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Welded Connections
A Primer for Engineers



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Course Description

21.1 Introduction and Welding Processes October 8, 2019

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.



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Learning Objectives

- Identify standards related to welding.
- Compare and contrast various arc welding processes.
- Define various welding and thermal cutting processes.
- Compare and contrast various joints and weld types.



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Night School 21 Course Schedule

10/8/2019	1. Introduction and Weld Processes
10/15/2019	2. Principles of Welded Connections
10/29/2019	3. Welded Connection Details
11/5/2019	4. Metallurgy and Cracking
11/19/2019	5. Fatigue of Welded Connections
11/26/2019	6. Seismic Welding Issues
12/3/2019	7. Special Welding Applications
12/10/2019	8. Problems and Fixes



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Night School 21 Welded Connections -- A Primer for Engineers

Session 1: Introduction and Welding Processes
October 8, 2019



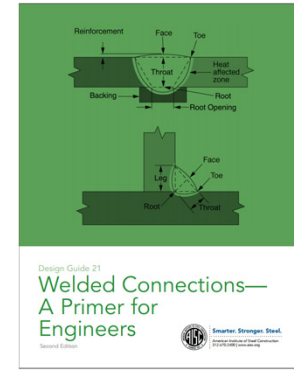
Duane K. Miller, PE, ScD
Manager of Engineering Services and Welding
Design Consultant



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AISC Design Guide 21, 2nd Edition

Welded Connections— A Primer for Engineers



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WELDED CONNECTIONS—A PRIMER FOR ENGINEERS

Chapter 1: Introduction

- 1.1 Importance of Welding
- 1.2 Scope of Welding
- 1.3 Welding-Related Codes and Specifications



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WELDED CONNECTIONS—A PRIMER FOR ENGINEERS

Chapter 2: Welding and Thermal Cutting Processes

- 2.1 Introduction
- 2.2 SMAW
- 2.3 FCAW
- 2.4 SAW
- 2.5 GMAW
- 2.6 ESW/EGW
- 2.7 GTAW





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WELDED CONNECTIONS—A PRIMER FOR ENGINEERS

Chapter 2: Welding and Thermal Cutting Processes

- 2.8 Arc Stud Welding
- 2.9 Thermal Cutting Processes
- 2.10 Water Jet Cutting





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WELDED CONNECTIONS—A PRIMER FOR ENGINEERS

Chapter 3: Welded Connection Basics

- 3.1 Joints
- 3.2 Weld Types—General
- 3.3 Complete-Joint-Penetration Groove Welds
- 3.4 Partial-Joint-Penetration Groove Welds
- 3.5 Fillet Welds
- 3.6 Plug/Slot Welds
- 3.7 Puddle Welds





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WELDED CONNECTIONS—A PRIMER FOR ENGINEERS

Chapter 3: Welded Connection Basics

- 3.8 Interaction of Joint Types and Weld Types
- 3.9 Selection of Weld Types
- 3.10 Required Filler Metal Strength
- 3.11 Determining Weld Strength
- 3.12 Specific Requirements for Various Joints
- 3.13 Weld Symbols





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WELDED CONNECTION BASICS

Outline

- Applicable Codes
- Arc Welding Processes – Overview
- Welding and Thermal Cutting Processes
- Joints and Weld Types




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WELDED CONNECTION BASICS

Outline



- Applicable Codes
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AWS D1.1

Structural Welding Code –
Steel




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AWS D1.1: 2015 Structural Welding Code – Steel

Major sections of AWS D1.1 include the following:

- Clause 1 – General Requirements
- Clause 2 – Design of Welded Connections
- Clause 3 – Prequalification of welding procedure specifications (WPS)
- Clause 4 – Qualification
- Clause 5 – Fabrication
- Clause 6 – Inspection




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AWS D1.1: 2015 Structural Welding Code – Steel

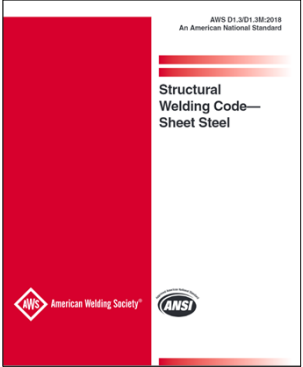
Major sections of AWS D1.1 include the following:

- Clause 7 – Stud Welding
- Clause 8 – Strengthening and Repair of Existing Structures
- Clause 9 – Tubular Structures
- AWS D1.1 also contains a series of Annexes and a helpful commentary that assists the user in correctly applying the code.



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AWS D1.3
Structural Welding Code –
Sheet Steel



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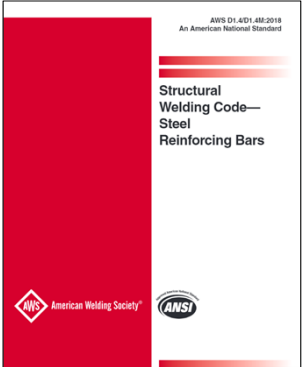
AWS D1.3: 2018 Structural Welding Code – Sheet Steel

AWS D1.3 covers:

- Welding of structural sheet and strip steels, including cold-formed members equal to or less than 3/16 in. [5mm] thick.
- The primary purpose for structural steel applications: welding sheet steel decking to supporting members with puddle welds.

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AWS D1.4
Structural Welding Code –
Steel Reinforcing Bars



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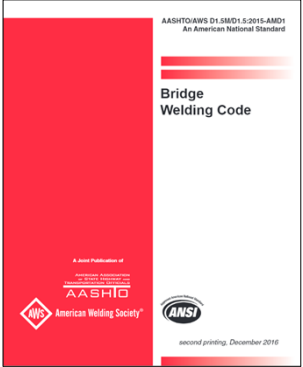
AWS D1.4: 2018 Structural Welding Code – Steel Reinforcing Bars

AWS D1.4 covers:

- Welding of reinforcing steel (rebar) to itself
- Welding of rebar to plate or shapes, including embed plates and steel used in composite construction

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AASHTO/AWS D1.5
Bridge Welding Code



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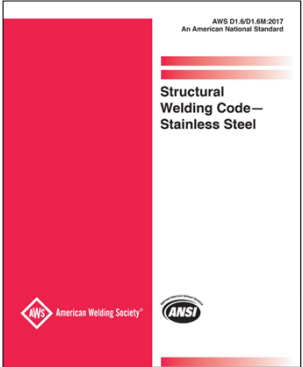
AASHTO/AWS D1.5: 2015 Bridge Welding Code

AASHTO/AWS D1.5:

- Joint standard of the AWS and the American Association of State Highway Transportation Officials (AASHTO)
- Generally requires that WPS be qualified by test, with a few exceptions
- Qualification testing involves Charpy V-notch (CVN) specimens and all weld metal tensile specimens
- Nondestructive testing (NDT) requirements

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AWS D1.6
Structural Welding Code –
Stainless Steel



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AWS D1.6: 2017 Structural Welding Code – Stainless Steel

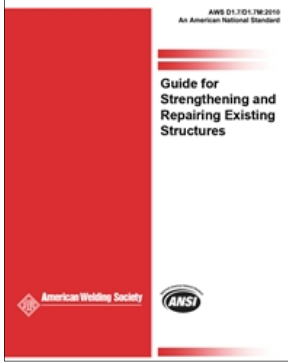
AWS D1.6 covers:

- Requirements for welding various grades of stainless to stainless, as well as stainless to carbon steel

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AWS D1.7

Guide for Strengthening and Repairing Existing Structures




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AWS D1.7: 2010 Guide for Strengthening and Repairing Existing Structures

AWS D1.7:


- D1.1 requires the Engineer to “establish a comprehensive plan for the work”: D1.7 can provide guidance
- Not a code, but a guide
- Provides guidance on: weldability, evaluation of existing welds, testing and sampling, heat strengthening, strengthening and damage repair



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AWS D1.8

Structural Welding Code – Seismic Supplement




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AWS D1.8: 2016 Structural Welding Code – Seismic Supplement

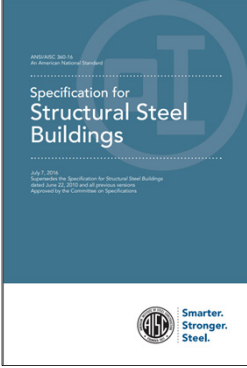
AWS D1.8:

- Supplements AWS D1.1
- When AWS D1.8 is specified, all the provisions of AWS D1.1 still apply, unless modified or superseded by AWS D1.8
- Assumes that the structure is designed with AISC *Seismic Provisions*



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AISC 360-16
Specification for Structural Steel
Buildings



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The image shows the cover of the AISC 360-16 Specification for Structural Steel Buildings. The cover is blue and white, featuring the AISC logo and the text 'Smarter. Stronger. Steel.' at the bottom. The title 'Specification for Structural Steel Buildings' is prominently displayed in the center.

AISC 360-16 Specification for Structural Steel Buildings

AISC 360 addresses the following major welding-related items:

- Acceptable steel designations (Section A3.1)
- Acceptable filler metals (Section A3.5)
- Requirements for splices in heavy sections (Section J1.5)
- Beam copes and weld access holes (Section J1.6)
- Welds in combination with bolts (Section J1.8)
- Details of groove welds (Section J2.2)
- Details of fillet welds (Section J2.2)

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The image shows a slide with a blue header containing the title 'AISC 360-16 Specification for Structural Steel Buildings'. Below the header, there is a list of seven welding-related items. The AISC logo is visible in the bottom left corner.

AISC 360-16 Specification for Structural Steel Buildings

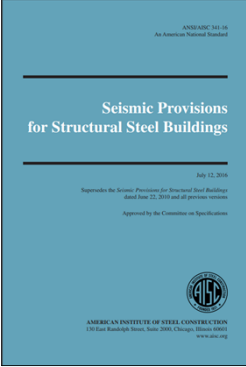
AISC 360 addresses the following major welding-related items:

- Available strength of welded joints (Table J2.5)
- Shop fabrication/welding issues (Section M2)
- Field erection/welding issues (Section M4)
- Weld quality control and quality assurance issues (Chapter N)
- Weld details for fatigue (Appendix 3)
- Welding issues associated with existing structures (Appendix 5)

35

The image shows a slide with a blue header containing the title 'AISC 360-16 Specification for Structural Steel Buildings'. Below the header, there is a list of six welding-related items. The AISC logo is visible in the bottom left corner.

