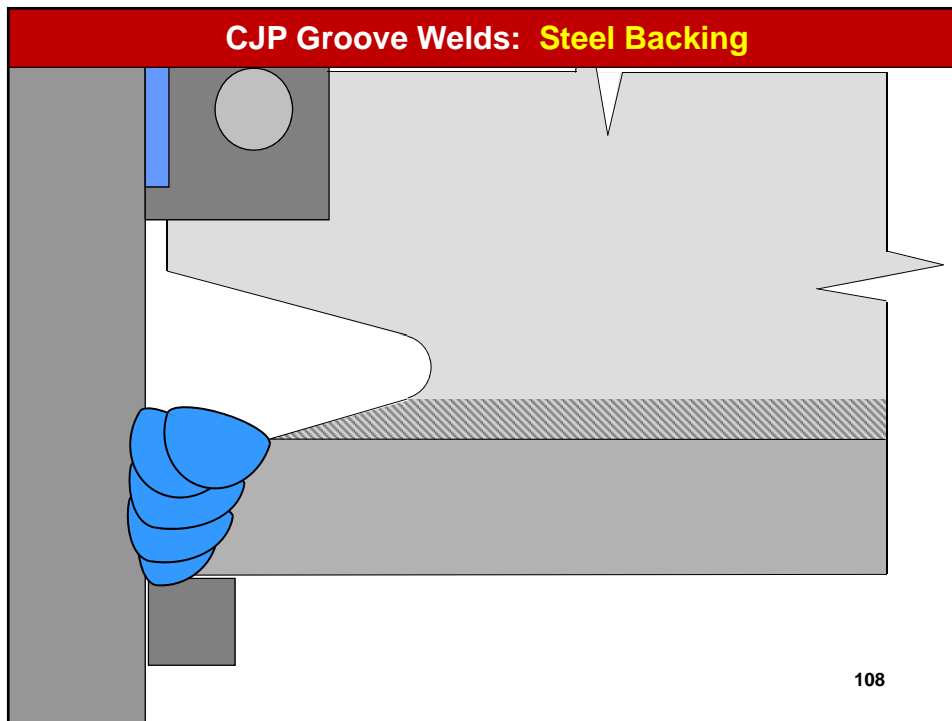
Steel backing:

- Permanent (unless deliberately removed)
- May be called “fusible” backing
- Becomes part of the weldment
- May introduce notches (depending on the joint type and direction of loading)

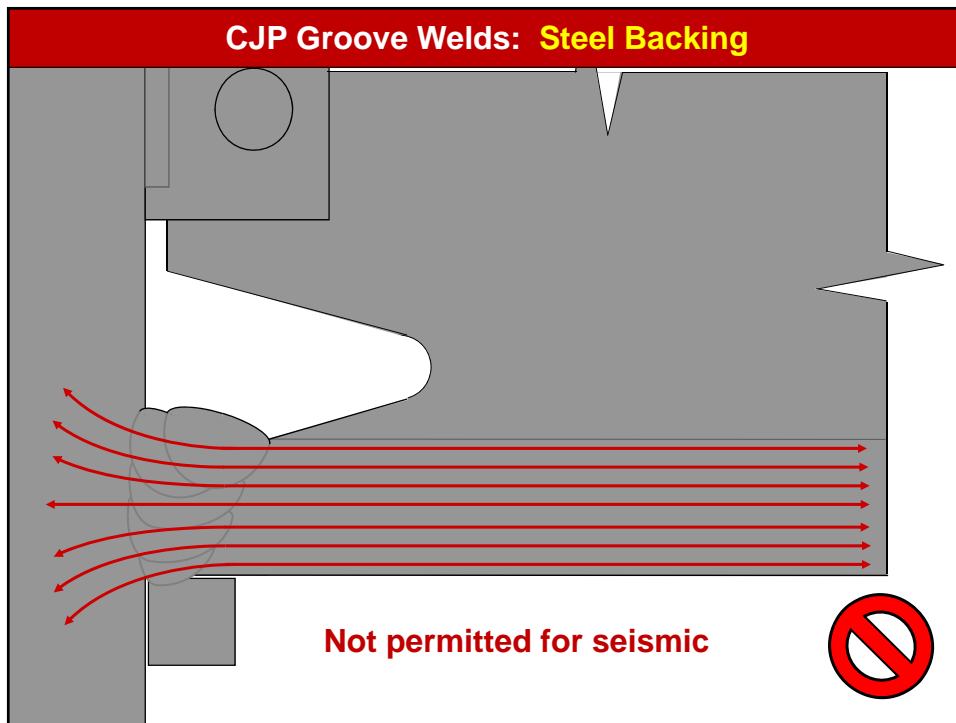
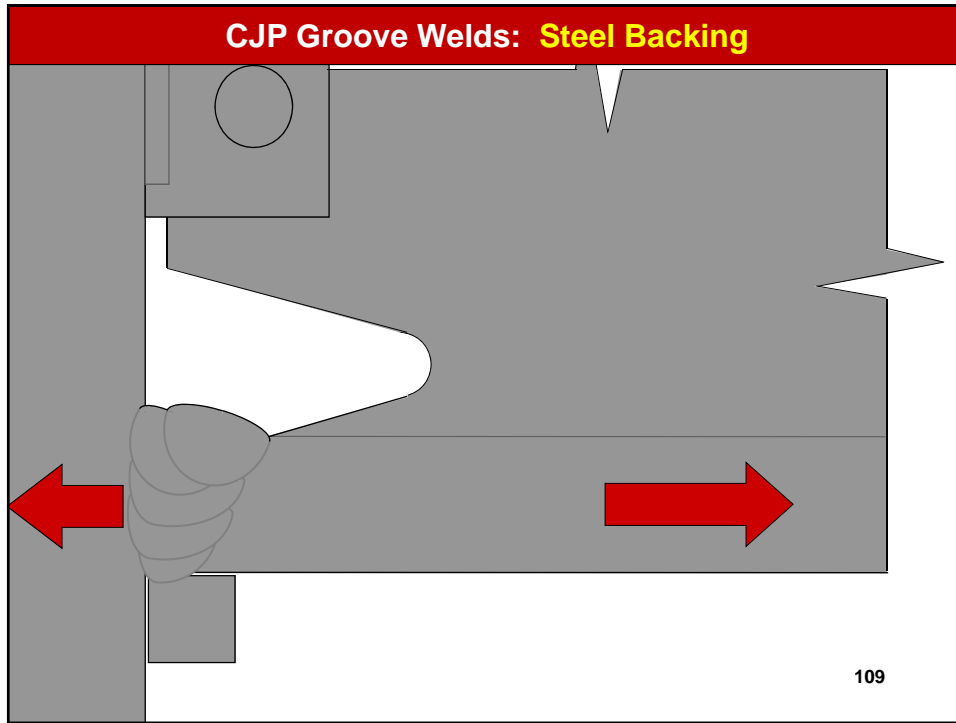


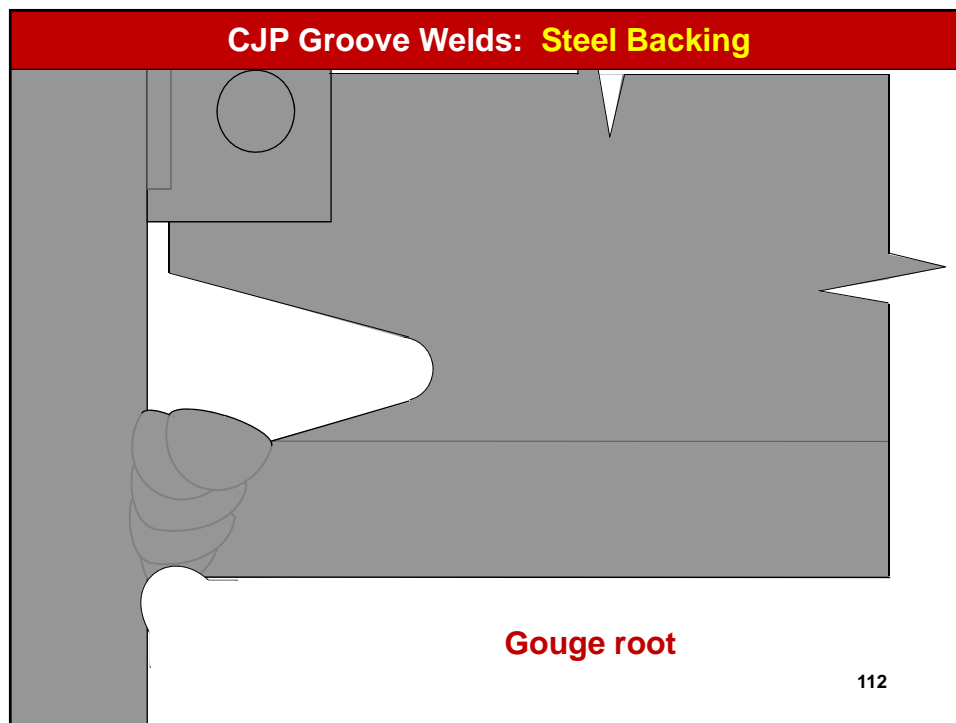
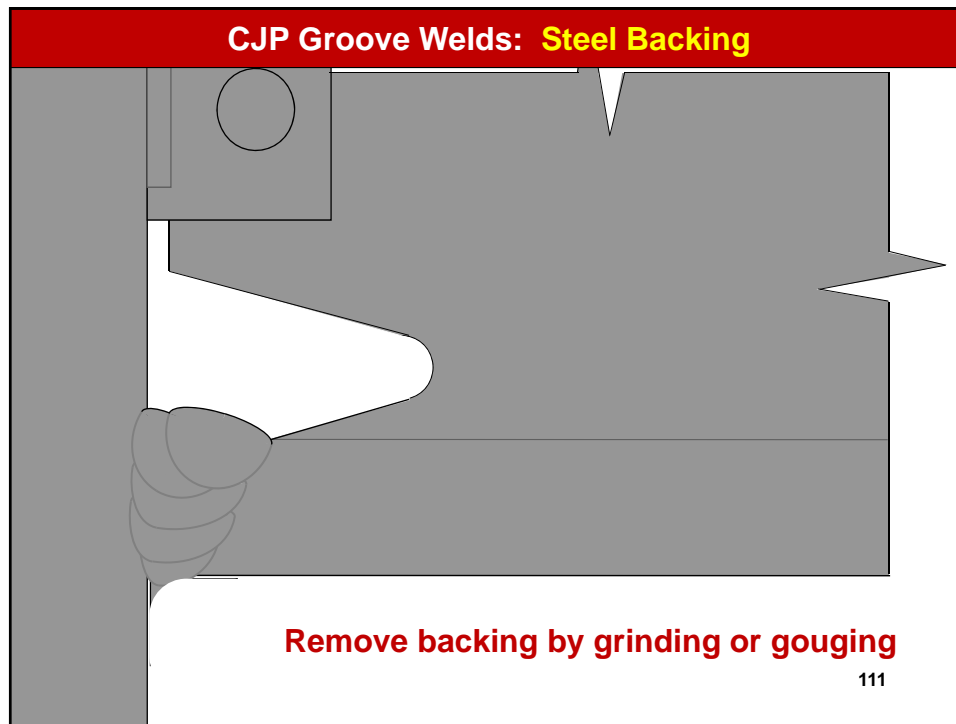
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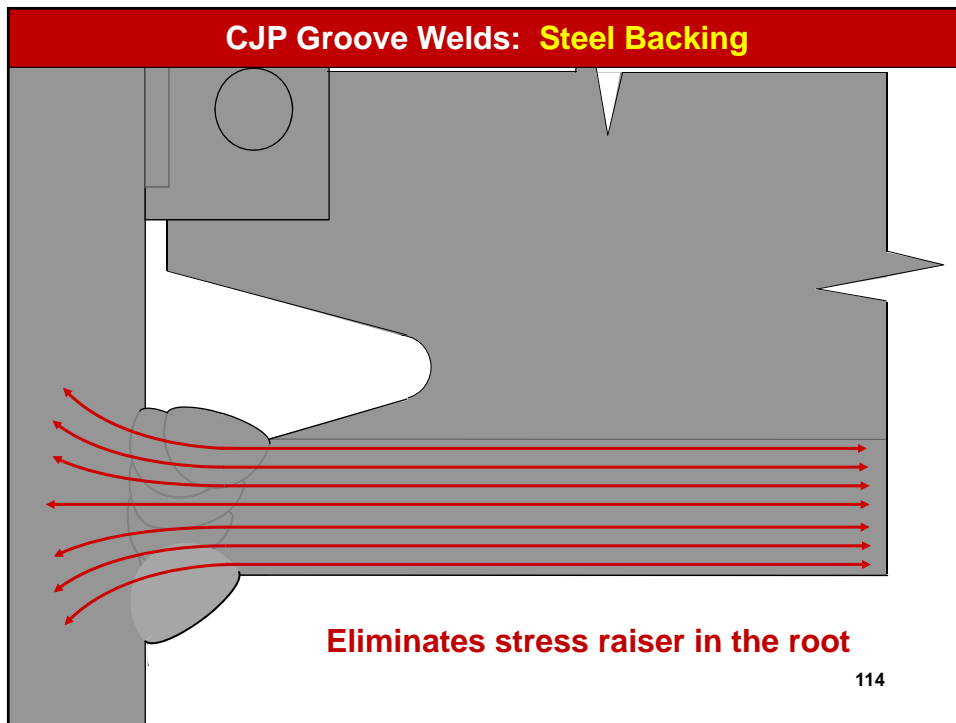
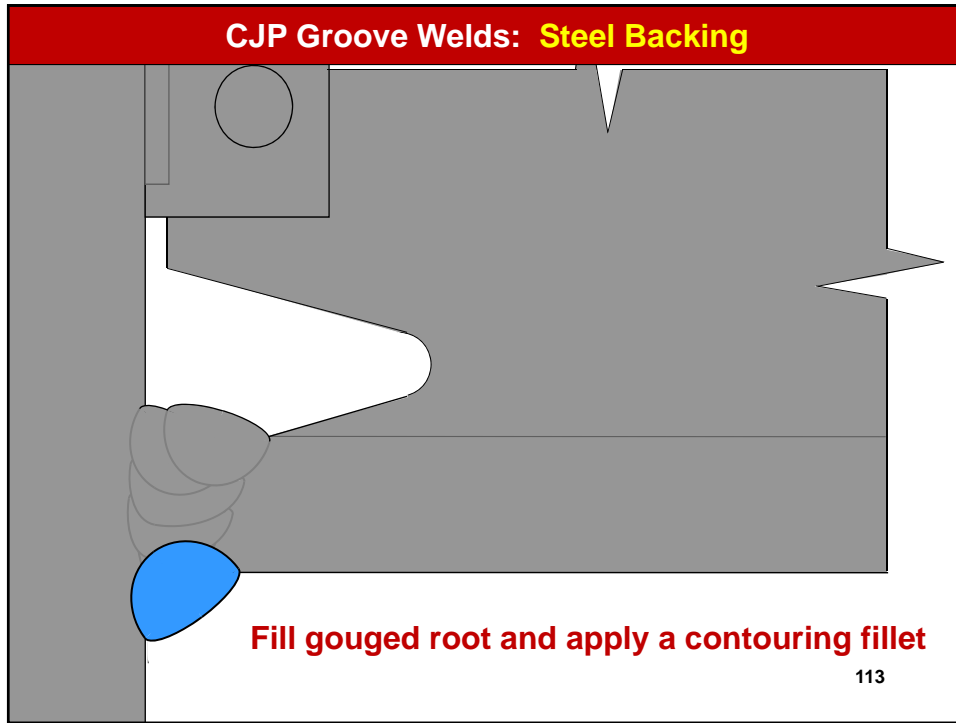
CJP Groove Welds: Steel Backing



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CJP Groove Welds: Backing

Backing materials for steel applications:

- Steel ← **Prequalified by AWS D1.1**
- Copper } **Require qualification testing by**
- Ceramic } **AWS D1.1**


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AISC 360-10 SPECIFICATION

Table J2.5

Allowable Strength
of Welded Joints

TABLE J2.5
Available Strength of Welded Joints,
ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	Nominal Stress (F _u or F _u /Ω)	Effective Area (A _e or A _w)	Required Filler Metal Strength Level
COMPLETE-JOINT-PENETRATION GROOVE WELDS				
Tension Normal to weld axis		Strength of the joint is controlled by the base metal		Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis		Strength of the joint is controlled by the base metal		Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis		Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.		Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear		Strength of the joint is controlled by the base metal		Matching filler metal shall be used. ¹
PARTIAL-JOINT-PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS				
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a
Compression Column to base plates and column splices designed per Section J1.4(1)		Compressive stress need not be considered in design of welds joining the parts.		
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a
Compression Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a
Tension or compression Parallel to weld axis	Base	Governed by J4		
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.1a


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AISC 360-10 SPECIFICATION

SPECIFICATION

 For Structural Steel Buildings
 June 23, 2010

Table J2.5

Allowable Strength of Welded Joints

TABLE J2.5 (continued)
Available Strength of Welded Joints,
ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{tBM} or F_{tW}) ksi (MPa)	Effective Area (A_{tBM} or A_{tW}) in. ² (mm ²)	Required Filler Metal Strength Level [a]
FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T-JOINTS					
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{tW}^{(b)}$	See J2.2a	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
PLUG AND SLOT WELDS					
Shear Parallel to lying surface on the effective area	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{tW}^{(b)}$	See J2.3a	

H For matching weld metal see AISC D1.1(D1.1M), Section 3.3.
 I Filler metal with a strength level one strength level greater than matching is permitted.
 J Filler metals with a strength level less than matching may be used for groove welds between the webs and flanges of built-up members transferring shear loads, or in applications where high restraint is a concern. In these applications, the weld joint shall be detailed and the weld shall be designed using the thickness of the material as the effective throat, where $a = 0.80$, $\Omega = 1.80$ and $0.60F_{tW}$ is the nominal strength.
 K Alternatively, the provisions of Section J2.4(a) are permitted provided the deformation compatibility of the various weld elements is considered. Sections J2.4(b) and (c) are special applications of Section J2.4(a) that provide for deformation compatibility.