AISC 341-16
Seismic Provisions for Structural Steel
Buildings





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The image shows the cover of the AISC 341-16 Seismic Provisions for Structural Steel Buildings. The cover is blue and white, featuring the AISC logo and the text 'Smarter. Stronger. Steel.' at the bottom. The title 'Seismic Provisions for Structural Steel Buildings' is prominently displayed in the center.

AISC 341-16 Seismic Provisions for Structural Steel Buildings

AISC 341:


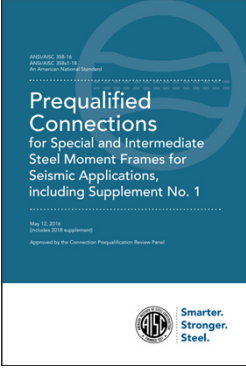
- Developed to augment the AISC *Specification*
- Adds provisions deemed necessary for high-seismic applications, where steel members are required to dissipate energy through controlled inelastic deformations in major seismic events
- For welding-related issues, primarily refers to D1.8
- Contains “grocery list” of items to be specified in contract documents, including many welding-related issues



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AISC 358-16

Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications





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AISC 358-16 Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications

AISC 358:



- Specifies design, detailing, fabrication, and quality criteria for connections that are prequalified in accordance with AISC *Seismic Provisions*
- For use with special moment frames (SMF) and intermediate moment frames (IMF)
- For welding-related issues, primarily refers to AISC 341
- Some prequalified connections have unique welded detail requirements (WUF-W, Endplate)



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AISC 303-16

Code of Standard Practice for Steel Buildings and Bridges




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AISC 341-16 Seismic Provisions for Structural Steel Buildings

AISC 303 addresses these major welding-related issues:

- Overall tolerances of fabricated members and erected assemblies
- Basic tolerances for architecturally exposed structural steel (AESS)




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Welding-Related Codes and Specifications

Other AWS D1 Codes:

- AWS D1.2/D1.2M *Structural Welding Code — Aluminum*
- AWS D1.9/D1.9M *Structural Welding Code — Titanium*




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Welding-Related Codes and Specifications

Other AWS Standards:

- AWS A5 *Filler Metal Specifications*
- AWS A2.4 *Standard Symbols for Welding, Bracing, and Nondestructive Examination*
- AWS A3.0/A3.0M *Standard Welding Terms and Definitions*




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WELDED CONNECTION BASICS

Outline

- Applicable Codes
- ➔ • Arc Welding Processes – Overview
- Welding and Thermal Cutting Processes
- Joints and Weld Types





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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

weld.

A localized coalescence of metals or nonmetals produced by heating the materials to the welding temperature, with or without the application of pressure, or by the application of pressure alone and with or without the use of filler metal.





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Arc Welding Processes

Requirements for fusion:

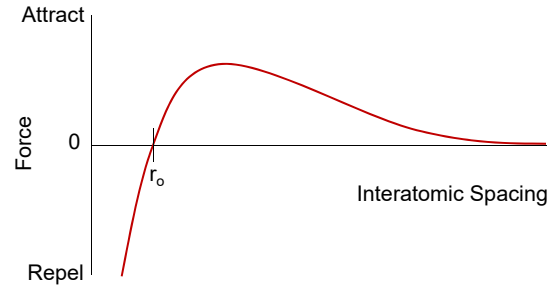
- Atomic closeness
- Atomic cleanliness




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Arc Welding Processes

Atomic Closeness




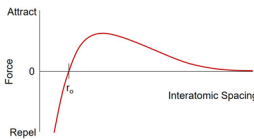
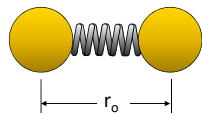
Adapted from W.F. Savage, as presented in *Weld Imperfections*, 1968



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Arc Welding Processes

Atomic Closeness



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Arc Welding Processes

Atomic Closeness

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Arc Welding Processes

Atomic Closeness

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Arc Welding Processes

Atomic Closeness

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Arc Welding Processes

Atomic Closeness:



- Very, very close
- Gaps exist between materials, even carefully machined parts (typically 100-1000 atom diameters from peak to valley of carefully machined parts)

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Arc Welding Processes

How to Achieve Atomic Closeness:

- Melt one material (brazing, soldering)
- Melt two or more materials (arc welding, resistance welding)
- Use pressure (with or without heat) to force closeness (forge welding, friction stir welding)





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Arc Welding Processes

Atomic Cleanliness:

- Oxides form very rapidly
- Oxides neutralize the attractive forces
- Other contaminants: water, oil, gasses





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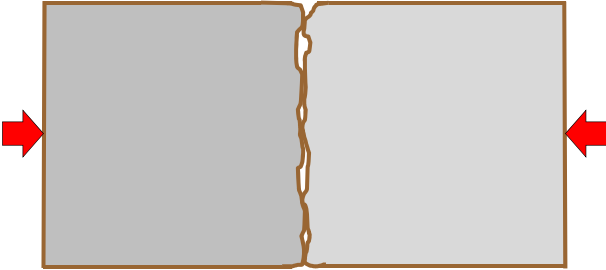
Arc Welding Processes

How to Achieve Atomic Cleanliness:

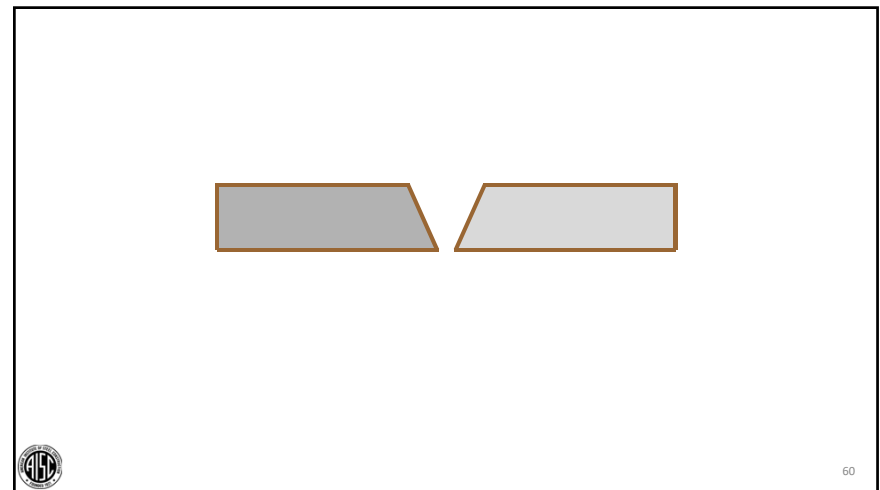
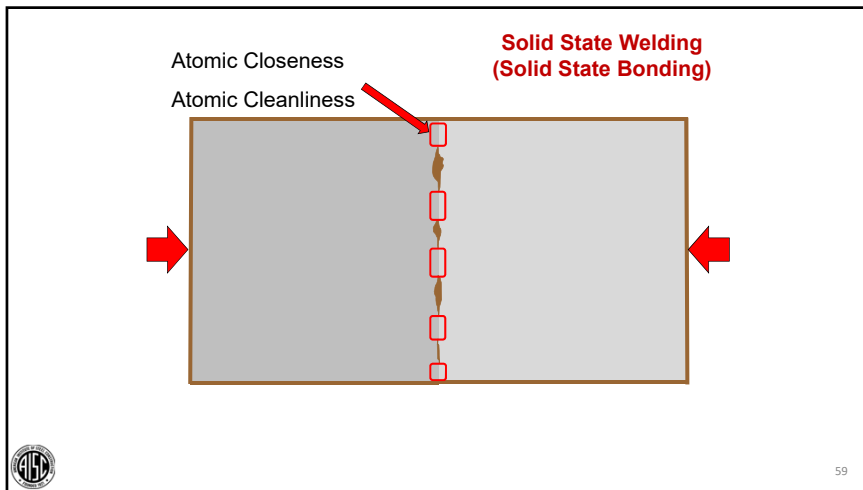
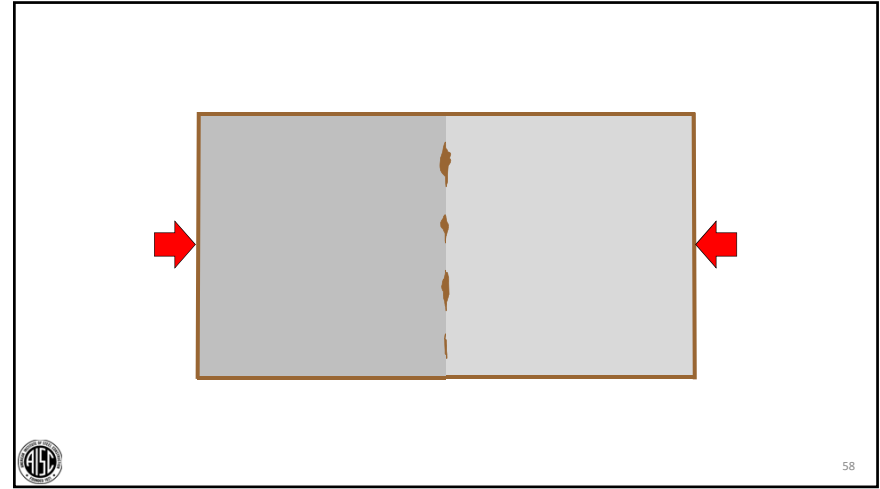
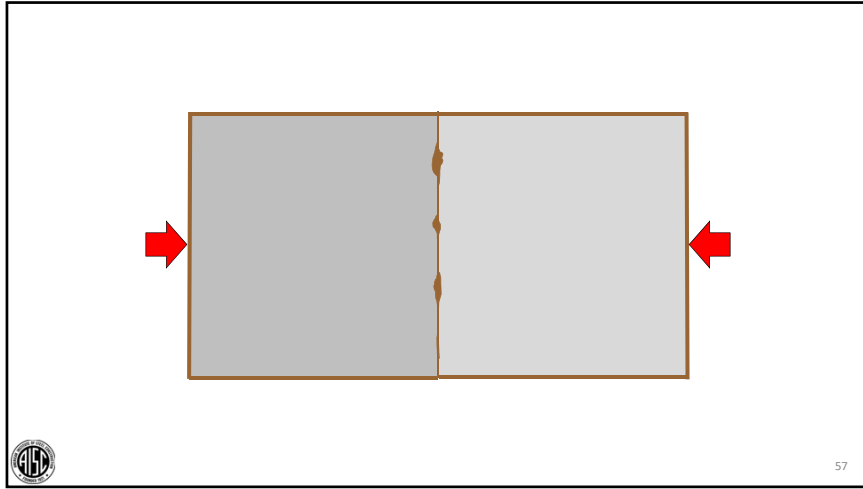
- Mechanically clean the part (scraping, machining)
- Chemically clean the part (fluxes)