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AISC 360-10 SPECIFICATION

SPECIFICATION

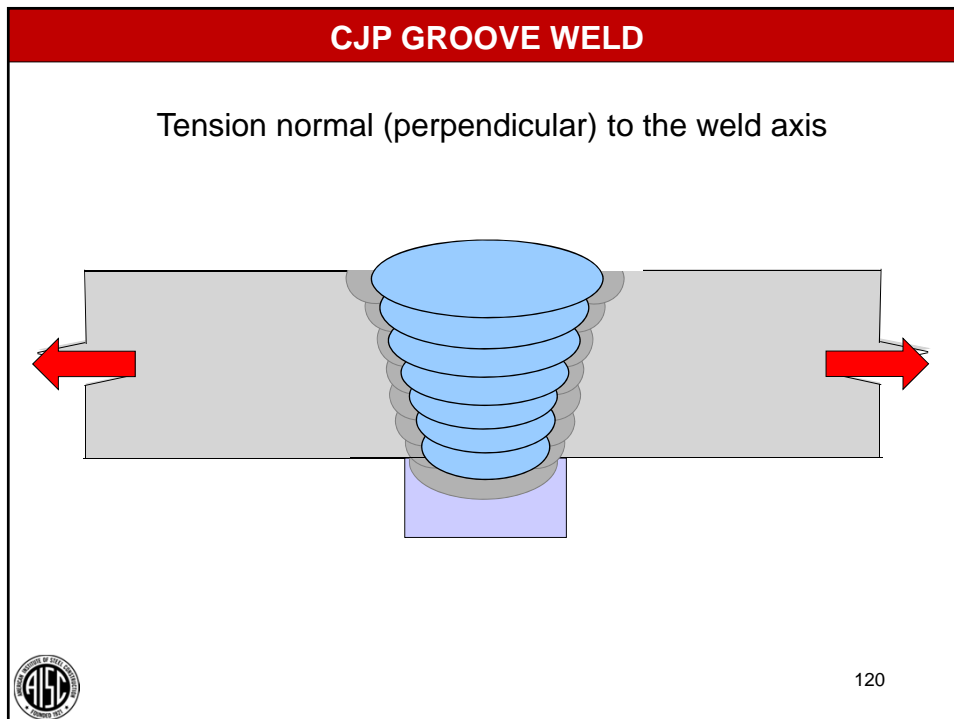
 For Structural Steel Buildings
 June 23, 2010

TABLE J2.5
Available Strength of Welded Joints,
ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{tBM} or F_{tW}) ksi (MPa)	Effective Area (A_{tBM} or A_{tW}) in. ² (mm ²)	Required Filler Metal Strength Level [a]
COMPLETE-JOINT-PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal			Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.	
Compression Normal to weld axis	Strength of the joint is controlled by the base metal			Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.			Filler metal with a strength level equal to or less than matching filler metal is permitted.	
Shear	Strength of the joint is controlled by the base metal			Matching filler metal shall be used.[c]	



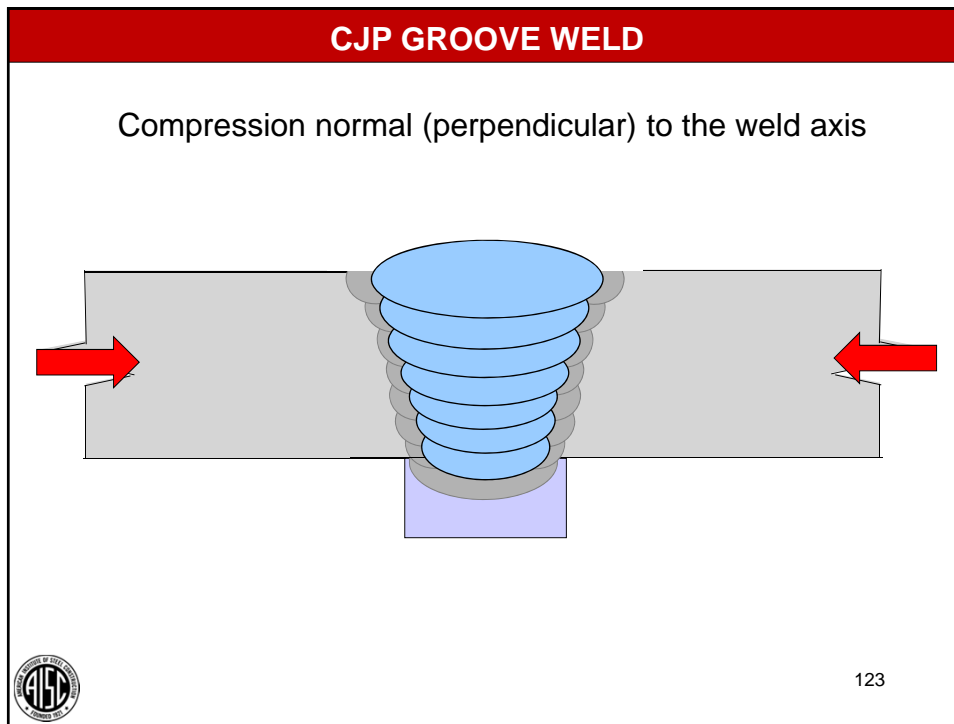
AISC 360-10 SPECIFICATION		
COMPLETE JOINT PENETRATION GROOVE WELDS		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
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Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]



AISC 360-10 SPECIFICATION		
COMPLETE JOINT PENETRATION GROOVE WELDS		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
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Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]


AISC 360-10 SPECIFICATION		
COMPLETE JOINT PENETRATION GROOVE WELDS		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
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Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]





AISC 360-10 SPECIFICATION

SPECIFICATION

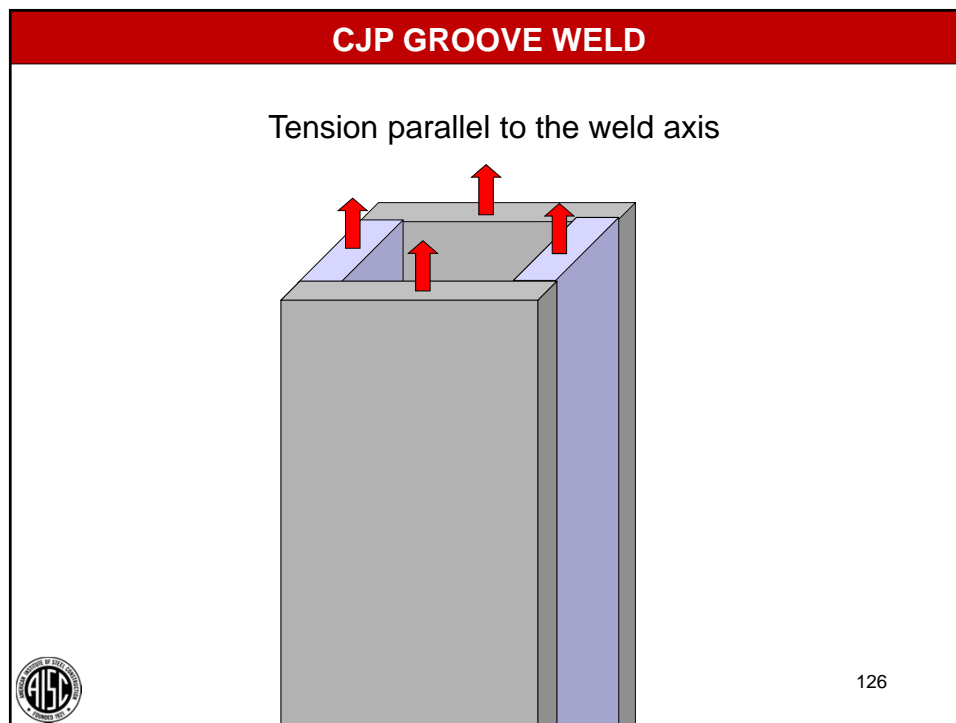


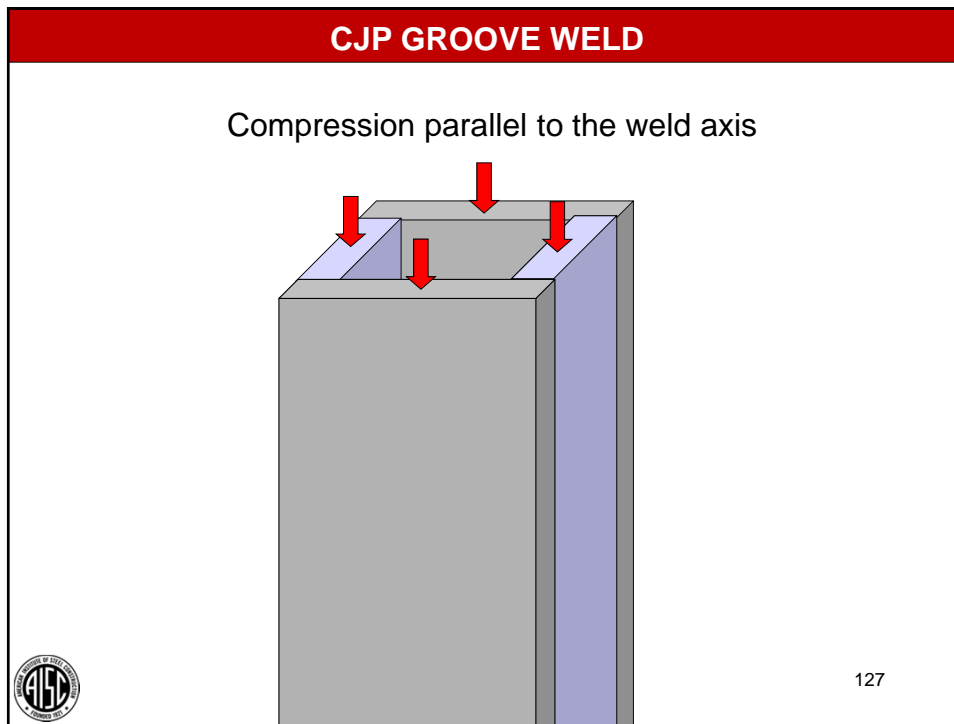
For Structural Steel Buildings
June 15, 2010

COMPLETE JOINT PENETRATION GROOVE WELDS

COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[3]

AISC 360-10 SPECIFICATION		
COMPLETE JOINT PENETRATION GROOVE WELDS		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
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Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[c]





AISC 360-10 SPECIFICATION		
COMPLETE JOINT PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[6]



AISC 360-10 SPECIFICATION		
COMPLETE JOINT PENETRATION GROOVE WELDS		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
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Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[6]




AISC 360-10 SPECIFICATION		
COMPLETE JOINT PENETRATION GROOVE WELDS		
COMPLETE-JOINT-PENETRATION GROOVE WELDS		
Tension Normal to weld axis	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal	Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
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Shear	Strength of the joint is controlled by the base metal	Matching filler metal shall be used. ^[6]



Fundamentals of Welded Connections

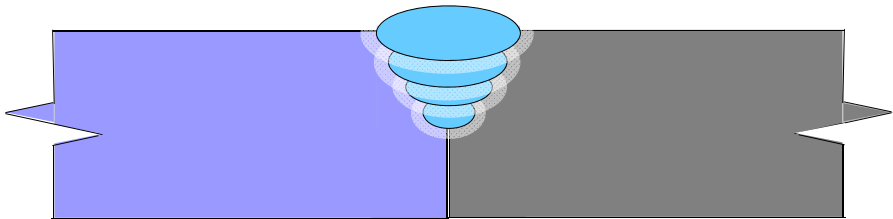
Outline

- Applicable Codes
- Welding Processes
- Joints and Weld Types
- CJP Details
- ➔ • PJP Details
- Fillet Weld Details




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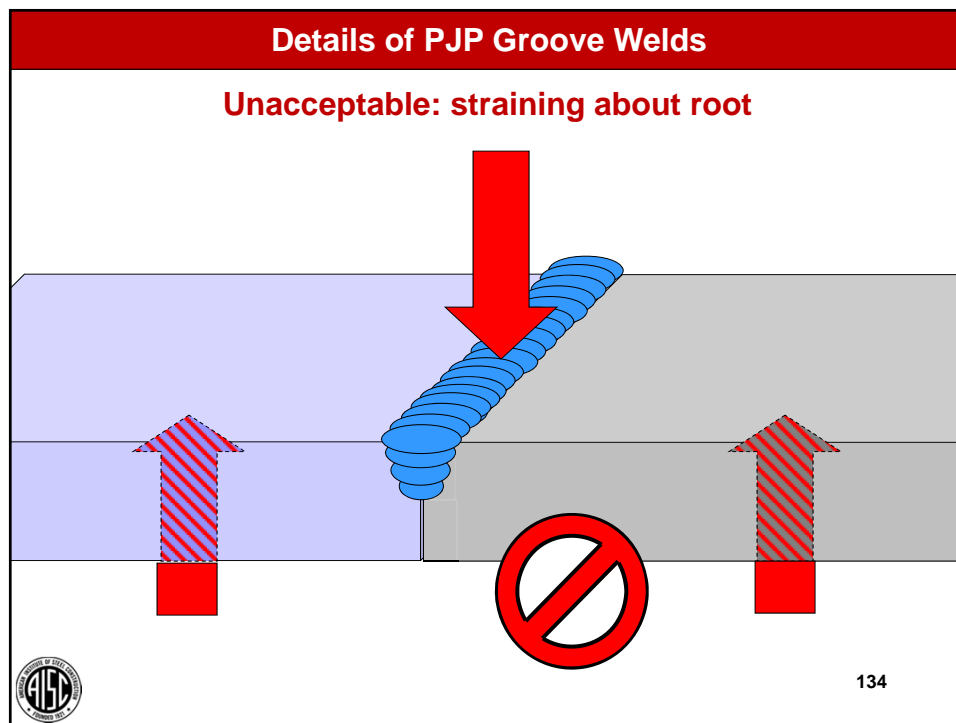
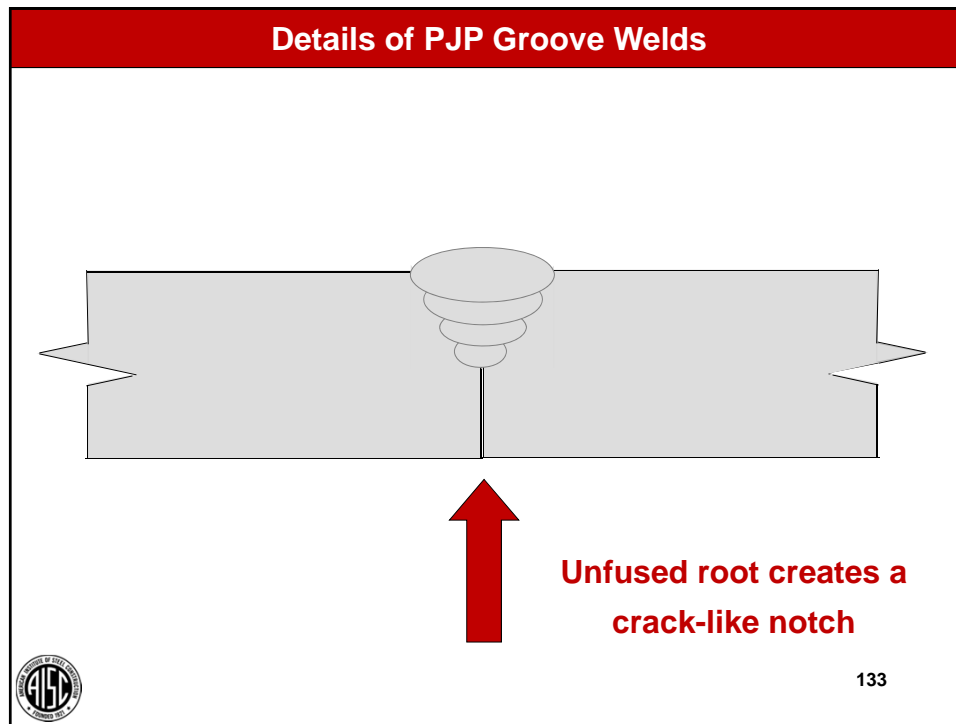
Details of PJP Groove Welds