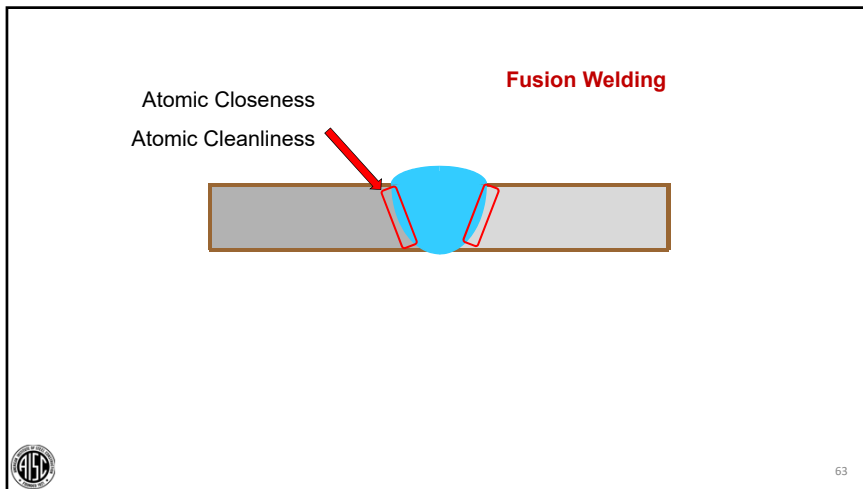
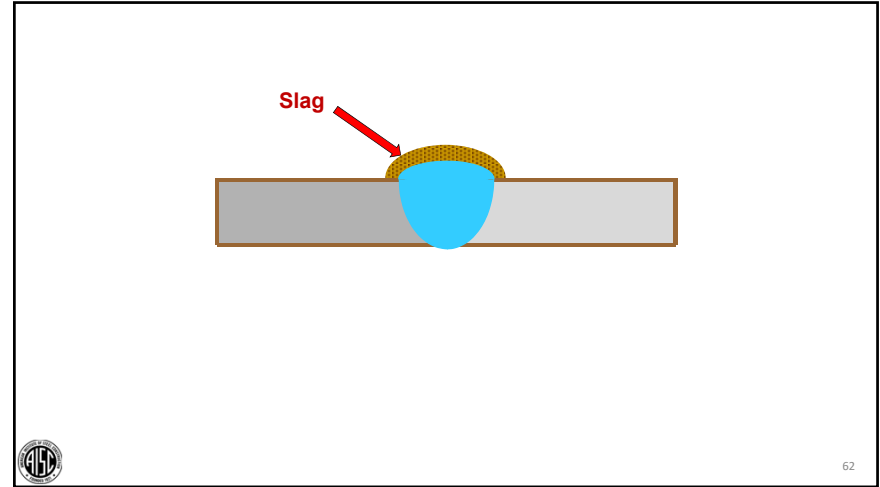
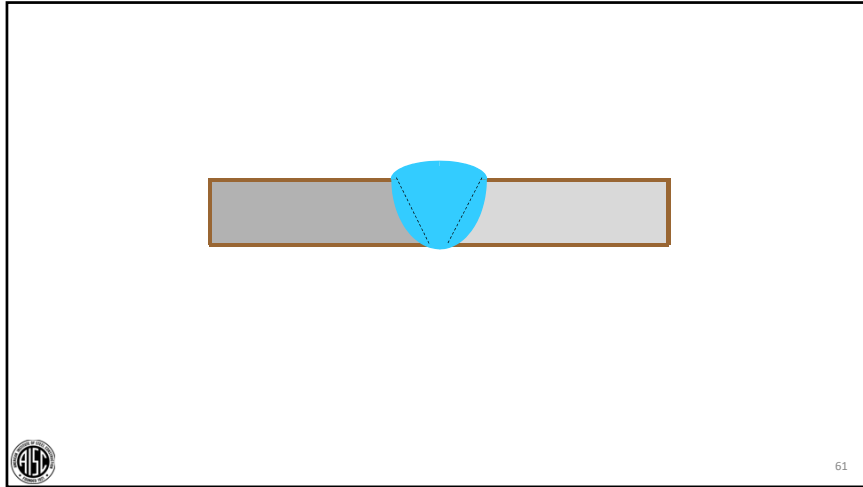


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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)





fusion, fusion welding.

The melting together of filler metal and base metal, or of base metal only, to produce a weld.

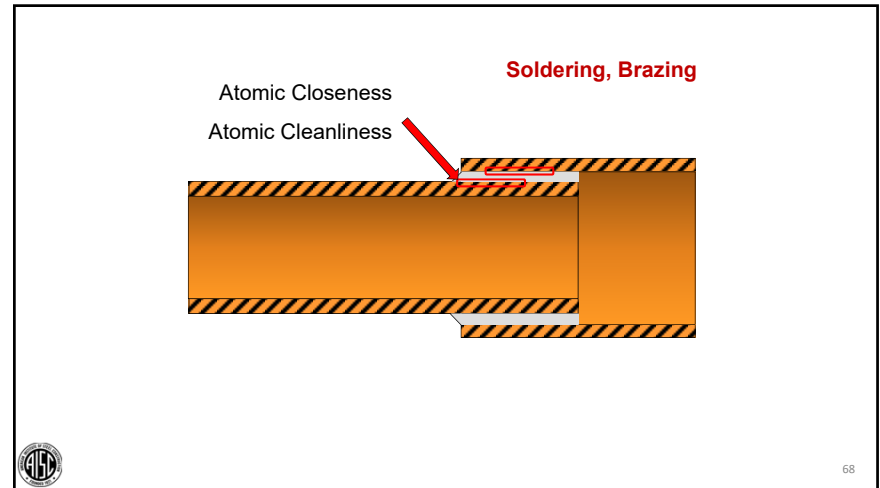
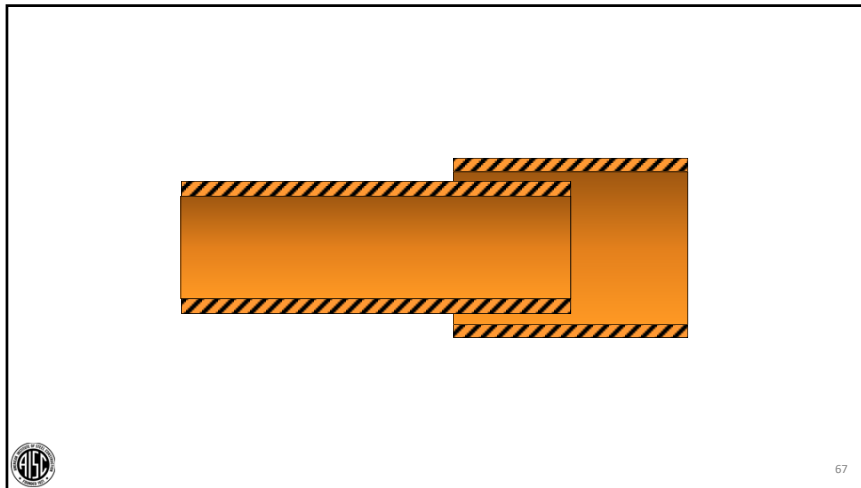
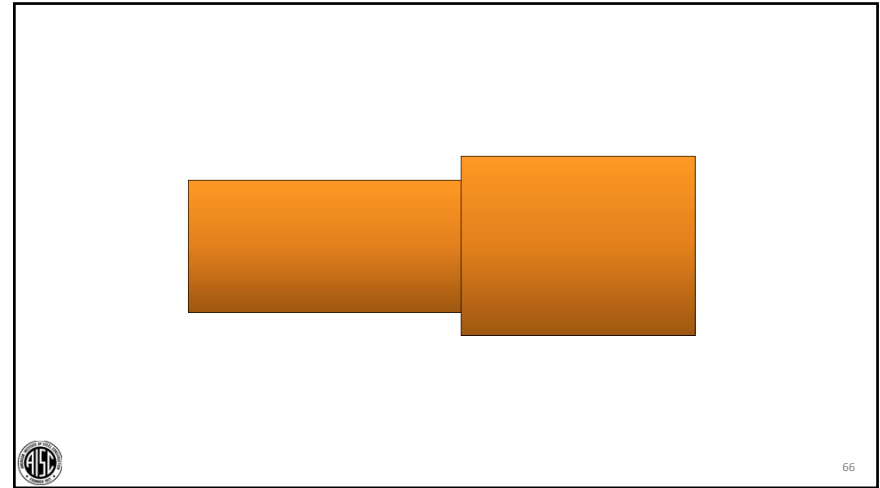
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

arc welding.

A group of welding processes producing coalescence of workpieces by melting them with an arc. The processes are used with or without the application of pressure and with or without filler metal.





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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

Soldering

A group of welding processes that produce coalescence of materials by heating them to the soldering temperature in the presence of a filler metal having a liquidus not exceeding 450 degrees C, 840 degrees F.





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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

Brazing

A group of welding processes that produce coalescence of materials by heating them to the brazing temperature in the presence of a filler metal having a liquidus above 450 degrees C, 840 degrees F.





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Arc Welding Processes

How to protect the metal puddle from the atmosphere:

- Inert gasses that displace the atmosphere
- Slags that form a mechanical barrier
- Both slags and gasses





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Arc Welding Processes

**Once a puddle is formed...
...the puddle must be protected from the atmosphere.**

- 80% Nitrogen
- 19% Oxygen

(Also, need to protect the metal droplets in the arc)





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Arc Welding Processes

Once a puddle is formed...
...need to control the shape of the puddle.