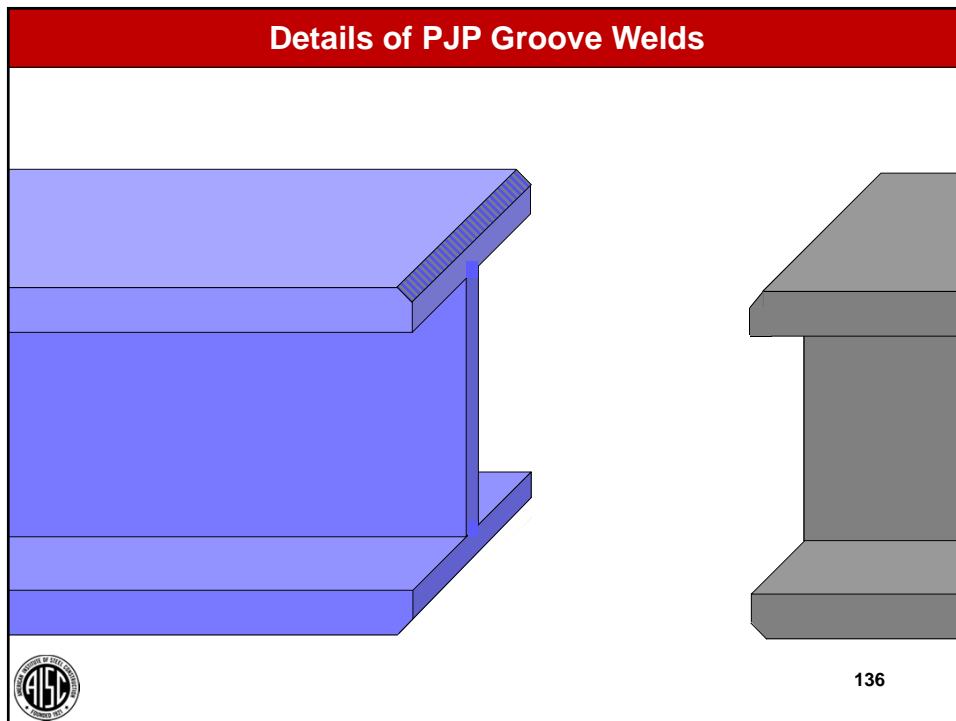
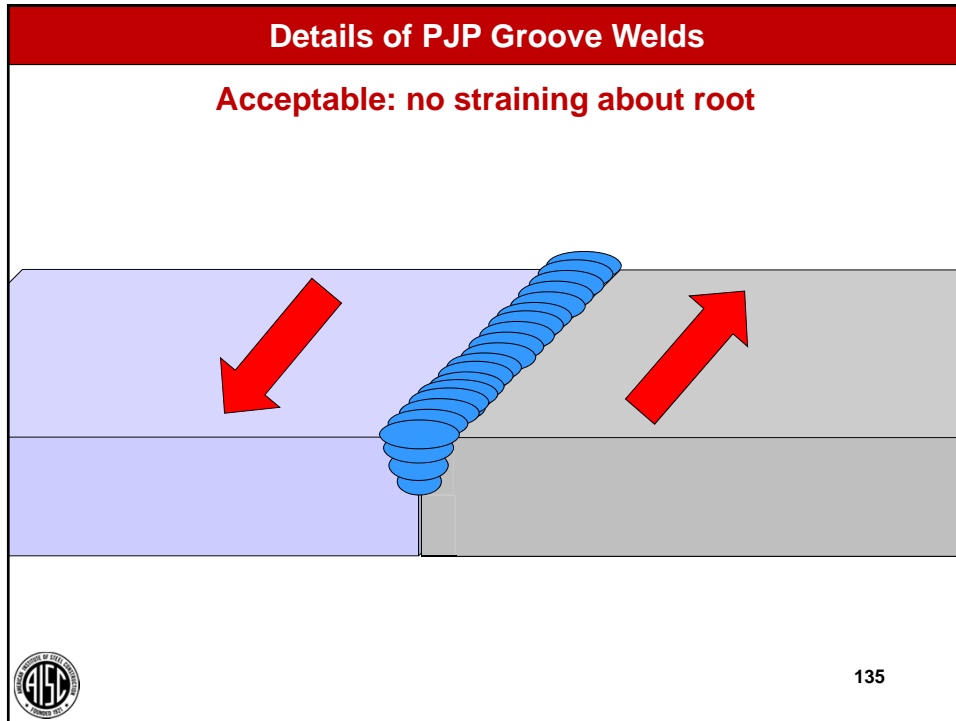


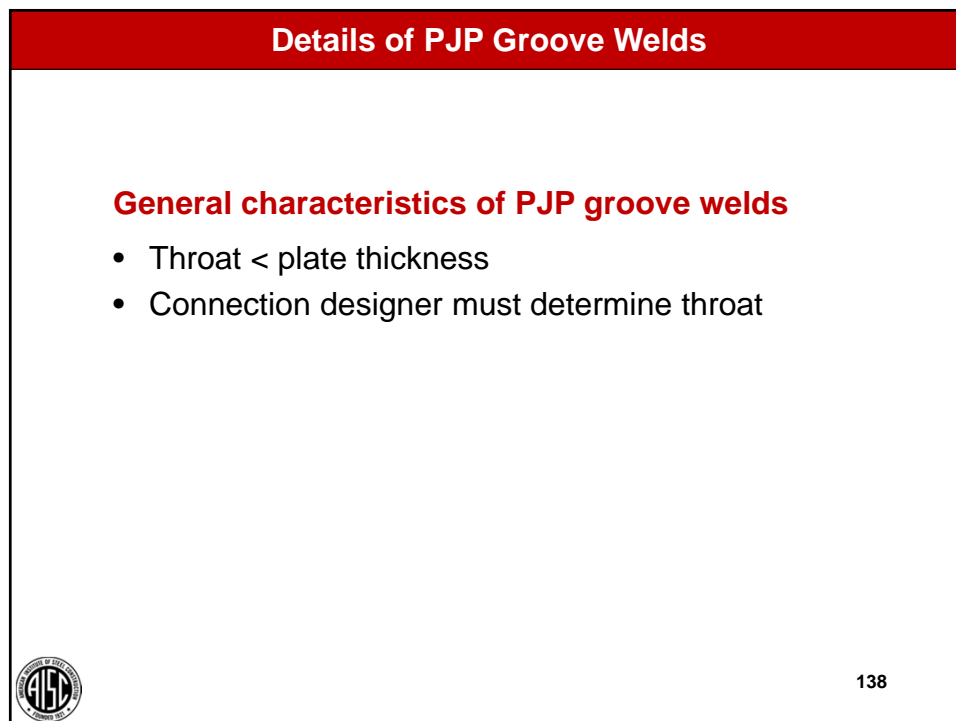
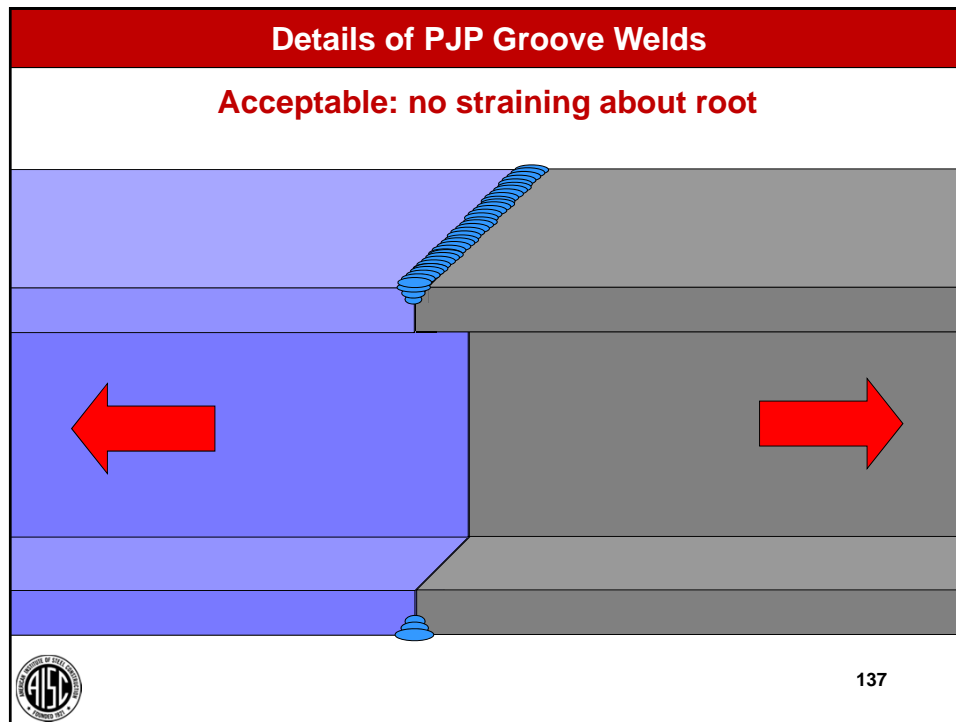
The diagram illustrates a Partial Joint Penetration (PJP) groove weld. It shows two steel plates, one colored blue and the other grey, joined by a groove weld. The weld metal is depicted in light blue, filling the groove between the plates. The weld is shown in a cross-sectional view, highlighting the partial penetration of the weld metal into the groove.

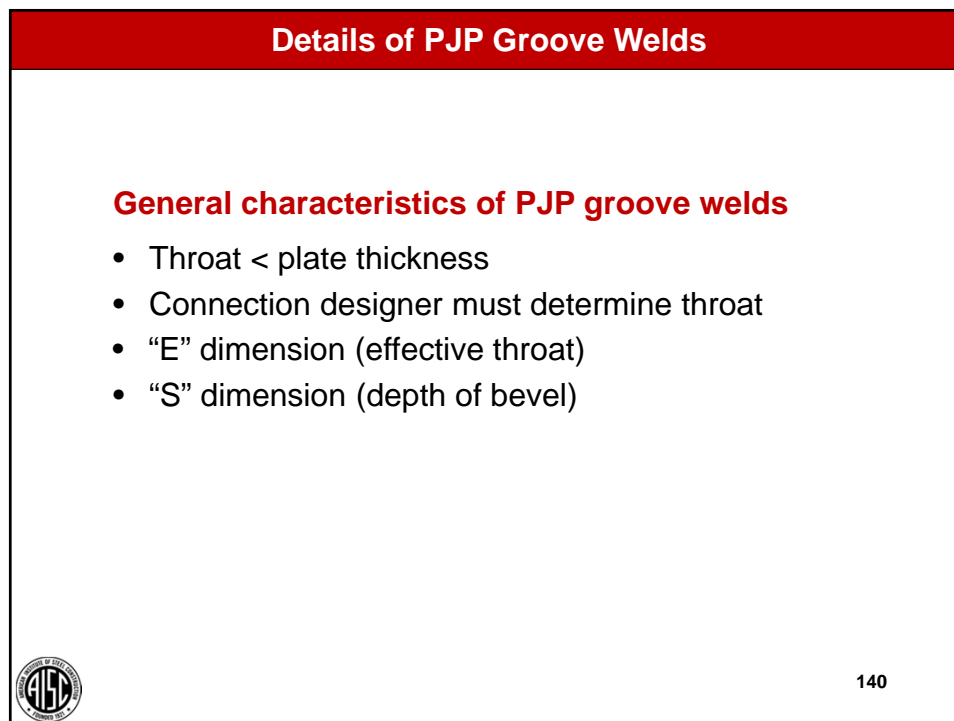
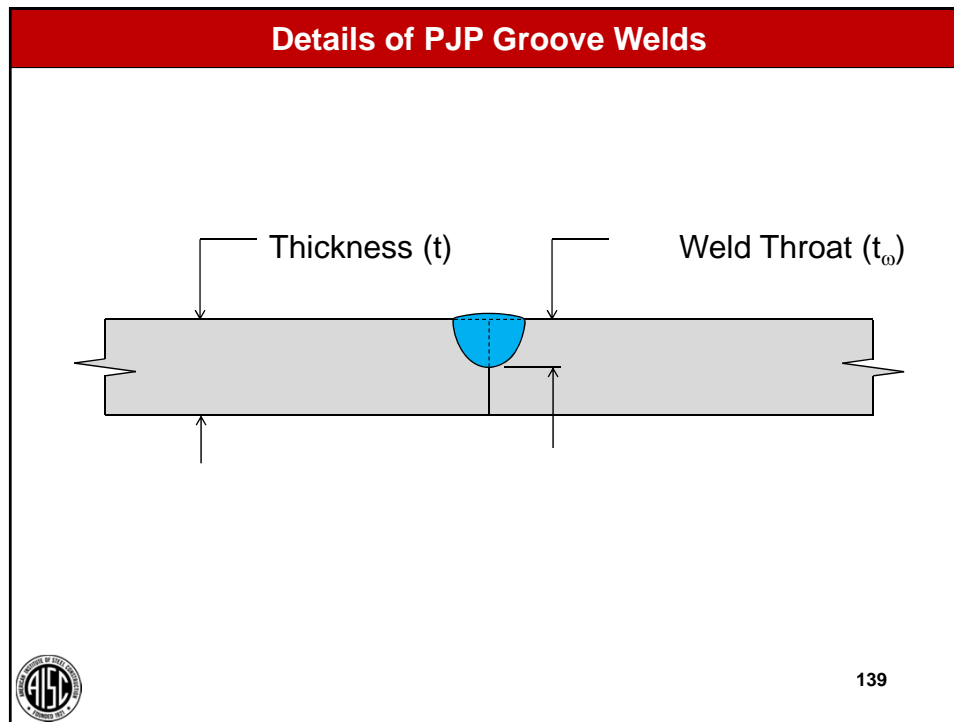


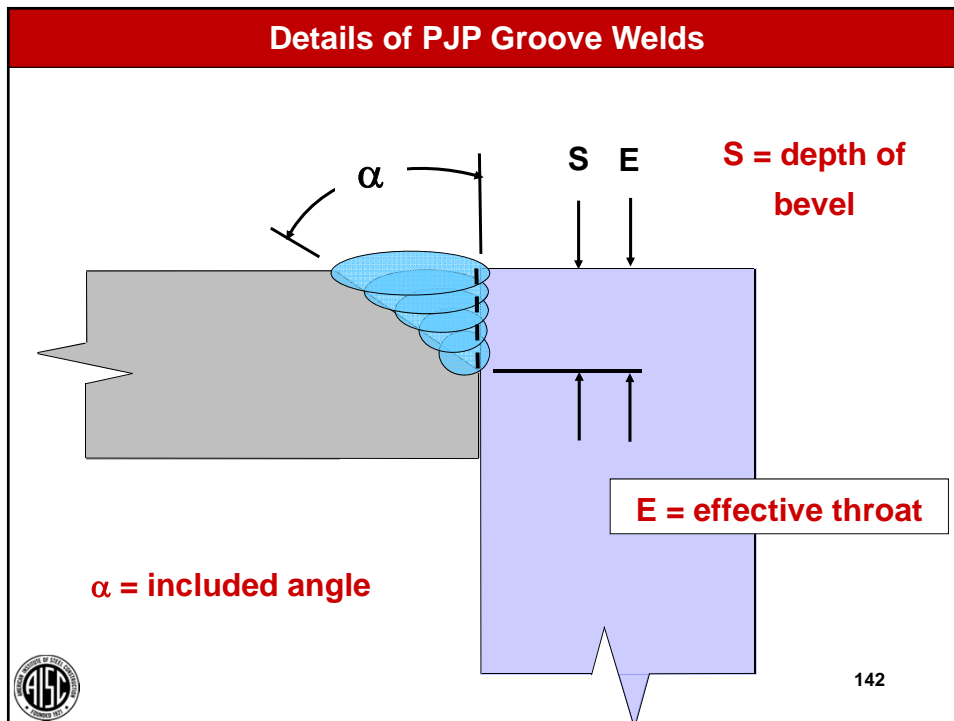
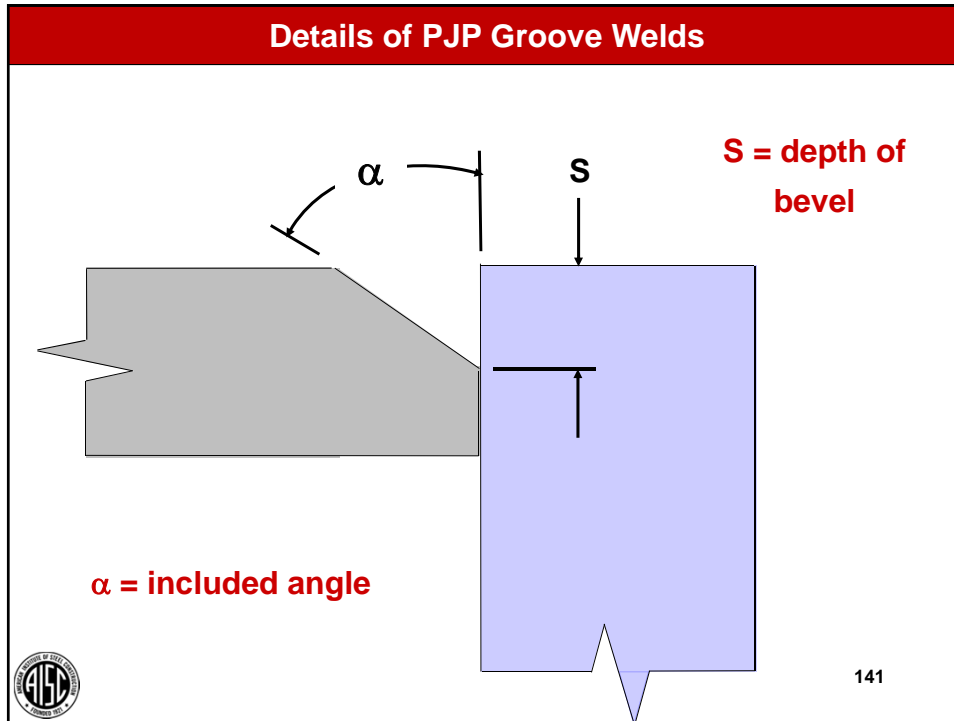
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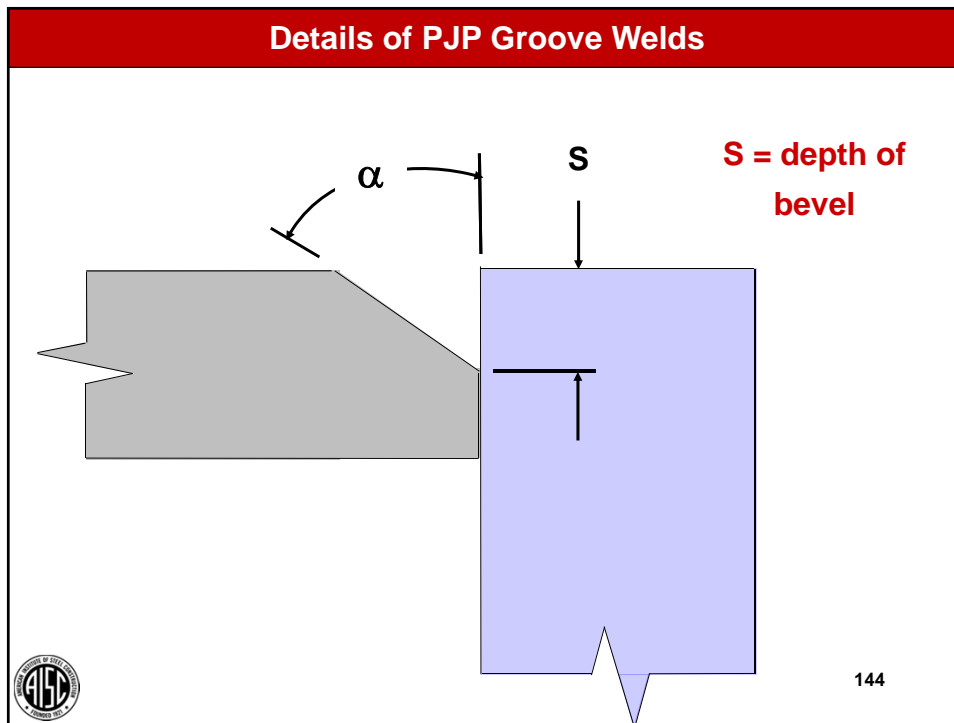
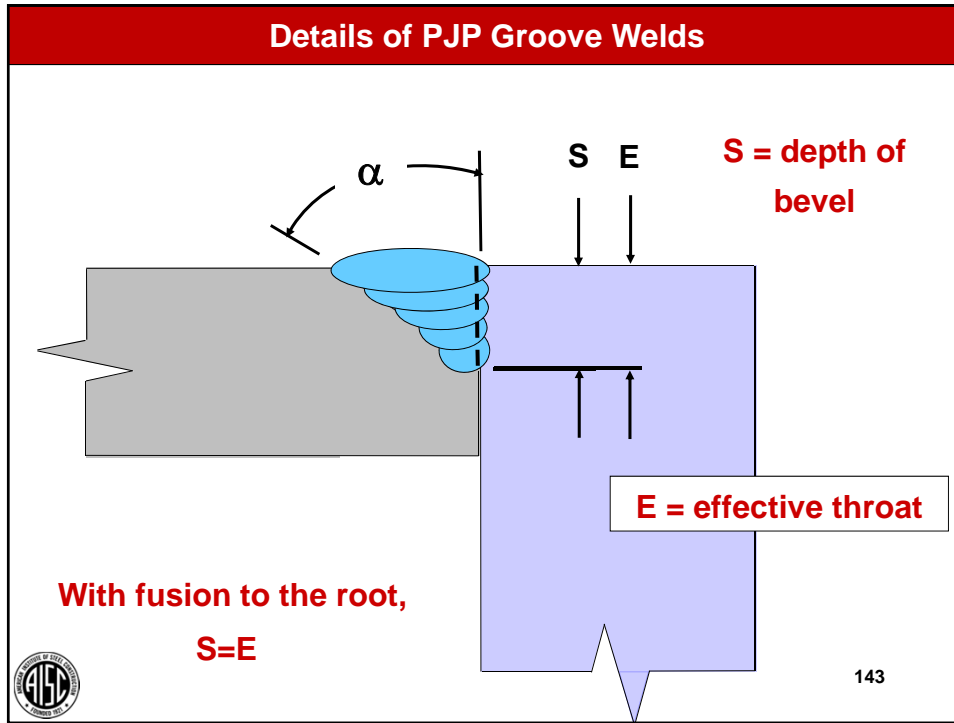


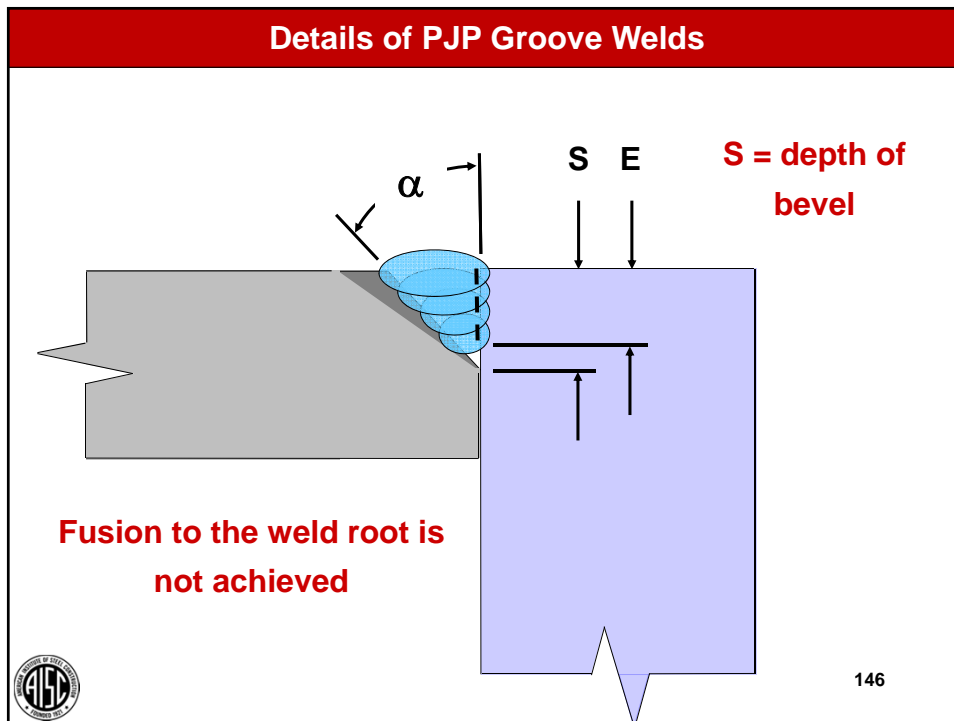
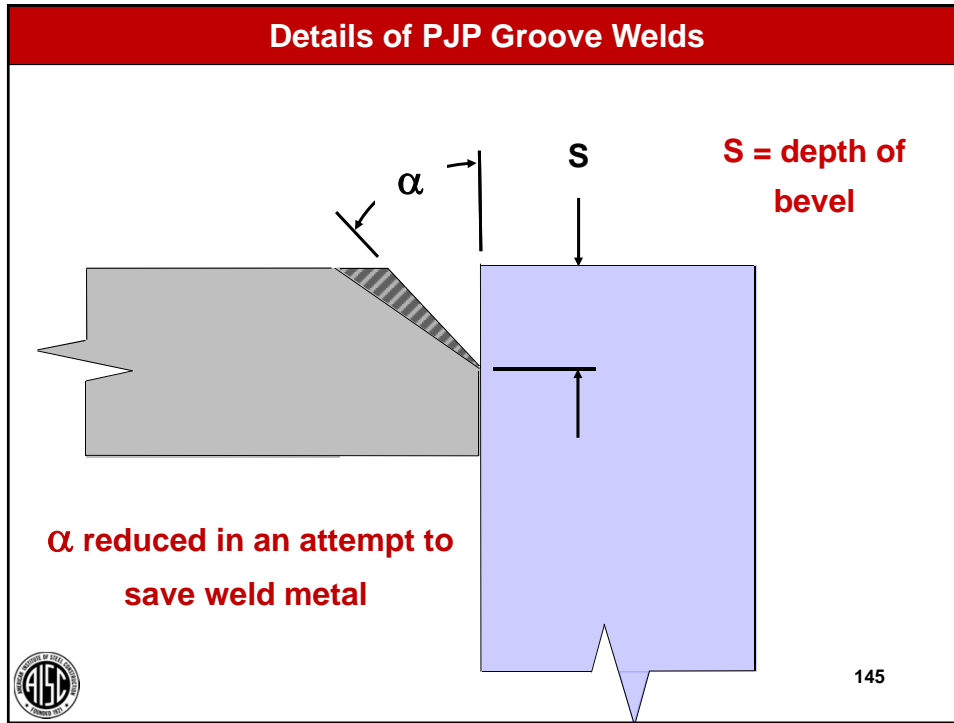












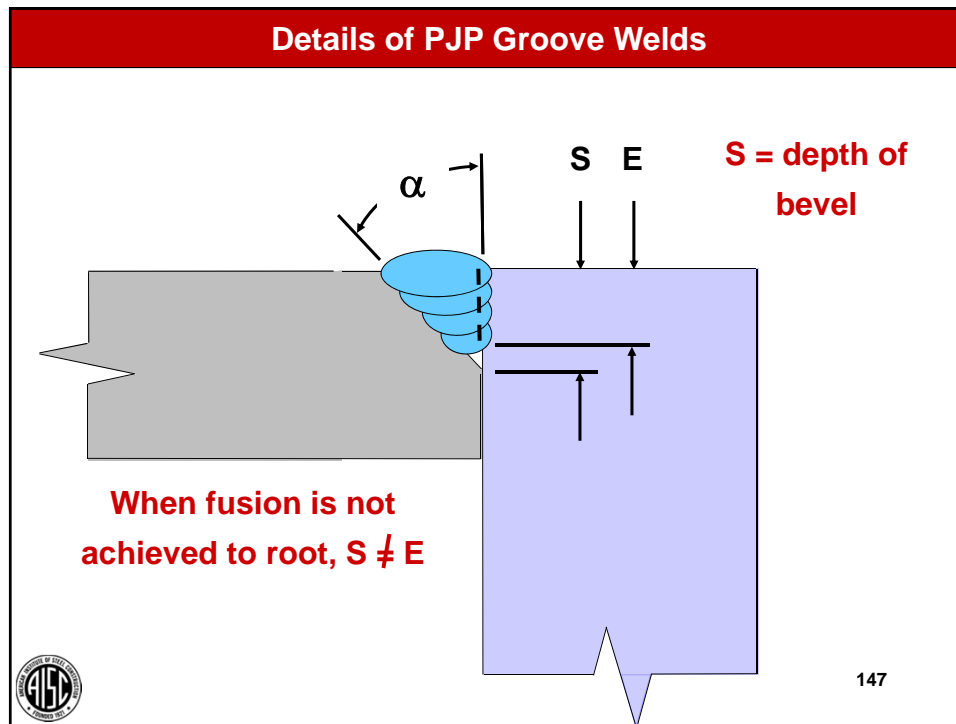
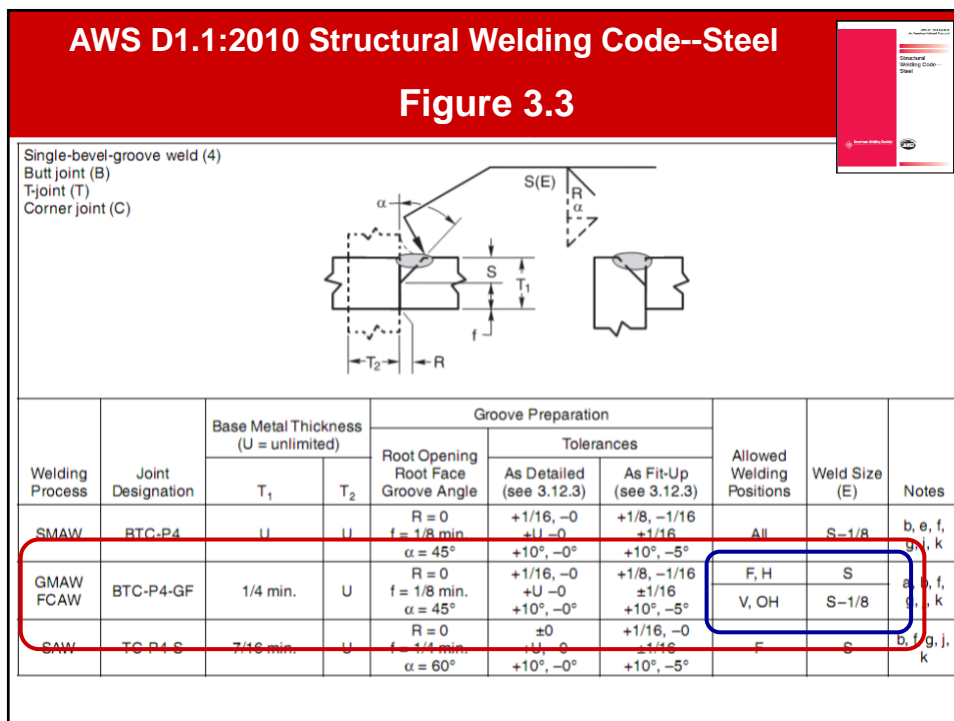
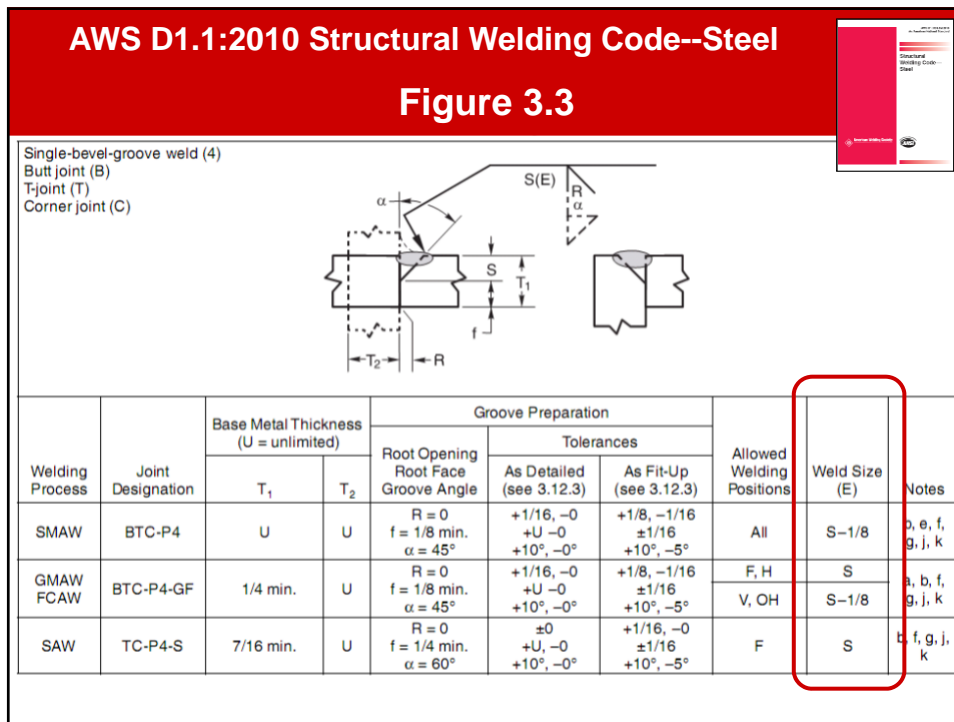
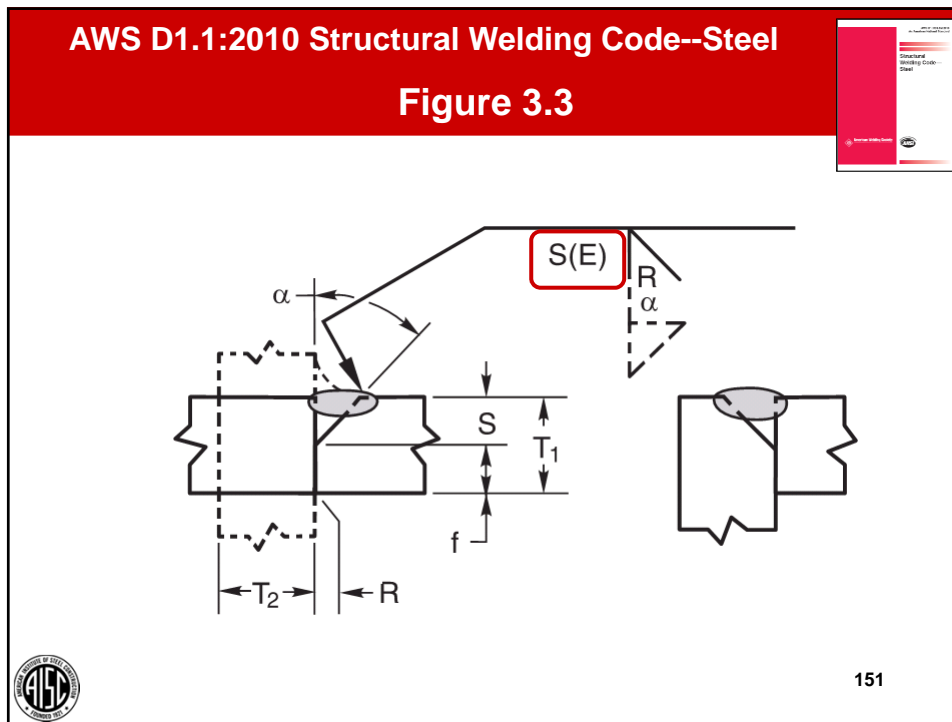


TABLE J2.1 Effective Throat of Partial Joint Penetration Groove Welds

Welding Process	Welding Position F (flat), H (horizontal), V (vertical), OH (overhead)	Groove Type (AWS D1.1/D1.1M, Figure 3.3)	Effective Throat
Shielded metal arc (SMAW)	All	J or U groove	depth of groove
Gas metal arc (GMAW) Flux cored arc (FCAW)		60° V	
Submerged arc (SAW)	F	J or U groove 60° bevel or V	depth of groove
Gas metal arc (GMAW) Flux cored arc (FCAW)	F, H	45° bevel	
Shielded metal arc (SMAW)	All	45° bevel	depth of groove minus 1/8 in. (3 mm)
Gas metal arc (GMAW) Flux cored arc (FCAW)	V, OH		





Details of PJP Groove Welds

General characteristics of PJP groove welds


- Throat < plate thickness
- Connection designer must determine throat
- “E” dimension (effective throat)
- “S” dimension (depth of bevel)
- The Connection Designer (the **E**ngineer) specifies the **E** dimension
- The **S**hop (the detailer) determines the required **S** dimension