- Shielding gasses affect weld puddle surface tension (and the wetting of the puddle to the base metal)
- Slags can be used to support and shape weld puddles





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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)
- Gas Tungsten Arc Welding (GTAW)
- Electroslag Welding (ESW)
- Electrogas Welding (EGW)
- Arc Stud Welding (ASW)





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Arc Welding Processes

Major thermal cutting processes:

- Oxy-fuel Cutting (OFC)
- Plasma Arc Cutting (PAC)
- Air Arc Gouging (AAG)





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WELDED CONNECTION BASICS

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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

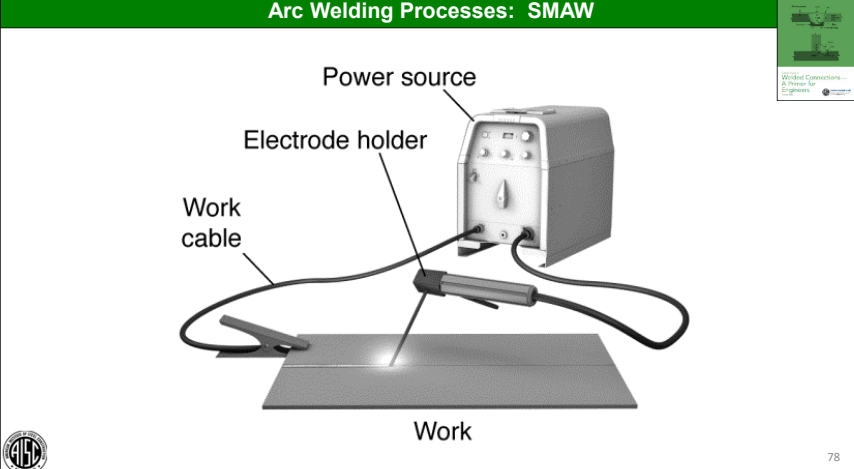
shielded metal arc welding (SMAW).

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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Arc Welding Processes: SMAW





Power source

Electrode holder

Work cable

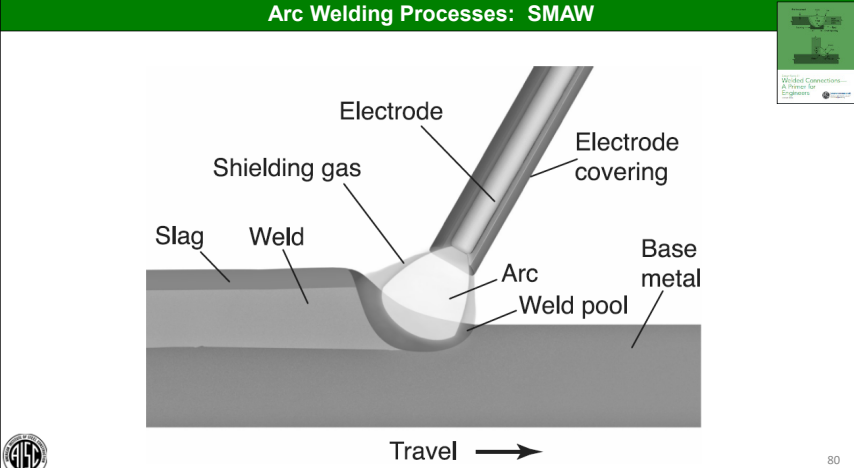
Work



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Arc Welding Processes: SMAW



Electrode

Shielding gas

Slag

Weld



Electrode covering

Arc

Weld pool

Base metal

Travel →





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Arc Welding Processes: SMAW

Advantages:

- Simplicity
- Flexibility
- Familiarity





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Arc Welding Processes: SMAW

Limitations:

- Variable resistor
- Electrodes are of finite length
- Stub loss
- Operator skill required



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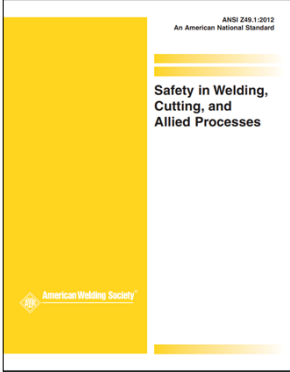
ANSI Z49.1

Safety in Welding, Cutting, and Allied Processes

Available by free download from AWS

aws.org

www.aws.org/technical/facts

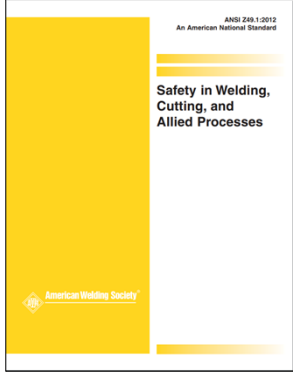


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The big four:

- Arc
- Fire
- Electrical
- Fume

Not comprehensive.
See Z49.1 for a complete listing



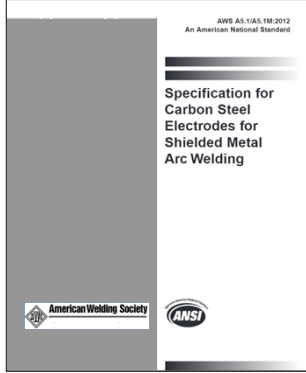
ANSI Z49.1-2012
An American National Standard
Safety in Welding,
Cutting, and
Allied Processes
American Welding Society




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AWS A5.1

Specification for Carbon Steel Electrodes
for Shielded Metal Arc Welding




AWS A5.1/A5.1M-2012
An American National Standard
Specification for Carbon Steel Electrodes for
Shielded Metal
Arc Welding
American Welding Society
ANSI



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AWS 5 Filler Metal Specifications




E7018

Electrode _____

70 ksi minimum specified tensile strength _____


1 = Position of welding _____

8 = Coating type, mechanical properties _____



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AWS 5 Filler Metal Specifications




E4918

Electrode _____

490 MPa min. specified tensile strength _____

1 = Position of welding _____

8 = Coating type, mechanical properties _____




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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

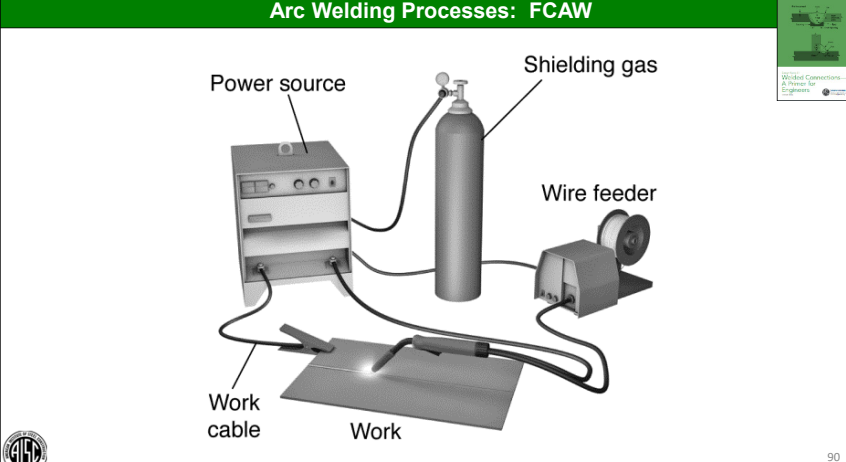
flux cored arc welding (FCAW).

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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Arc Welding Processes: FCAW




Power source

Shielding gas

Wire feeder

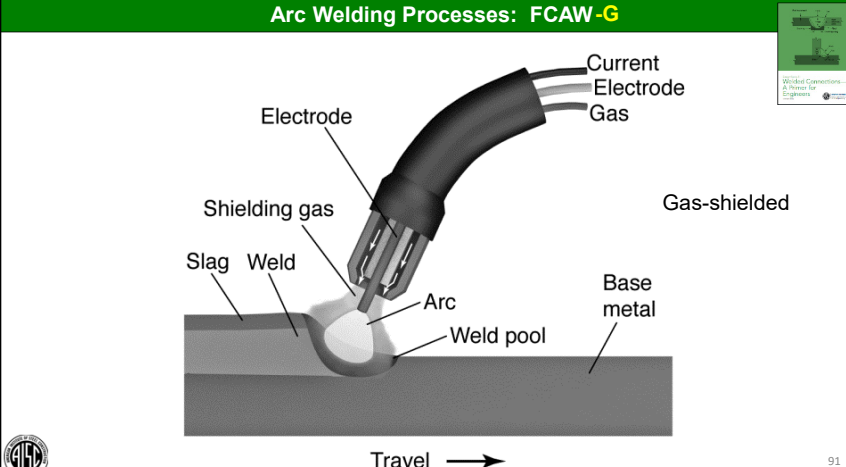
Work cable

Work



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Arc Welding Processes: FCAW-G



Current

Electrode

Gas

Electrode

Shielding gas

Gas-shielded

Slag


Weld

Arc

Weld pool

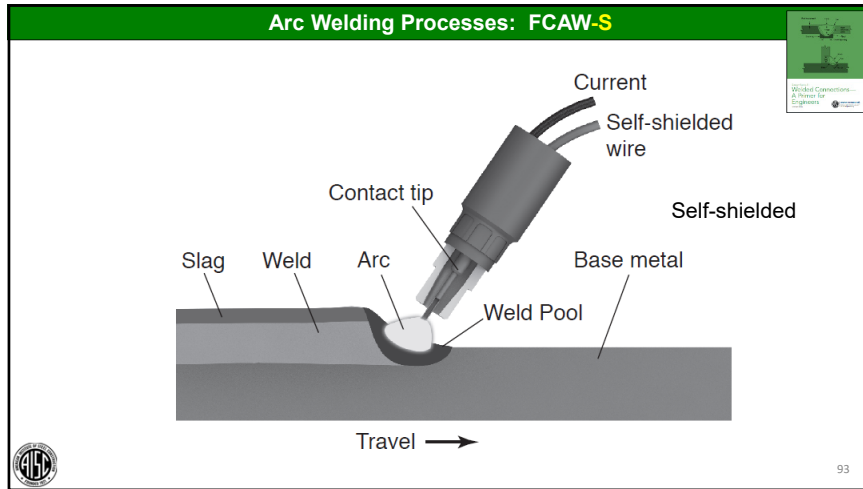
Base metal

Travel →



91





Arc Welding Processes: FCAW

Advantages:

- Electrode is continuous
 - Eliminates built-in starts and stops
 - Economic advantage
 - Starts and stops are potential sources of weld discontinuities
- Increased amperages (over SMAW)
 - Increased deposition rate and productivity
- Fixed resistance for a given electrode extension
 - More uniform welding conditions are maintained

A small AISC logo is in the bottom left corner, and the number 95 is in the bottom right corner.