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Details of PJP Groove Welds

Minimum sizes of PJP groove welds

- AISC Table J2.3
- AWS D1.1 Table 3.4



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TABLE J2.3
Minimum Effective Throat of
Partial Joint Penetration Groove Welds




Minimum Thickness of Thinner Part Joined	Minimum Effective Throat Thickness
To 1/4" inclusive	1/8"
Over 1/4" to 1/2"	3/16"
Over 1/2" to 3/4"	1/4"
Over 3/4" to 1 1/2"	5/16"
Over 1 1/2" to 2 1/4"	3/8"
Over 2 1/4" to 6"	1/2"
Over 6"	5/8"



Details of PJP Groove Welds

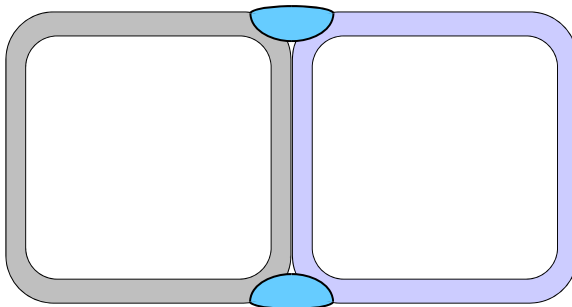
Minimum sizes of PJP groove welds

- AISC Table J2.3
- AWS D1.1 Table 3.4
- Has nothing to do with design
- Deals with ensuring adequate heat input for fusion and fabrication-related cracking resistance
- Helps achieve some reasonable proportionality between plate thickness and weld size
- These are minimum weld sizes; larger welds can be used

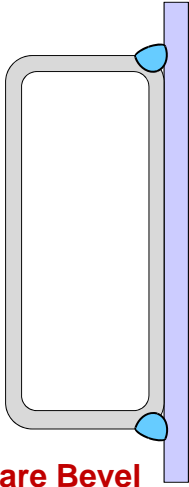


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Details of PJP Groove Welds



Flare V



Flare Bevel



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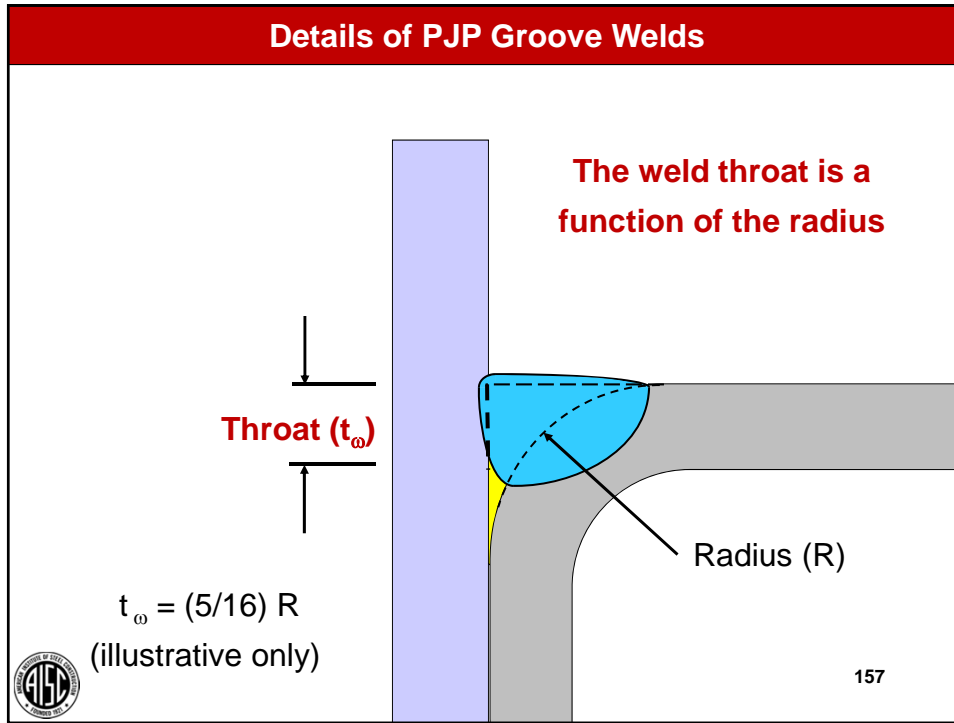
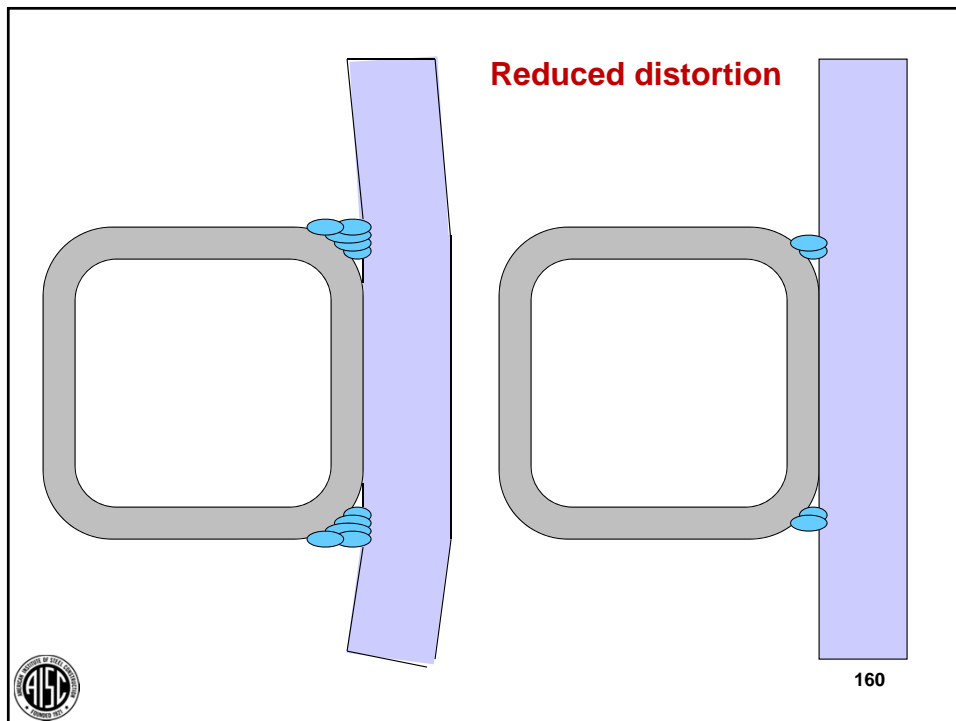
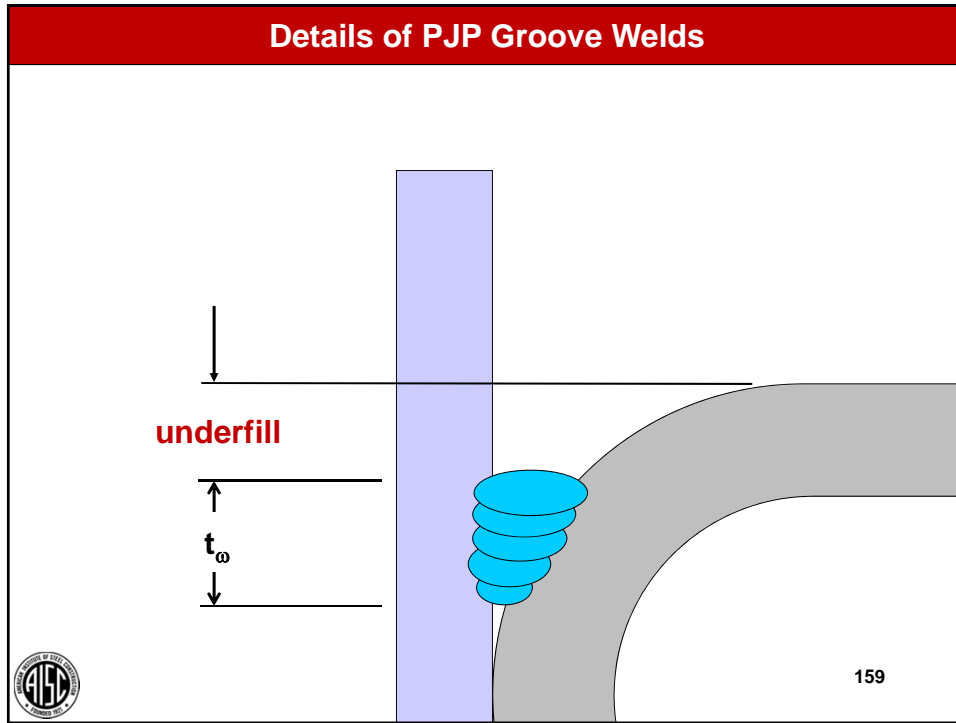


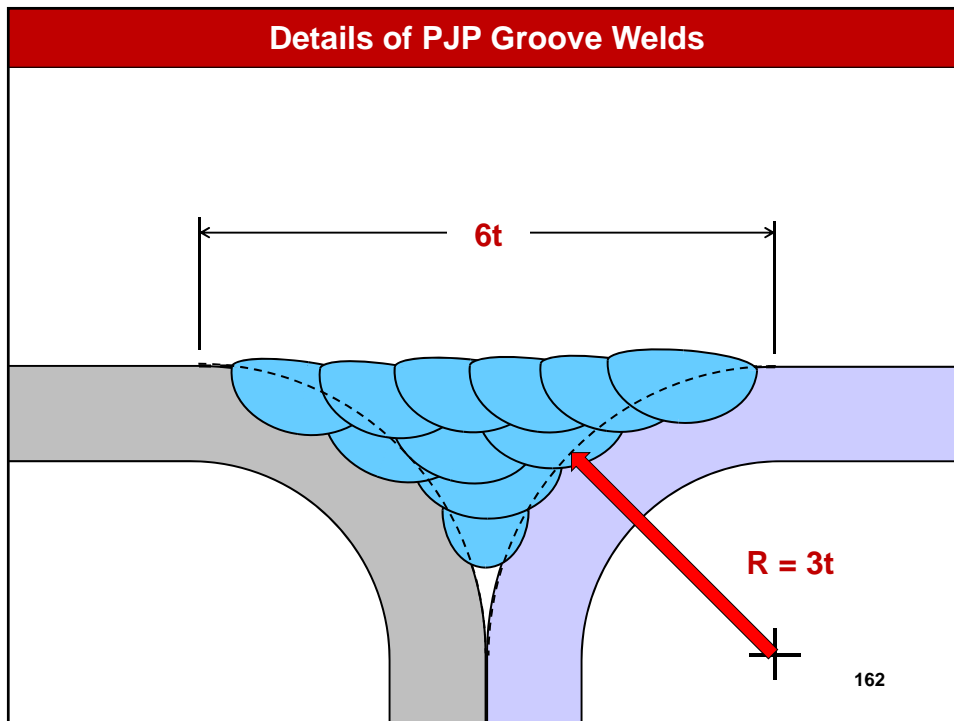
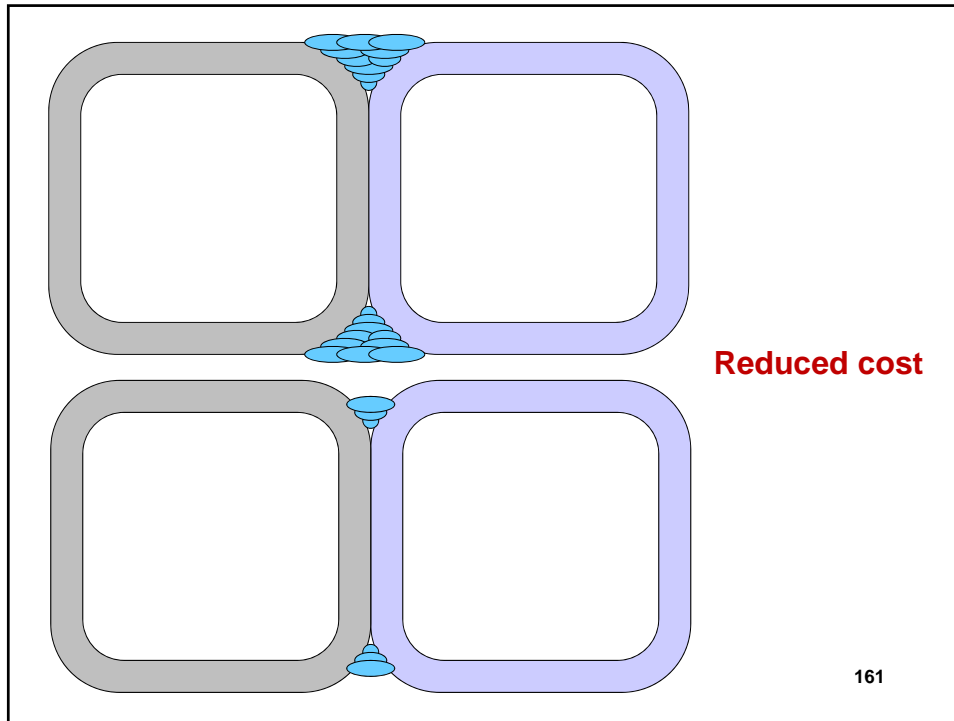
Table J2.2
Effective Weld Sizes of Flare Groove Welds

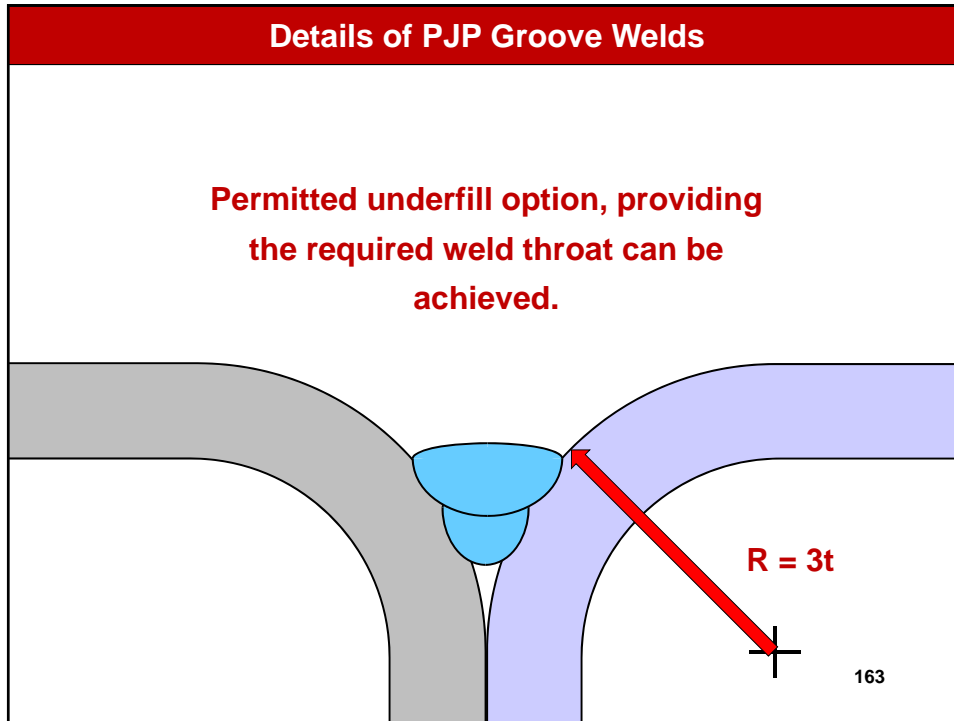
Welding Process	Flare-Bevel	Flare-Vee
SMAW FCAW-S	5/16 R	5/8 R
GMAW FCAW-G	5/8 R	3/4 R
SAW	5/16 R	1/2 R

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AWS D1.1:2010 Structural Welding Code--Steel

Single V Groove Weld: PJP

Single-V-groove weld (2)
Butt joint (B)
Corner joint (C)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW	BC-P2	1/4 min.	U	R = 0 f = 1/32 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S	b, e, f, j
GMAW FCAW	BC-P2-GF	1/4 min.	U	R = 0 f = 1/8 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S	a, b, f, j
SAW	BC-P2-S	7/16 min.	U	R = 0 f = 1/4 min. α = 60°	±0 +U, -0 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S	b, f, j

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AWS D1.1:2010 Structural Welding Code--Steel

Double V Groove Weld: PJP

Double-V-groove weld (3)
Butt joint (B)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW	B-P3	1/2 min.	—	R = 0 f = 1/8 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	e, f, i, j
GMAW FCAW	B-P3-GF	1/2 min.	—	R = 0 f = 1/8 min. α = 60°	+1/16, -0 +U, -0 +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	a, f, i, j
SAW	B-P3-S	3/4 min.	—	R = 0 f = 1/4 min. α = 60°	±0 +U, -0 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S ₁ + S ₂	f, i, j

AWS D1.1:2010 Structural Welding Code--Steel

Flare Bevel Groove Weld: PJP

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

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



AWS D1.1:2010 Structural Welding Code--Steel

Flare V Groove Weld: PJP

Flare-V-groove weld (11)
Butt joint (B)

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening	Tolerances				
SMAW FCAW-S	B-P11	3/16 min.	T ₁ min.	R = 0 f = 3/16 min. r = $\frac{3T_1}{2}$ min.	+1/16, -0 +U, -0 +U, -0	+1/8, -1/16 +U, -1/16 +U, -0	All	5/8 r	e, j, l, m, n
GMAW FCAW-G	B-P11-GF	3/16 min.	T ₁ min.	R = 0 f = 3/16 min. r = $\frac{3T_1}{2}$ min.	+1/16, -0 +U, -0 +U, -0	+1/8, -1/16 +U, -1/16 +U, -0	All	3/4 r	a, j, l, m, n
SAW	B-P11-S	1/2 min.	T ₁ min.	R = 0 f = 1/2 min. r = $\frac{3T_1}{2}$ min.	±0 +U, -0 +U, -0	+1/16, -0 +U, -1/16 +U, -0	F	1/2 r	j, l, m, n