Arc Welding Processes: FCAW

Advantages:



- Process is semiautomatic
 - Welders maintains the electrode extension (i.e., stickout distance) but do not need to maintain an arc length, nor do they feed the filler metal into the joint
- Process can also be mechanized or automatic

A small AISC logo is in the bottom left corner, and the number 96 is in the bottom right corner.

Arc Welding Processes: FCAW

Limitations:

- Welding equipment costs more and is less portable than for SMAW
- Changes are more complicated than for SMAW





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Arc Welding Processes: FCAW-G

Advantages:

- More versatile than self-shielded flux-cored electrodes
- Provide better arc action
- High operator appeal
- Shielding from wind is not difficult in enclosed shop fabrication situations
- Weld appearance and quality are very good
- Higher-strength gas-shielded FCAW electrodes are available than for FCAW-S





98

Arc Welding Processes: FCAW-G

Limitations:

- The need to protect the gas shield
 - AWS D1.1 limits the maximum wind velocity to 5 mph [8 km/h]
- When welding under windy conditions, porosity is likely
- Studies have shown that at wind speeds less than 5 mph, and before onset of porosity, ductility and toughness may decrease
 - AWS D1.8 has limited maximum wind velocity to 3 mph [5 km/h]





99

Arc Welding Processes: FCAW-S

Advantages:

- Ideal when wind may disturb the gas shield (e.g., field conditions or relatively open fabrication shops)
 - Welds have been made up to 10 mph [16 km/h] without harmful effects
- No need for gas cylinders, hoses and regulators
- No concerns about gas nozzles being plugged with weld spatter
- Gun and cable assembly is simpler than for gas-shielded
 - More suitable for welding in restricted spaces





100

Arc Welding Processes: FCAW-S

Limitations:

- Technology is limited to 90 ksi [620 MPa] tensile strength or less
- Arc action not as good as FCAW-G





101

AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

gas metal arc welding (GMAW).

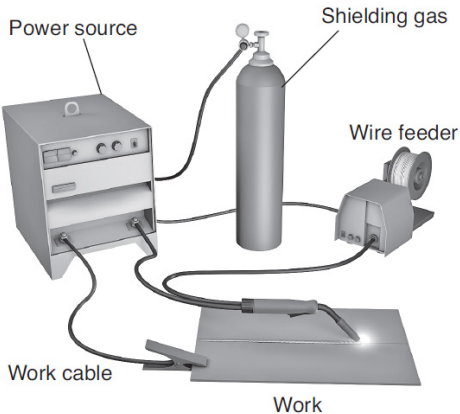
An arc welding process using an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

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



102

Arc Welding Processes: GMAW





Power source

Shielding gas

Wire feeder

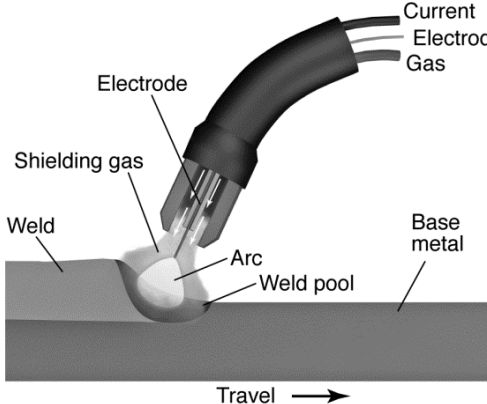
Work cable

Work



103

Arc Welding Processes: GMAW



Current

Electrode

Gas

Shielding gas



Weld

Arc

Weld pool

Base metal

Travel →





104



Arc Welding Processes: GMAW

GMAW Modes of Metal Transfer


- Spray
- Globular
- Short-Circuiting (shortarc)
- Pulsed



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Arc Welding Processes: GMAW Spray


The diagram illustrates the spray metal transfer process. An electrode is positioned vertically above a weld pool. A spray of molten metal particles is shown being directed from the electrode tip into the weld pool. Labels include: Electrode, Arc, Spray, Bright inner cone, and Weld pool.



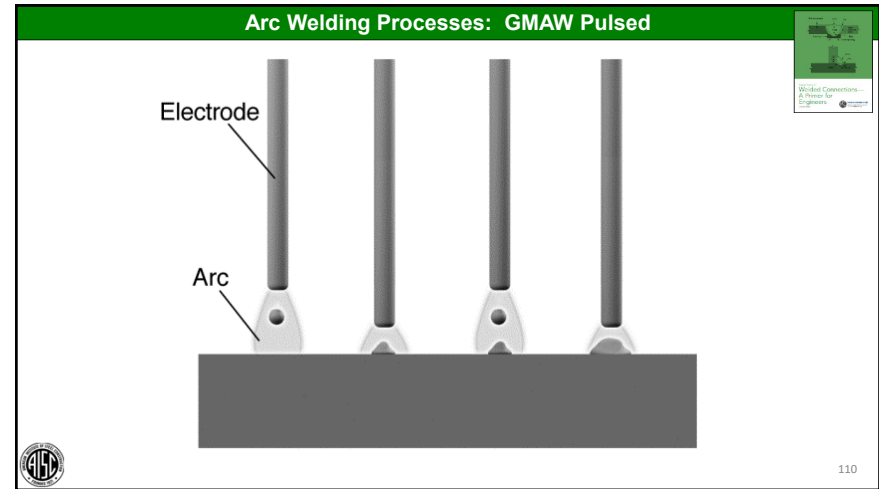
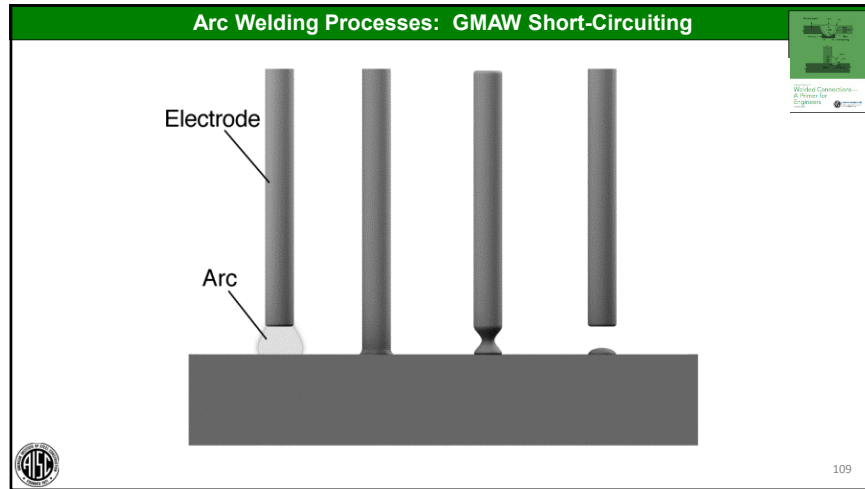
107

Arc Welding Processes: GMAW Globular

The diagram illustrates the globular metal transfer process. An electrode is positioned vertically above a weld pool. A single, large globule of molten metal is shown falling from the electrode tip into the weld pool. Labels include: Electrode, Arc, Globule, and Weld pool.



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Arc Welding Processes: GMAW

Advantages:

- No slag covers the weld; cleanup is simple and low cost
- Electrodes cost less than flux-cored electrodes
- Deposits welds with low levels of diffusible hydrogen
 - Significant advantage for welding on high strength steels
- Carries advantages of automatic and semiautomatic processes
 - Many robotic welding applications use GMAW, due to freedom from slag cleanup
 - Multiple-pass welding is easily accomplished

A small inset diagram in the top right corner shows a simplified version of the process. The AISC logo is in the bottom left, and the number 111 is in the bottom right.

Arc Welding Processes: GMAW

Limitations:



- Process is more sensitive to contaminants on the steel surface (such as mill scale, rust, and oil)
 - May result in porosity
 - Heavy scale may inhibit fusion
- Limited similar to FCAW-G
 - If gas shield is disturbed, porosity will result
 - Even before onset of porosity, ductility and toughness may deteriorate

A small inset diagram in the top right corner shows a simplified version of the process. The AISC logo is in the bottom left, and the number 112 is in the bottom right.

Arc Welding Processes: GMAW

Mode of Transfer-dependent Advantages and Limitations:

- Spray
 - Permits higher deposition rates and deposits welds with good appearance
 - Requires higher-cost, argon-based shielding gas mixtures, and can only be used in horizontal and flat positions





113

Arc Welding Processes: GMAW

Mode of Transfer-dependent Advantages and Limitations:

- Globular
 - Uses low-cost carbon dioxide shielding and offers high deposition rates
 - Weld appearance is inferior to spray transfer; excessive weld spatter is typical; restricted to horizontal and flat positions





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Arc Welding Processes: GMAW

Mode of Transfer-dependent Advantages and Limitations:

- Short-circuit
 - Ideal for sheet metal; can be used for vertical and overhead positions
 - Strong tendency for fusion-type defects (incomplete fusion) makes it undesirable for most structural applications
 - Not prequalified in AWS D1.1
 - Welders must be qualified with the short-circuit mode of transfer





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Arc Welding Processes: GMAW

Mode of Transfer-dependent Advantages and Limitations:

- Pulsed
 - Permits all-position welding; deposits weld with good appearance
 - Requires use of more expensive, argon-based shielding gas mixtures
 - Welding equipment is more expensive and complex





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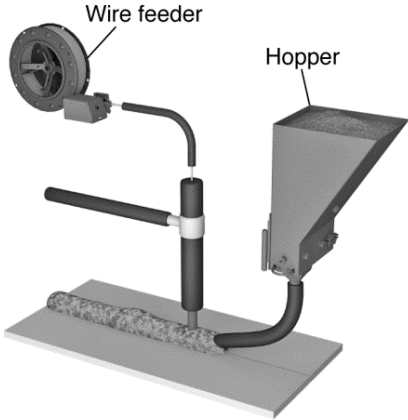
submerged arc welding (SAW).

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).





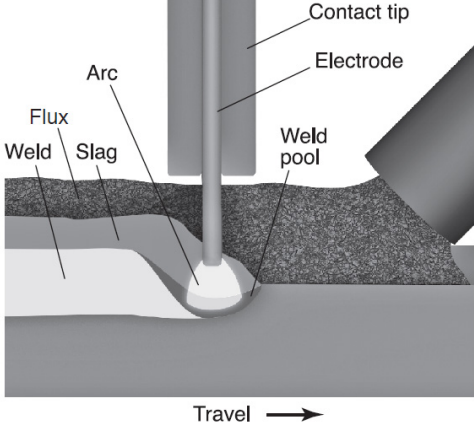
117

Arc Welding Processes: SAW



118

Arc Welding Processes: SAW



119







Arc Welding Processes: SAW

Advantages:

- Uses higher welding currents, leading to higher productivity and deeper penetration
 - Deeper penetration may allow fillet weld sizes to be reduced or may permit the use of groove weld details that require less weld metal
- Square wave technology may further increase deposition rate without increasing current
- For higher deposition rates, a second or third electrode can be added into the system to further increase productivity
- Process is typically mechanized or automatic
 - Welds are usually continuous for length of the joint





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Arc Welding Processes: SAW

Advantages:

- Welds made under protective layer of flux are excellent in appearance and spatter-free
 - Particularly significant for architecturally exposed structural steel (AESS)
- Freedom from the open arc
 - Welder does not need to use the standard protective helmet
 - Operations can be done in tight, restricted areas
 - Produces little smoke, therefore can be used in situations with restricted ventilation





125

Arc Welding Processes: SAW

Limitations:

- Freedom from open arc does not allow the operator to observe the weld puddle
 - When done semiautomatically, operator must learn to propel gun carefully to ensure uniform bead contour
 - Degree of skill is significant for multiple-pass welds
- Better for long, uninterrupted seams rather than short, intermittent welds
- Restricted to flat and horizontal position





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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

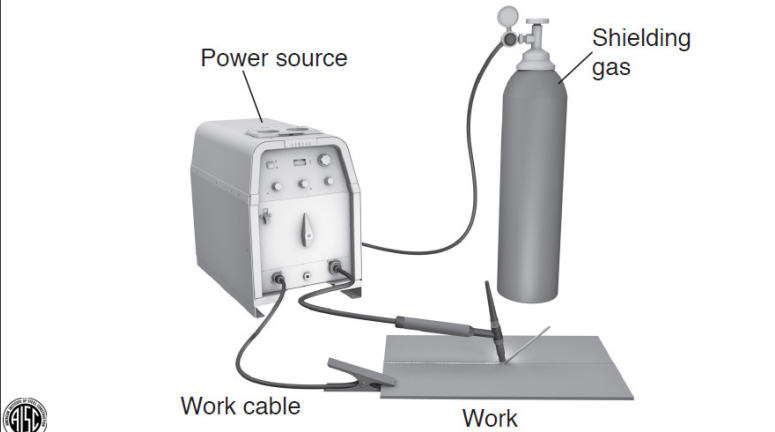
gas tungsten arc welding (GTAW).

An arc welding process using an arc between a tungsten electrode (nonconsumable) and the weld pool. The process is used with shielding gas and without the application of pressure.



127

Arc Welding Processes: GTAW





Power source

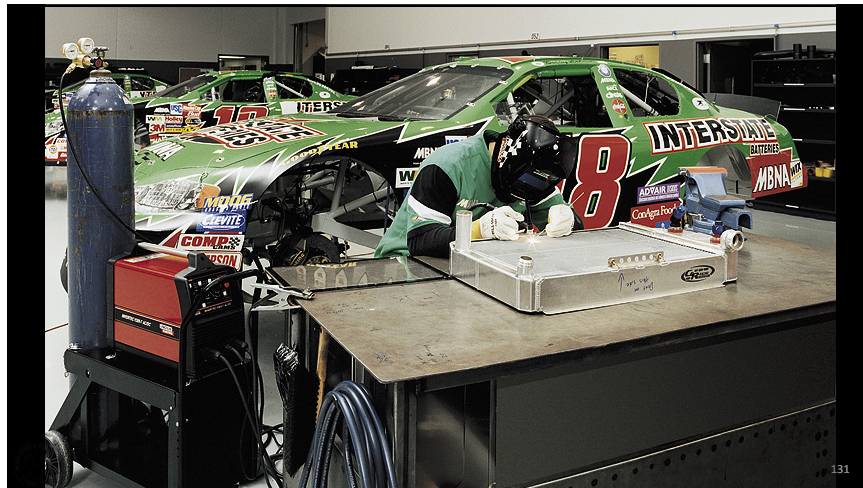
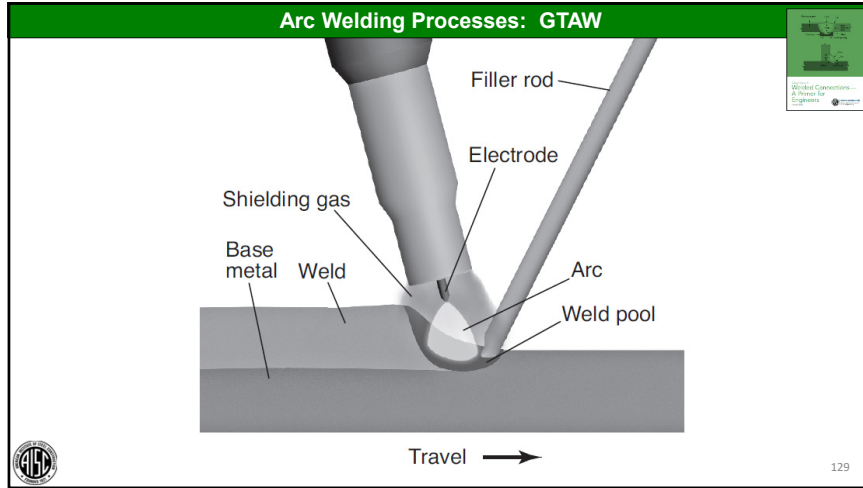
Shielding gas

Work cable

Work



128

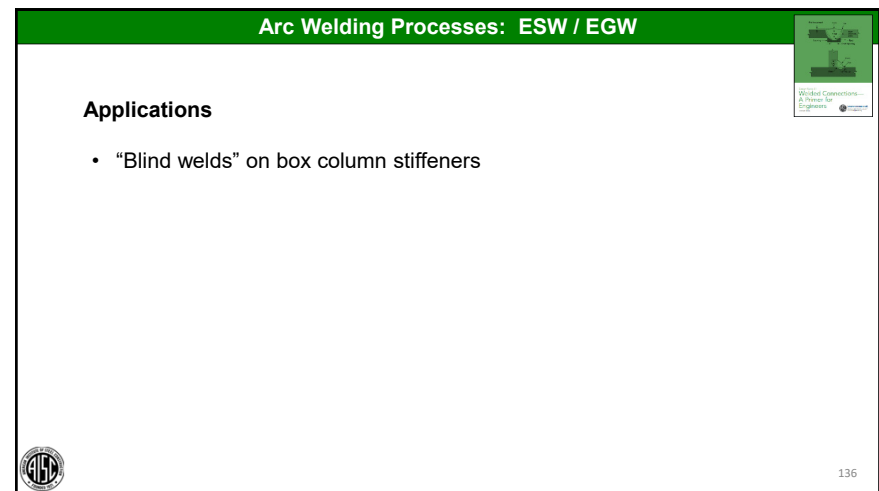
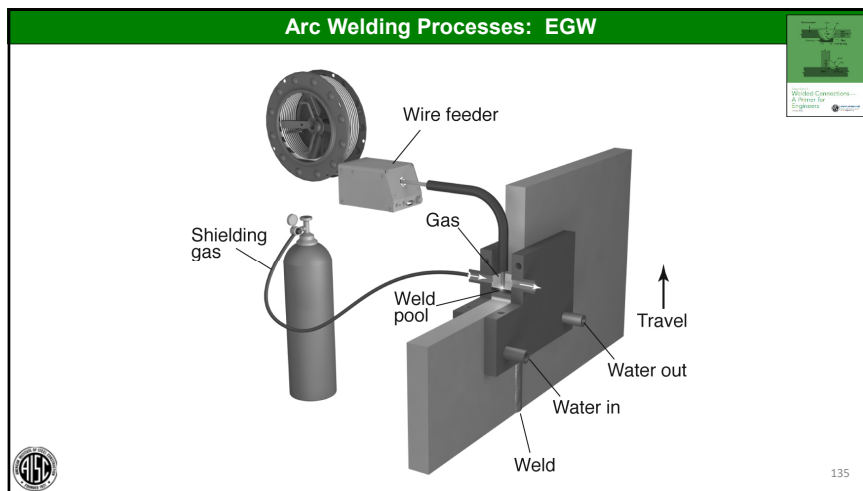
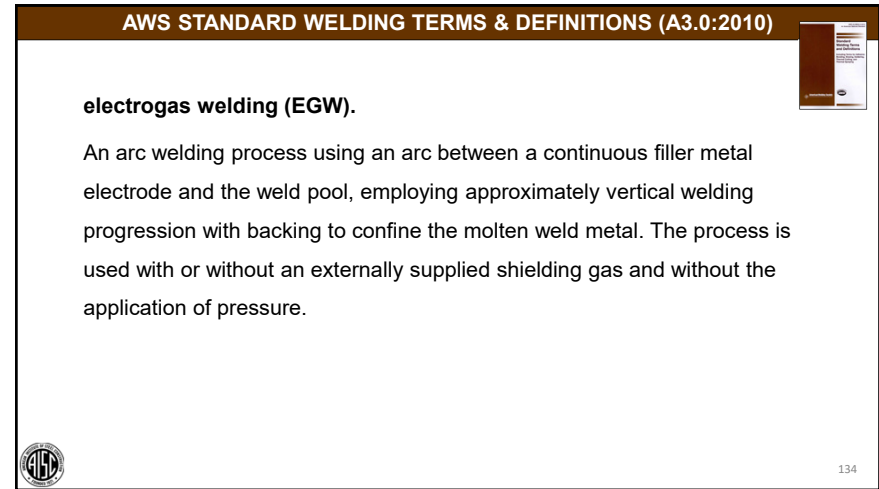
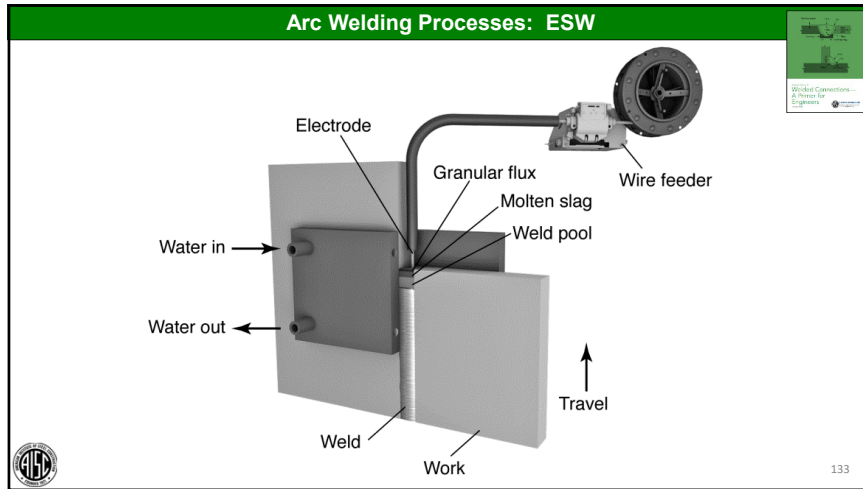