AISC 360-10 SPECIFICATION

TABLE J2.5
Available Strength of Welded Joints,
ksi (MPa)

Filler metal with a strength level equal to or less than matching filler metal is permitted. →

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F _{base} or F _{fill}) ksi (MPa)	Effective Area (A _{base} or A _{fill}) in ² (mm ²)	Required Filler Metal Strength Level ¹
COMPLETE-JOINT-PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal		Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.		
Compression Normal to weld axis	Strength of the joint is controlled by the base metal		Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.		
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.		Filler metal with a strength level equal to or less than matching filler metal is permitted.		
Shear	Strength of the joint is controlled by the base metal		Matching filler metal shall be used. ¹		
PARTIAL-JOINT-PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS					
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F _y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.80$ $\Omega = 1.88$	0.85F _{EXX}	See J2.1a	
Compression Column to base plate and column splices designed per Section J1.4(1)	Compressive stress need not be considered in design of welds joining the parts.				
	Base	$\phi = 0.90$ $\Omega = 1.67$	F _y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.80$ $\Omega = 1.88$	0.85F _{EXX}	See J2.1a		
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Compressive stress need not be considered in design of welds joining the parts.				
	Base	$\phi = 0.90$ $\Omega = 1.67$	F _y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.80$ $\Omega = 1.88$	0.90F _{EXX}	See J2.1a		
Compression Connections not finished-to-bear	Compressive stress need not be considered in design of welds joining the parts.				
	Base	$\phi = 0.90$ $\Omega = 1.67$	F _y	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
Weld	$\phi = 0.80$ $\Omega = 1.88$	0.90F _{EXX}	See J2.1a		
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
	Base	Governed by J4			
Shear	Strength of the joint is controlled by the base metal.				
	Weld	$\phi = 0.75$ $\Omega = 2.00$	0.60F _{EXX}	See J2.1a	

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Fundamentals of Welded Connections


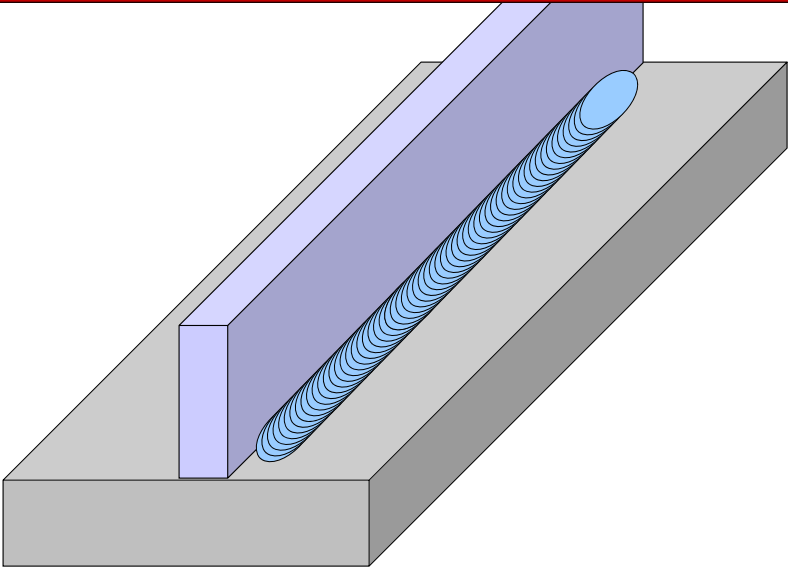
Outline

- Applicable Codes
- Welding Processes
- Joints and Weld Types
- CJP Details
- PJP Details
- ➔ • Fillet Weld Details



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Details of Fillet Welds




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Details of Fillet Welds


Minimum sizes of fillet welds

- AISC Table J2.4
- AWS D1.1 Table 5.8
- Has nothing to do with design
- Deals with ensuring adequate heat input for fusion and fabrication-related cracking resistance
- Helps achieve some reasonable proportionality between plate thickness and weld size
- These are minimum weld sizes; larger welds can be used



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TABLE J2.4
Minimum Size of Fillet Welds




Material Thickness of Thinner Part Joined	Minimum Size of Fillet Weld
To 1/4", inclusive	1/8"
Over 1/4" to 1/2"	3/16"
Over 1/2" to 3/4"	1/4"
Over 3/4"	5/16"

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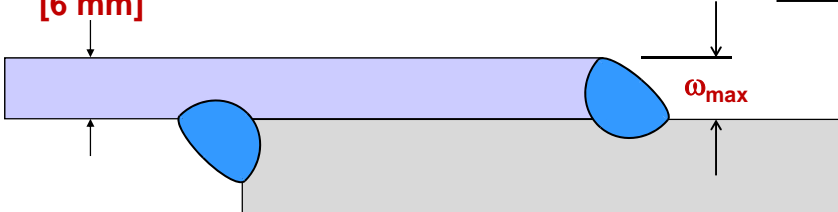


AISC 360-10 SPECIFICATION J2.2b



Maximum Fillet Weld Size

$t \leq 1/4''$
[6 mm]




The maximum size of a fillet weld of connected parts shall be:

(a) Along edges of material less than ¼ in. [6 mm] thick, not greater than the thickness of the material.

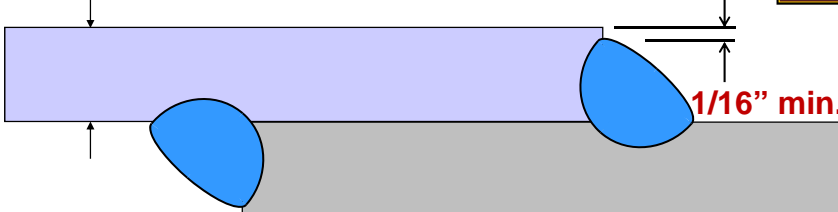
Also addressed in AWS D1.1:2010 clause 2.4.2.9

AISC 360-10 SPECIFICATION J2.2b



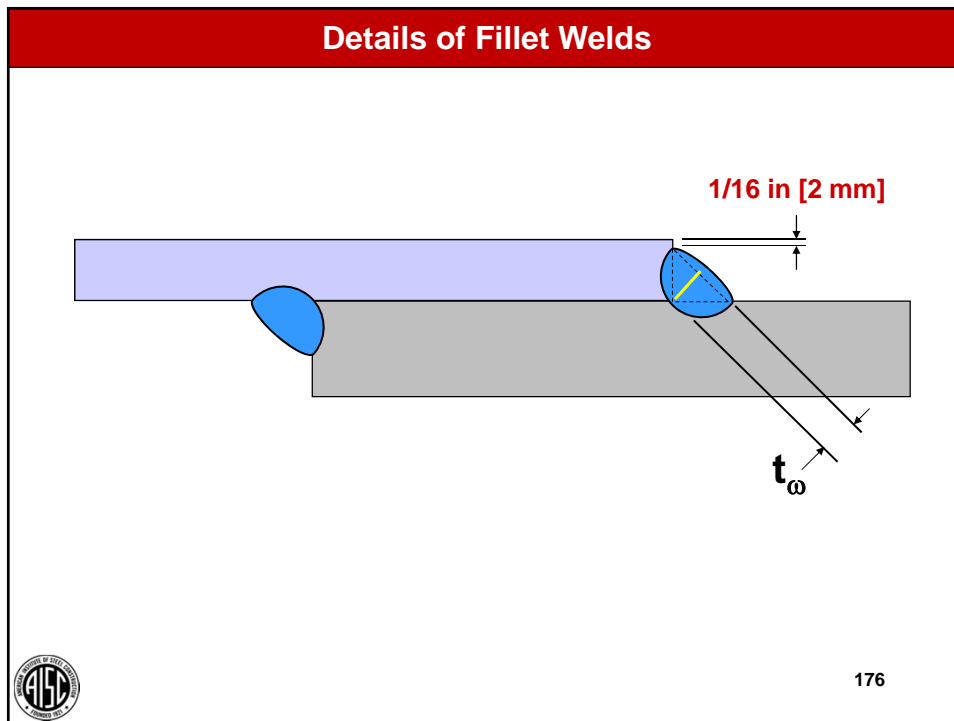
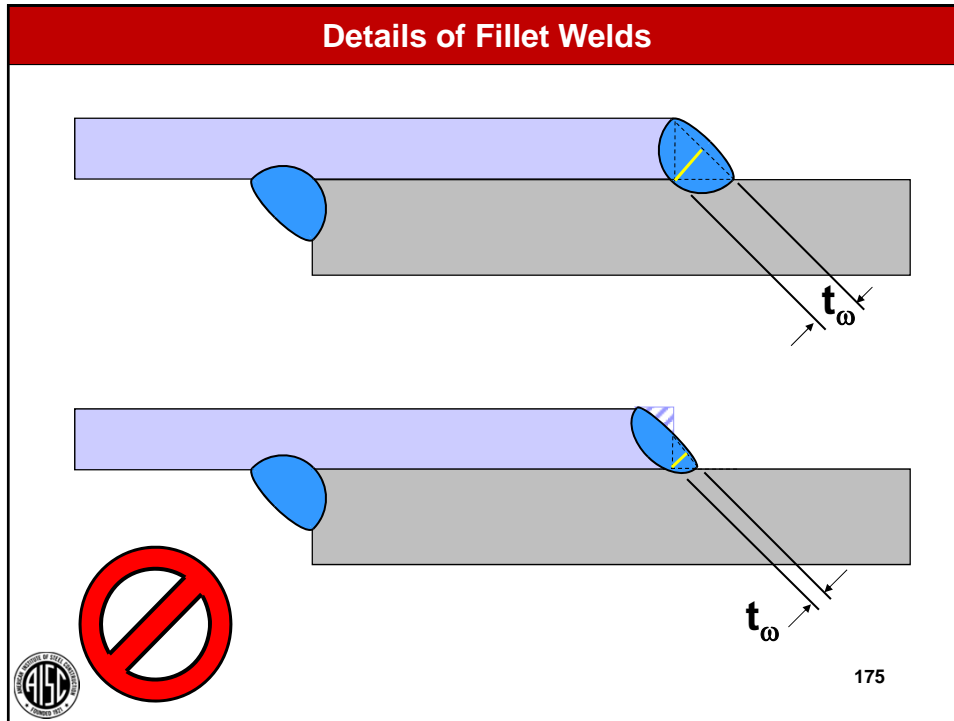
Maximum Fillet Weld Size

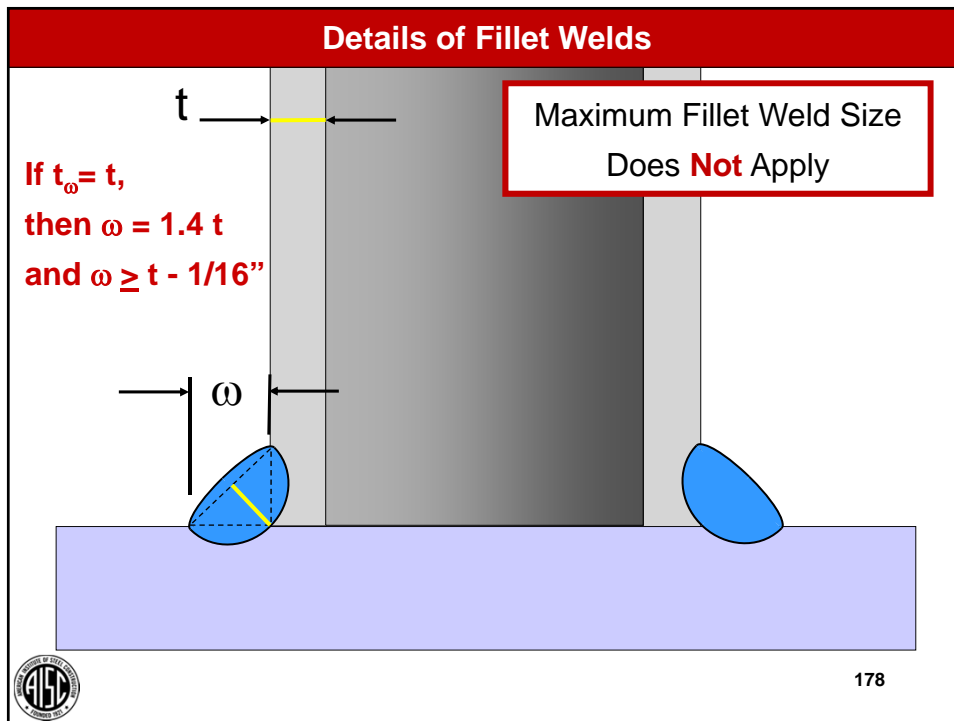
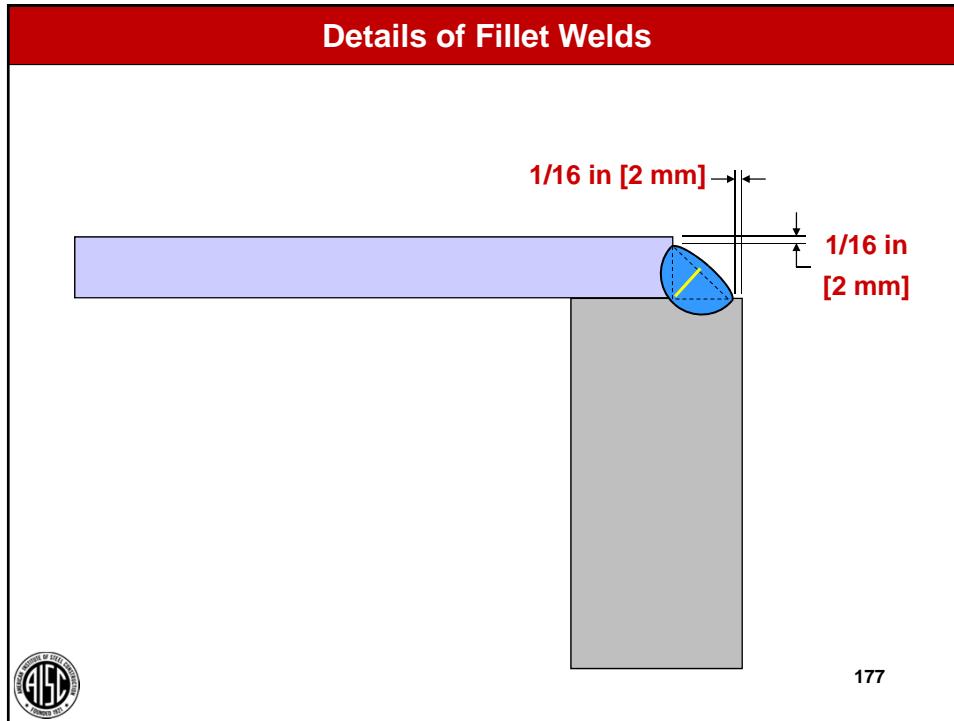
$t > 1/4''$
[6 mm]



(b) Along edges of materials ¼ in. [6 mm] or more in thickness, not greater than the thickness of the material minus 1/16 in [2 mm], unless the weld is especially designated on the drawings to be built out to obtain full-throat thickness.


Also addressed in AWS D1.1:2010 clause 2.4.2.9





Details of Fillet Welds

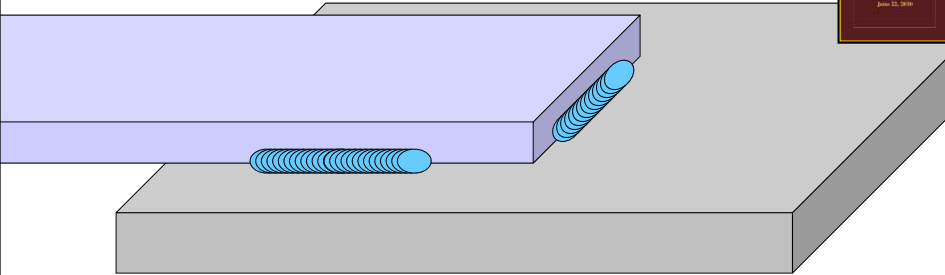
Minimum length of fillet welds



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AISC 360-10 SPECIFICATION J2.2b

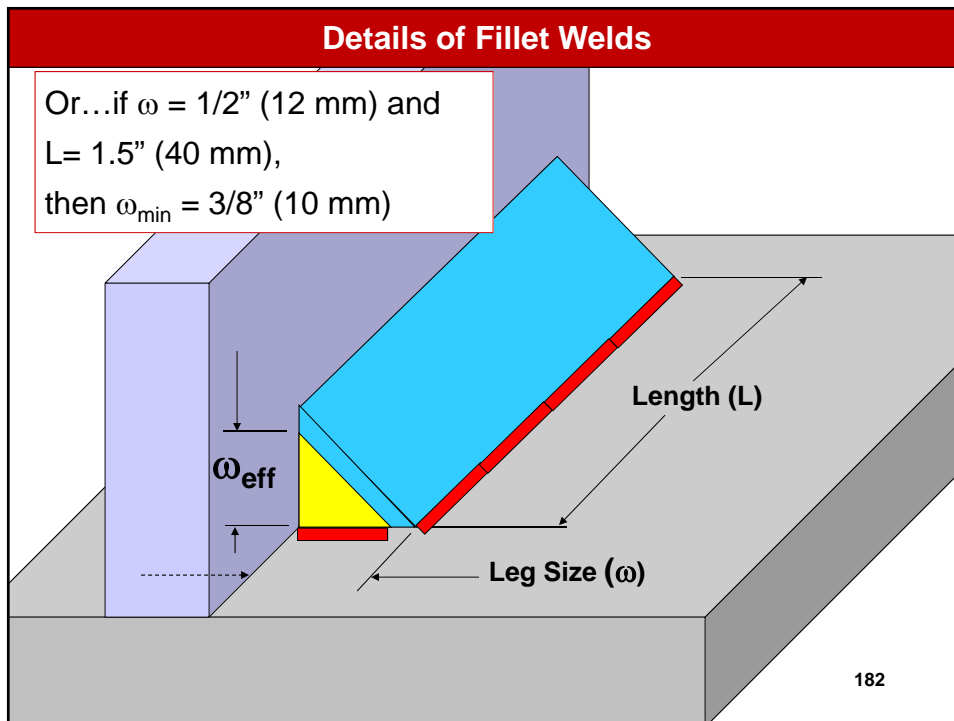
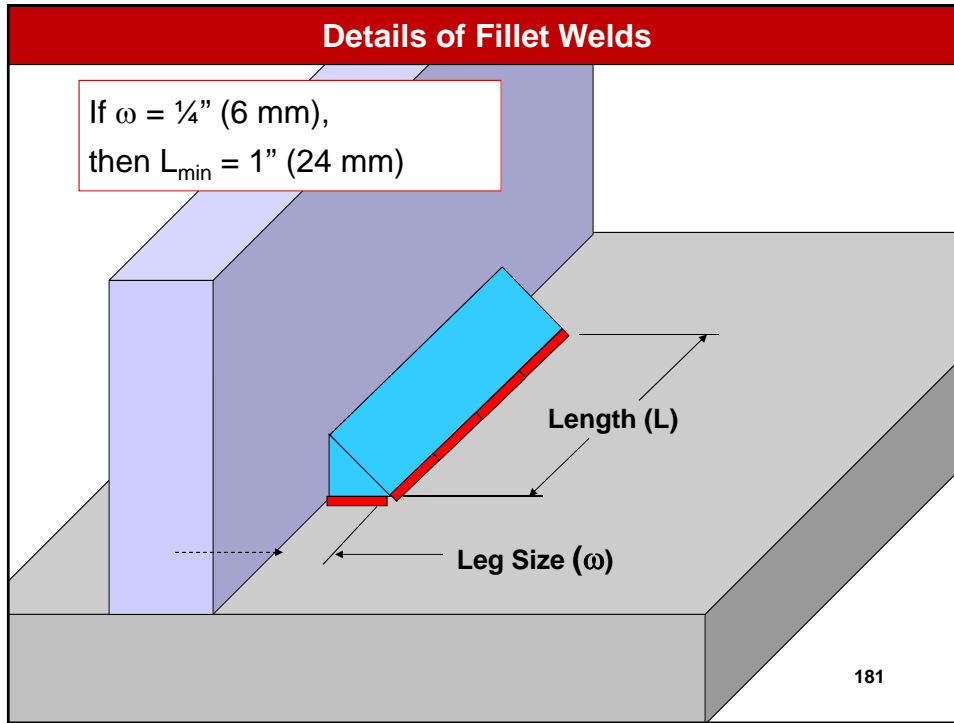
Minimum Fillet Weld Length



The minimum effective length of fillet welds designed on the basis of strength shall be not less than four times the nominal size, or else the size of the weld shall be considered not to exceed 1/4 of its effective length.


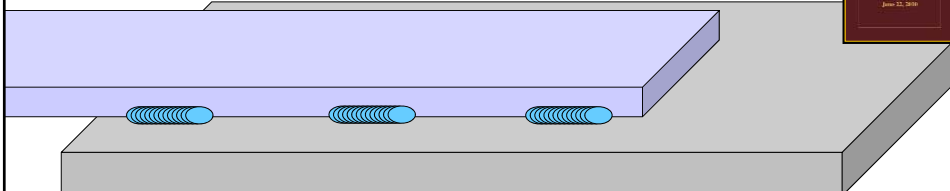
Also addressed in AWS D1.1:2010 clause 2.4.2.3





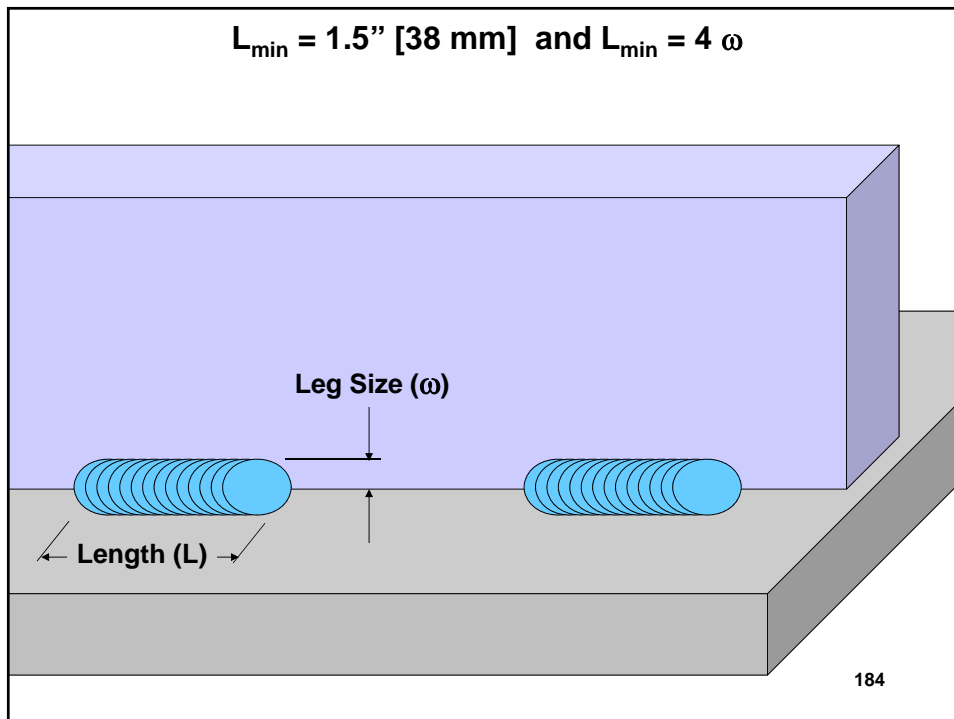
AISC 360-10 SPECIFICATION J2.2b

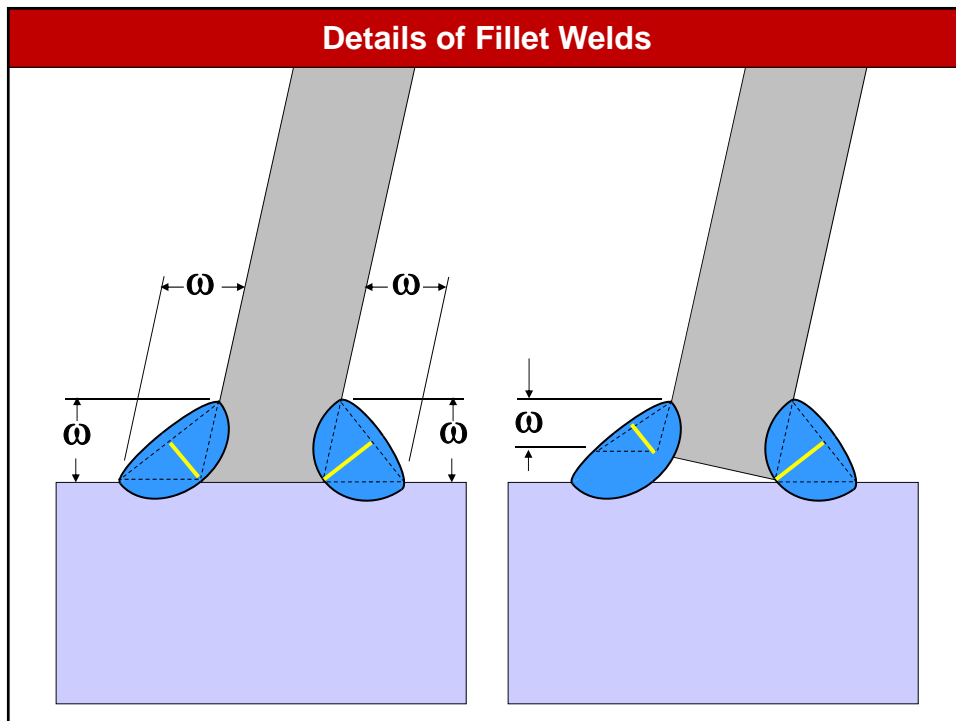
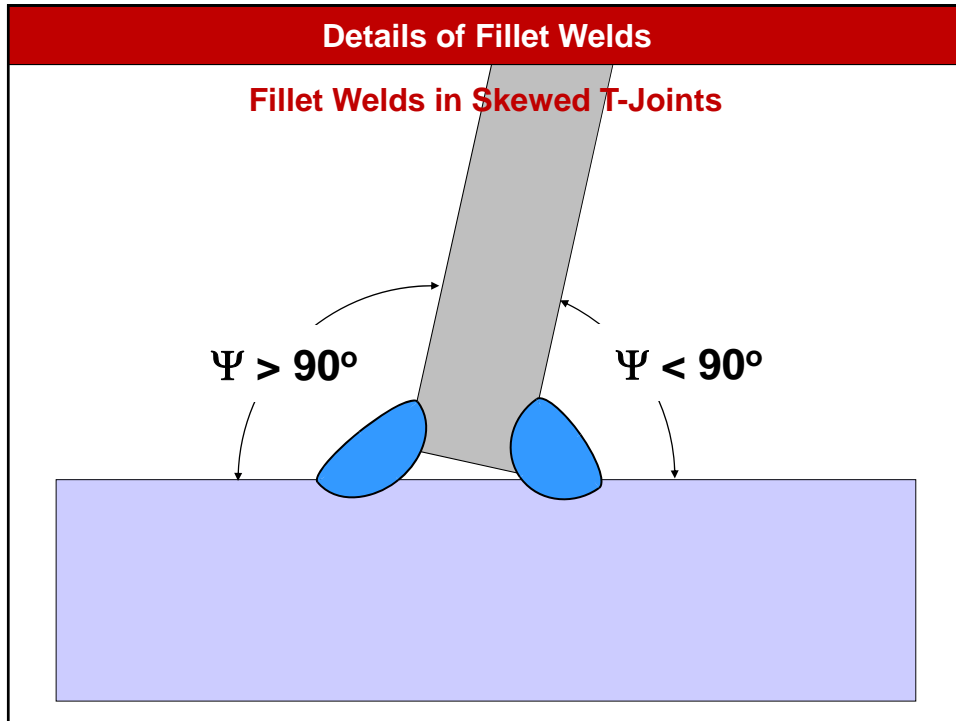
Intermittent Fillet Welds

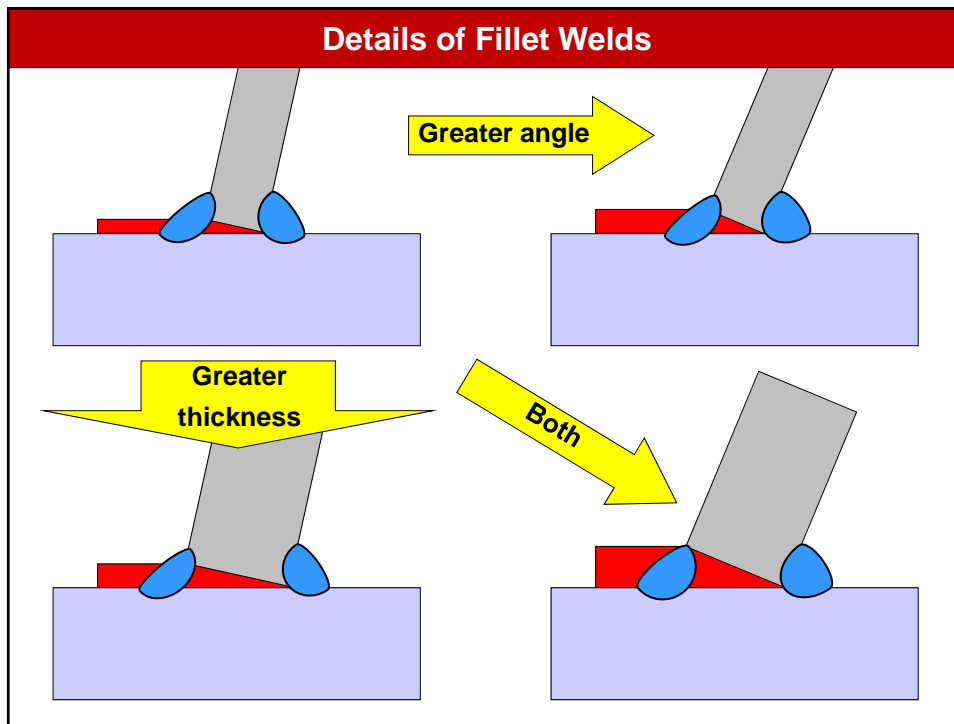


Intermittent fillet welds are permitted to be used to transfer calculated stress across a joint or faying surfaces when the required strength is less than that developed by a continuous fillet weld of the smallest permitted size, and to join components of built-up members. The effective length of any segment of intermittent fillet welding shall be not less than four times the weld size, with a minimum of 1-1/2 in. (38 mm).

Also addressed in AWS D1.1:2010 clause 2.4.2.4







AWS D1.1:2010 Structural Welding Code--Steel



2.3.4 Weld Size and Length.

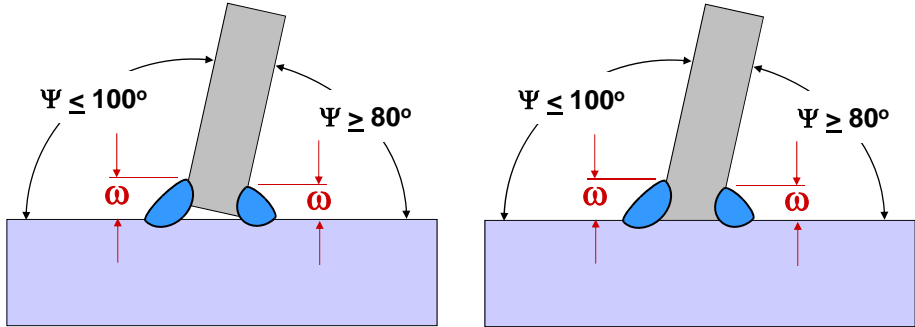
For fillet welds and skewed T-joints, the following shall be provided on the contract documents.

- (1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , contract documents shall specify the fillet weld leg size.
- (2) For welds between parts with the surfaces meeting at an angle less than 80° or greater than 100° , the contract documents shall specify the effective throat.



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Specify **fillet weld leg size (ω)** within these limits:
 $80^\circ \leq \Psi \leq 100^\circ$



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AWS D1.1:2010 Structural Welding Code--Steel

2.3.4 Weld Size and Length.

For fillet welds and skewed T-joints, the following shall be provided on the contract documents.

- (1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , contract documents shall specify the fillet weld leg size.
- (2) For welds between parts with the surfaces meeting at an angle less than 80° or greater than 100° , the contract documents shall specify the effective throat.

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AWS D1.1:2010 Structural Welding Code--Steel

Specify **effective throat** ($t_{\omega\text{-eff}}$) within these limits:
for $\Psi > 100^\circ$ and $\Psi < 80^\circ$

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2.3.5.2 Fillet Welds and Welds in Skewed T-Joints.

The following shall be provided on the **shop drawings**:

(1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , shop drawings shall show the fillet weld leg size,

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AWS D1.1:2010 Structural Welding Code--Steel



2.3.5.2 Fillet Welds and Welds in Skewed T-Joints.


The following shall be provided on the **shop drawings** (cont'd):

(2) For welds between parts with surfaces meeting at an angle less than 80° or greater than 100°, the shop drawings shall show the detailed arrangement of welds and required leg size to account for effects of joint geometry and, where appropriate, the Z-loss reduction for the process to be used and the angle,




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**Table 2.2
 Z Loss Dimension (Nontubular) (see 2.4.3.3)**

Dihedral Angle Ψ	Position of Welding—V or OH			Position of Welding—H or F		
	Process	Z (in)	Z (mm)	Process	Z (in)	Z (mm)
$60^\circ > \Psi \geq 45^\circ$	SMAW	1/8	3	SMAW	1/8	3
	FCAW-S	1/8	3	FCAW-S	0	0
	FCAW-G	1/8	3	FCAW-G	0	0
	GMAW	N/A	N/A	GMAW	0	0
$45^\circ > \Psi \geq 30^\circ$	SMAW	1/4	6	SMAW	1/4	6
	FCAW-S	1/4	6	FCAW-S	1/8	3
	FCAW-G	3/8	10	FCAW-G	1/4	6
	GMAW	N/A	N/A	GMAW	1/4	6



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Dihedral Angle Ψ	Position of Welding—V or OH			Position of Welding—H or F		
	Process	Z (in)	Z (mm)	Process	Z (in)	Z (mm)
$60^\circ > \Psi \geq 45^\circ$	SMAW	1/8	3	SMAW	1/8	3
	FCAW-S	1/8	3	FCAW-S	0	0
	FCAW-G	1/8	3	FCAW-G	0	0
	GMAW	N/A	N/A	GMAW	0	0
$45^\circ > \Psi \geq 30^\circ$	SMAW	1/4	6	SMAW	1/4	6
	FCAW-S	1/4	6	FCAW-S	1/8	3
	FCAW-G	3/8	10	FCAW-G	1/4	6
	GMAW	N/A	N/A	GMAW	1/4	6

The diagram illustrates a fillet weld joint between a vertical plate and a horizontal plate. The weld is shown in blue. The thickness of the weld metal is labeled t_w . The dihedral angle Ψ is indicated between the two plates. A red arrow points to the 'Z-loss' dimension, which is the distance from the root of the weld to the point where the weld metal thickness is t_w .