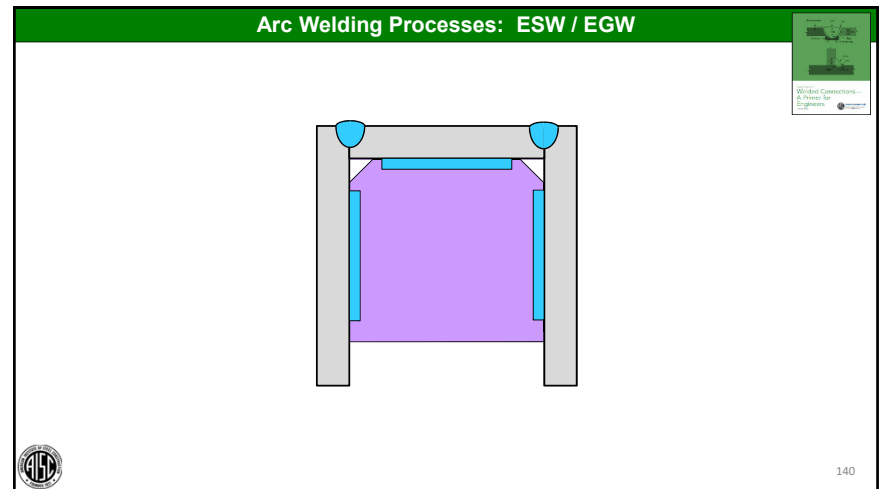
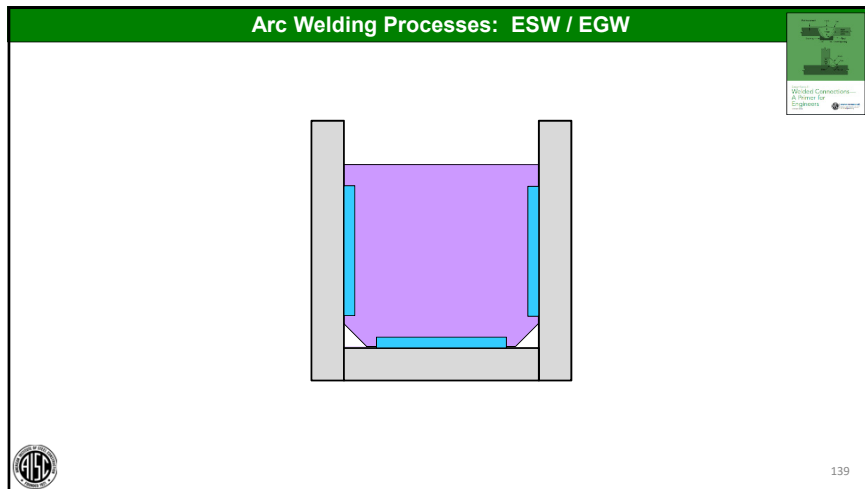
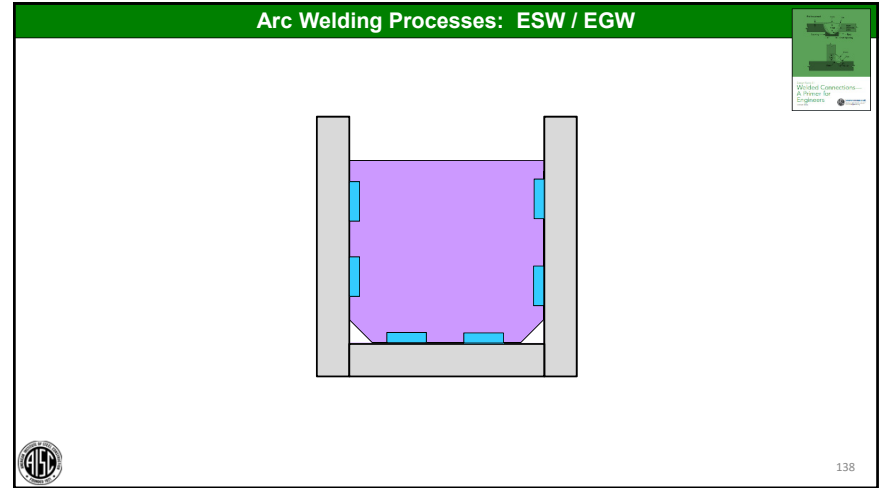
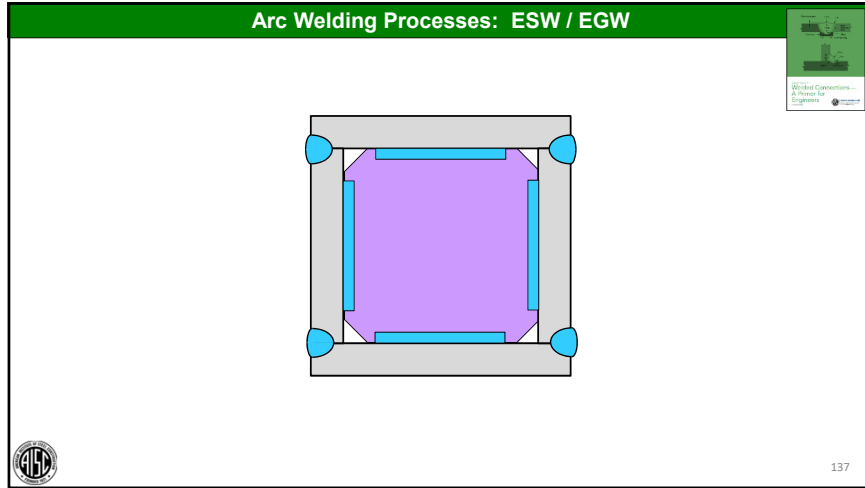
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

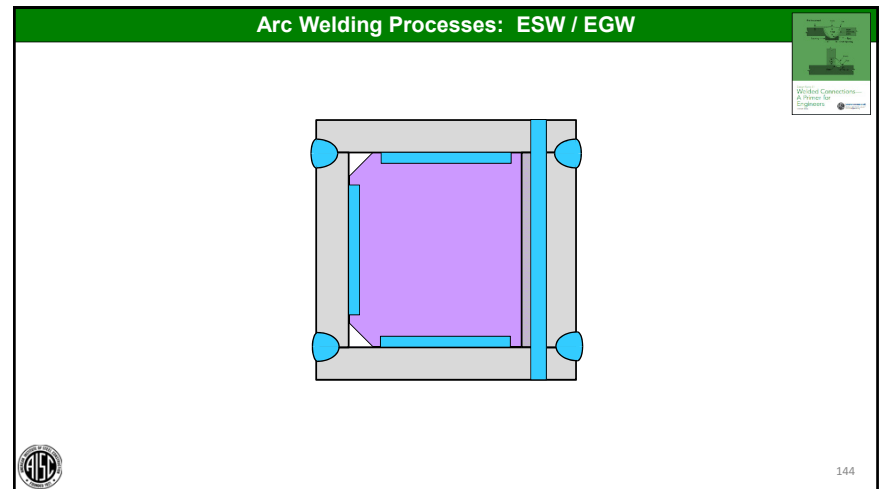
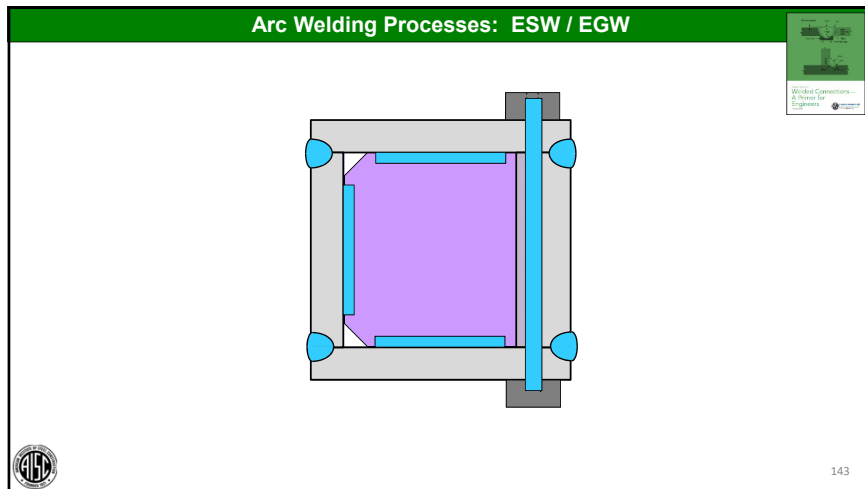
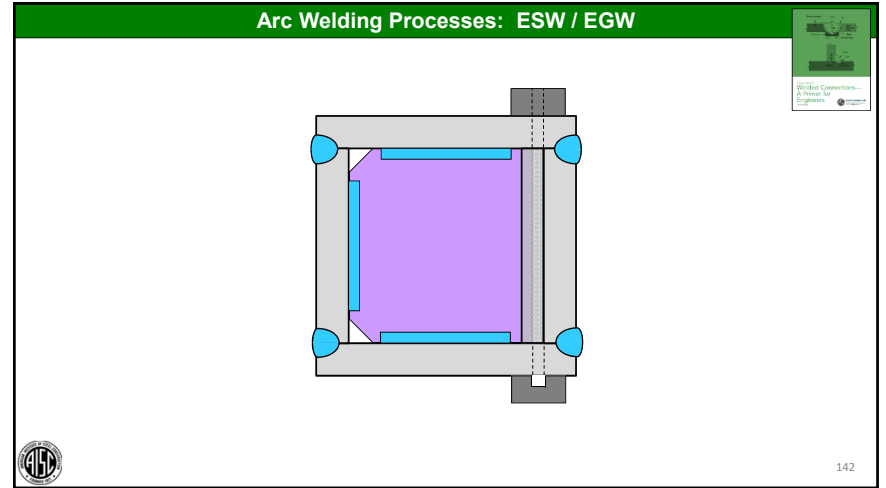
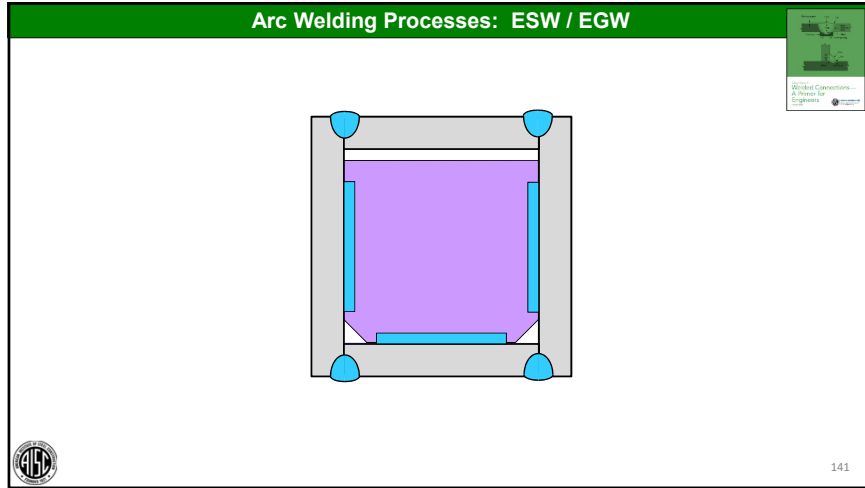
electroslag welding (ESW).