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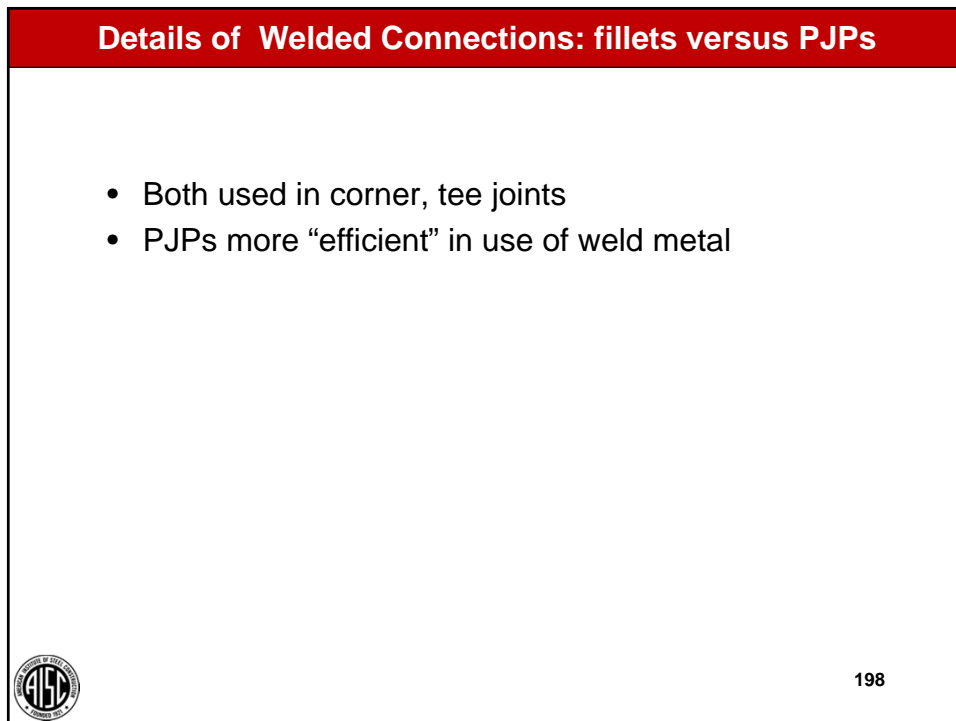
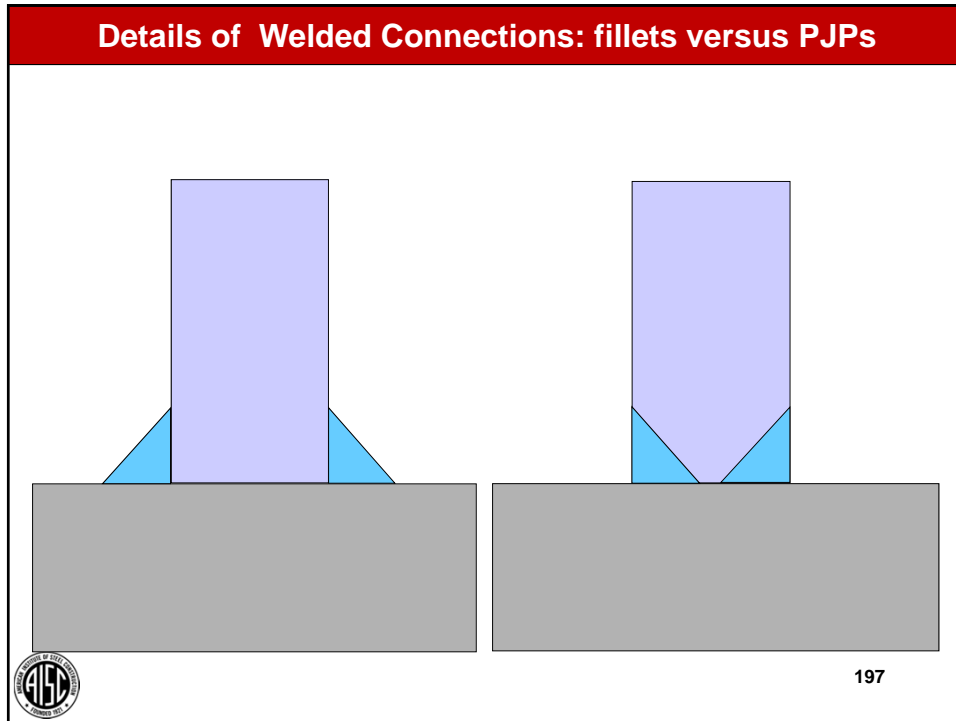
AISC 360-10 SPECIFICATION

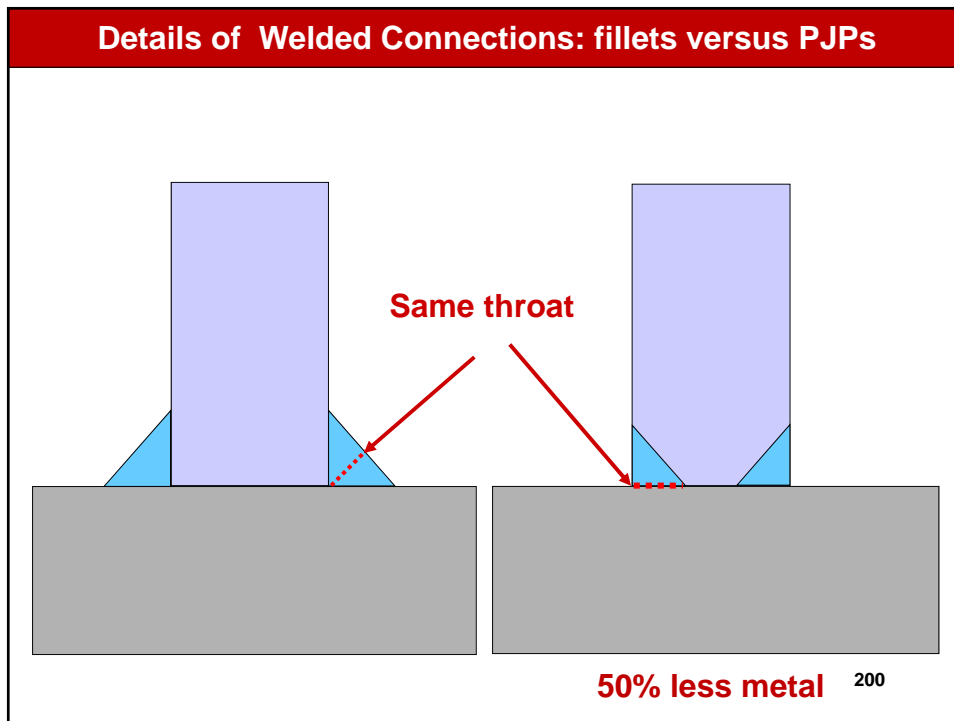
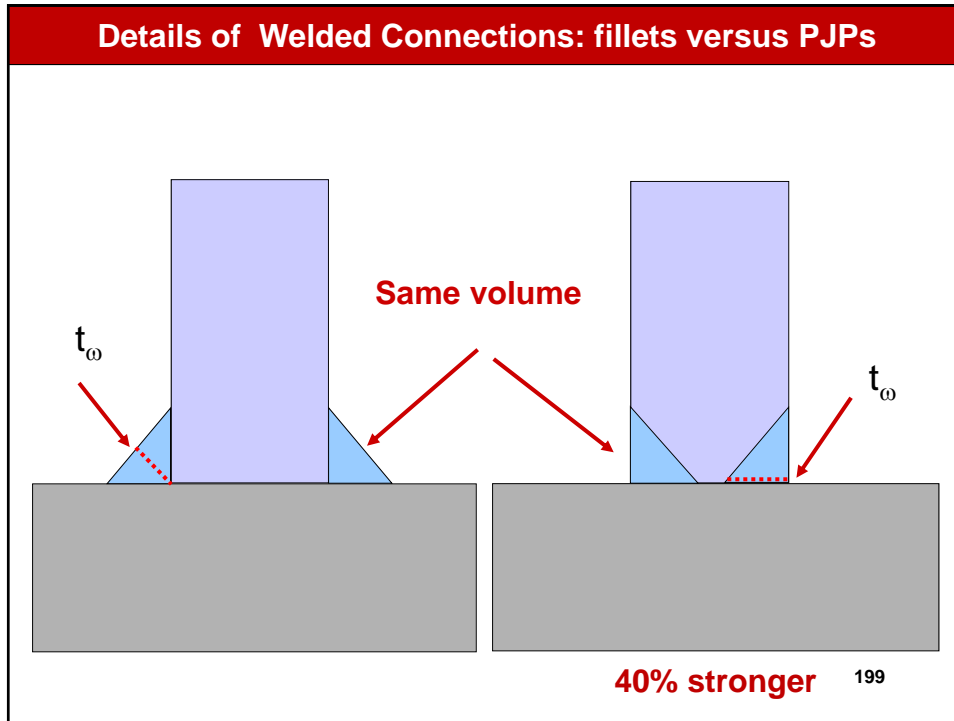
FILLET WELDS

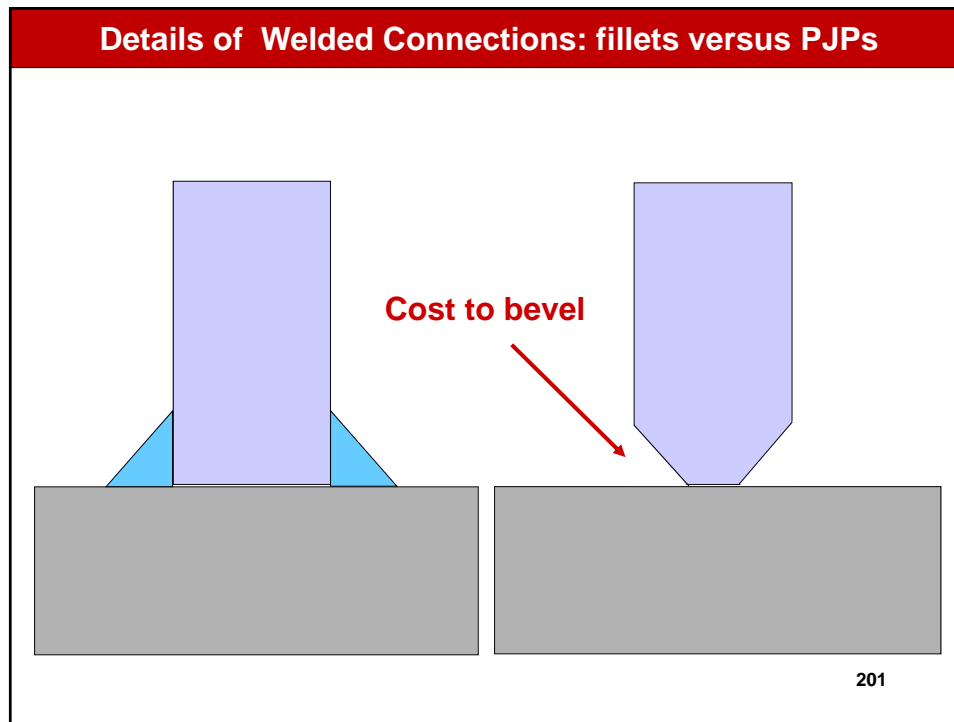
SPECIFICATION
For Structural Steel Buildings
June 15, 2010

FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T-JOINTS					
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}^{(d)}$	See J2.2a	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				

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Details of Welded Connections: fillets versus PJPs


- Both used in corner, tee joints
- PJPs more “efficient” in use of weld metal
- PJPs require joint preparation, adding cost
- Rule of thumb: if the weld throat is less than 3/4” [18 mm], use fillet welds. Note: that corresponds to a leg size of approximately 1” [25 mm].
- Rule of thumb: if the weld throat is greater than 3/4” [18 mm], use PJP groove welds.

The AISC logo is in the bottom left corner, and the number "202" is in the bottom right corner.

Fundamentals of Welded Connections


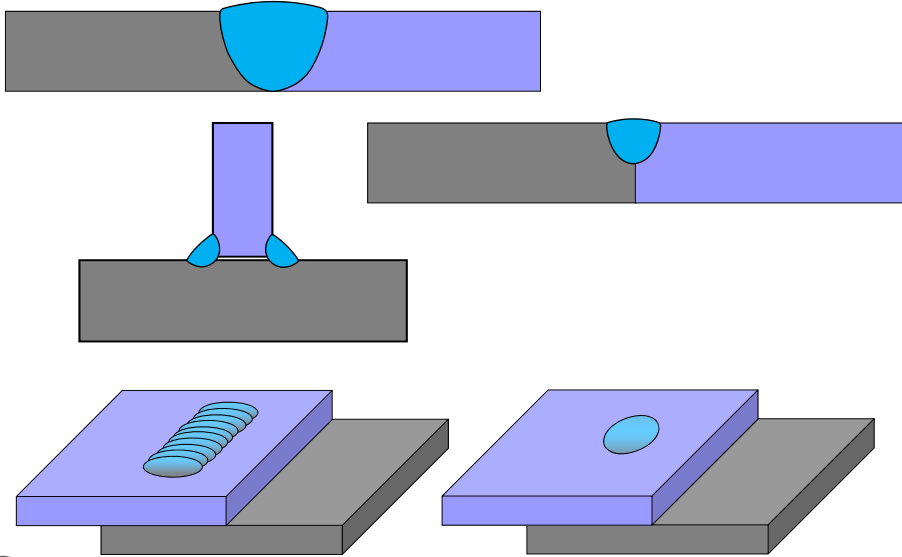
Outline

- Applicable Codes
- Welding Processes
- Joints and Weld Types
- CJP Details
- PJP Details
- Fillet Weld Details



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Fundamentals of Welded Connections



Individual Webinar Registrants

PDH Certificates

Within 2 business days...

- You will receive an email on how to report 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!



Individual Webinar Registrants

PDH Certificates

Within 2 business days...

- Reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.



3-Session Package Registrants

PDH Certificates

One certificate will be issued at the conclusion of all 3 sessions.



3-Session Package Registrants

Quizzes

Within two days, you will receive access to the quiz for this webinar. Quizzes are due three weeks after the live session.

Reasons for quiz:

PROFESSIONAL DEVELOPMENT HOURS – If you watch a recorded session you must take quiz for PDHs.

REINFORCEMENT – Reinforce what you learn. Get more out of the course.

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



3-Session Package Registrants

Recordings

Within two days, you will receive access to the recording for this webinar. The recording will be available for three weeks after the live session. For 3-session registrants only.

PROFESSIONAL DEVELOPMENT HOURS – If you watch a recorded session you must take AND PASS the quiz for PDHs.



3-Session Package Registrants

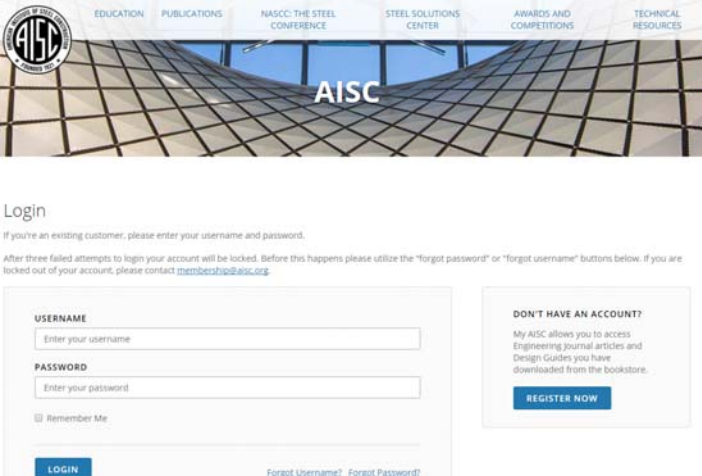
Course Resources

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

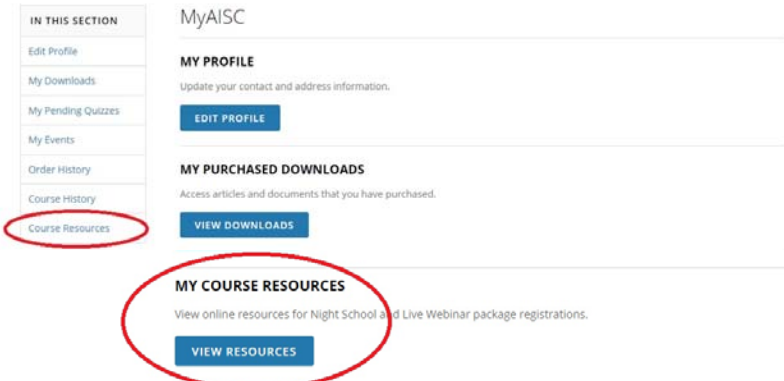


3-Session Package Registrants Course Resources


Go to www.aisc.org and sign in.



3-Session Package Registrants Course Resources



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Course Resources

Event	Start Date
Live Webinar - 3-Session Package: Welded Connections - A Three-Part Webinar Series	6/29/2017 1:30:00 PM
NS 14 8-Session Package-Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM
NS 13 8-Session Package-Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM



3-Session Package Registrants Course Resources




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Welded Connections

3-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
Part 1: Fundamentals of Welded Connections	Jun 29 2017 1:30PM EDT	Handouts	Available 07/01/2017 5pm EDT	Available 07/01/2017 5pm EDT	Pending
Part 2: Welded Connections for Seismic Service	Jul 6 2017 1:30PM EDT	Handouts	Available 07/08/2017 5pm EDT	Available 07/08/2017 5pm EDT	Pending
Part 3: Special Welding Applications and Field Fixes	Jul 13 2017 1:30PM EDT	Handouts	Available 07/15/2017 5pm EDT	Available 07/15/2017 5pm EDT	Pending




3-Session Package Registrants

Quiz and Recording Email Notification

Within two days, you will receive an email notification regarding access to the quiz and recording for this session. The email will include links to the quiz and recording.

EMAIL COMES FROM WEBINARS@AISC.ORG



Reminder to All Registrants

Connection Information and Handouts

Webinar connection information:

- Can be found in your confirmation/registration receipt
- Reminder sent out Wednesday afternoon

Link to handouts also found here



There's always a solution in steel.

Thank You

Please give us your feedback!
Survey at conclusion of webinar.