A welding process producing coalescence of metals with molten slag, melting the filler metal and the surfaces of the workpieces. The weld pool is shielded by this slag, which moves along the full cross section of the joint as welding progresses. The process is initiated by an arc that heats the slag. The arc is then extinguished by the conductive slag, which is kept molten by its resistance to electric current passing between the electrode and the workpieces.

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Arc Welding Processes: ESW / EGW

Applications

- “Blind welds” on box column stiffeners
- Flange splices for plate girders
- Miscellaneous applications (columns to base plates, flange plates to columns, continuity plates)





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Arc Welding Processes: ESW / EGW

Advantages:

- Very high deposition rates
- Normally, joint details involve square edges, eliminating beveling costs
- Material handling might be reduced because plates do not need to be flipped as is the case for double-sided welds made with SAW, for example
- Angular distortion can be reduced
- Advantageous for cyclically loaded structures
 - Center of the vertical weld is last to solidify, putting the face of the weld in compression, enabling better resistance to cyclic tensile stresses





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Arc Welding Processes: ESW / EGW

Advantages:

- Ability to weld in blind joints (e.g., diaphragm plates in box columns)
 - Can weld through a hole in the box
- Ideal for welding on thicker materials (1 in. [25 mm] or greater)





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Arc Welding Processes: ESW / EGW

Limitations:

- Not well-suited for thinner materials
- Equipment and fixturing are more expensive and less flexible
- Sensitive process with many variables
 - Specific operator training is required
 - AWS D1.1 requires all ESW and EGW welding procedure specifications be qualified by test
 - Different variables: fit of copper shoes to the work, temperature of the shoes, thickness of the slag layer
- Large heat affected zone and potentially low fracture toughness of welds





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AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

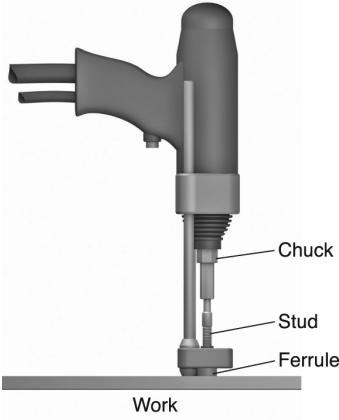
arc stud welding (SW).

An arc welding process using an arc between a metal stud, or similar part, and the other workpiece. The process is used without filler metal, with or without shielding gas or flux, with or without partial shielding from a ceramic or graphite ferrule surrounding the stud, and with the application of pressure after the faying surfaces are sufficiently heated.



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Arc Welding Processes: SW





Chuck

Stud



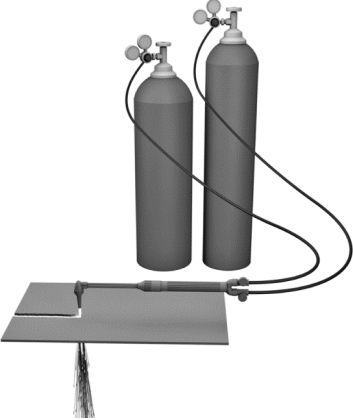
Ferrule

Work





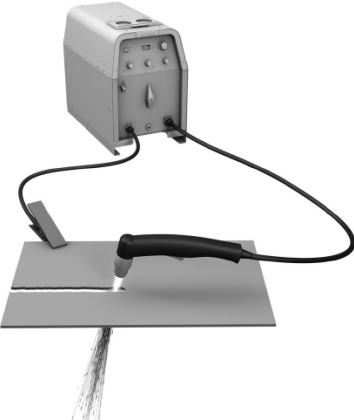
150

Thermal Cutting Processes: Oxyfuel Cutting



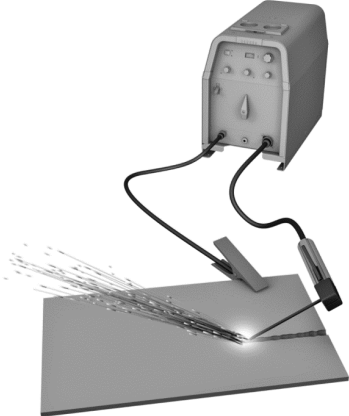
151

Thermal Cutting Processes: Plasma Cutting



152

Thermal Cutting Processes: Air Arc Gouging



153

Cutting Process: Water jet cutting

- Used pressurized stream of water to cut material
- Automated and accurate
- No oxidized surface and no heat affected zone (HAZ)
- More costly and not normally used in steel fabrication
- Permitted by AISC 360 (for cutting holes)

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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
- Typically viewed as part of the Contractor's means and methods

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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 steel with mill scale, rust
- **FCAW-S:** for field welding
- **SAW:** for big, long welds that lend themselves to automation
- **GTAW:** for special alloys, high quality welds, critical repairs
- **SMAW:** maintenance welding, field welding, tack welding, repair welding, miscellaneous fabrication

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WELDED CONNECTION BASICS


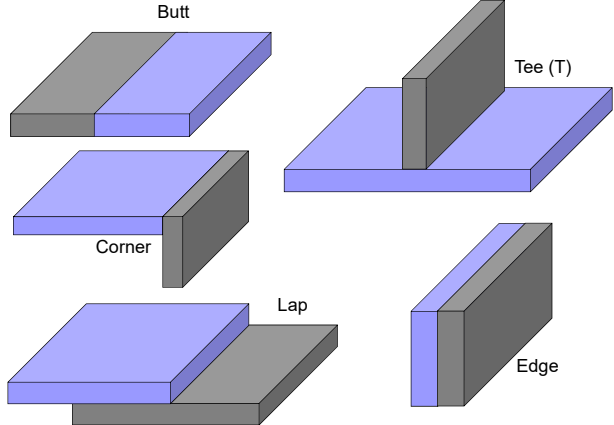
Outline

- Applicable Codes
- Arc Welding Processes – Overview
- Welding and Thermal Cutting Processes
- ➔ • Joints and Weld Types



157

Joint Types




158

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



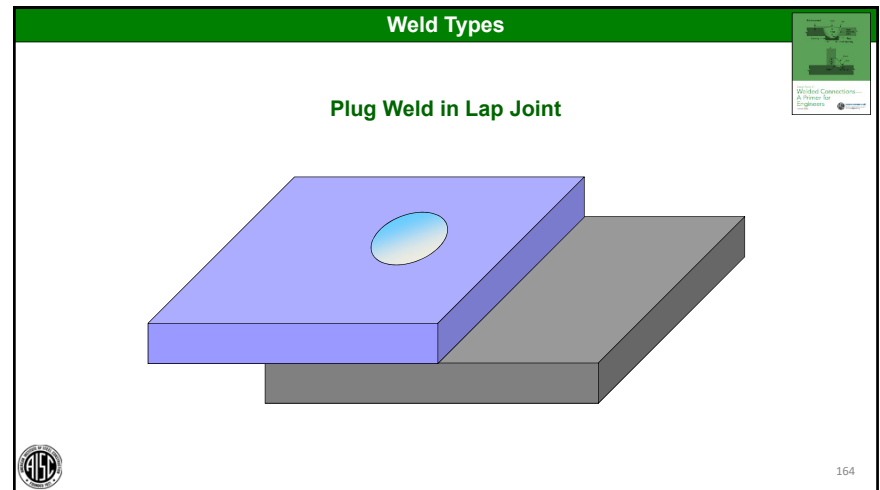
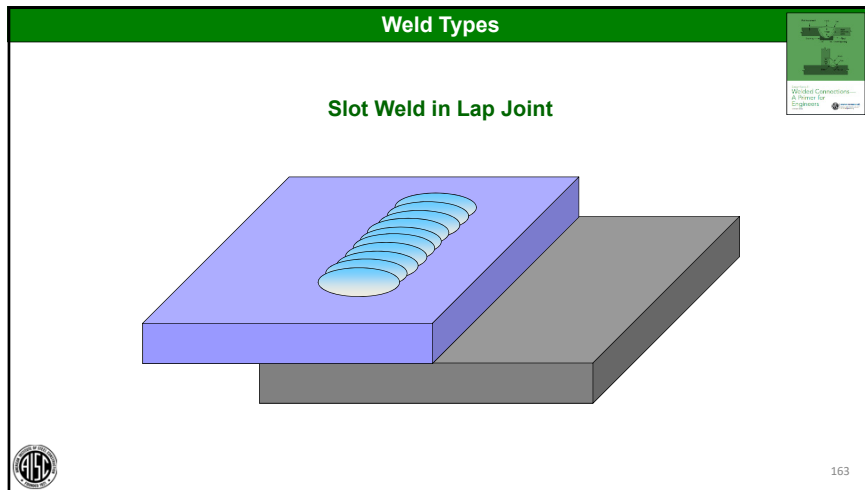
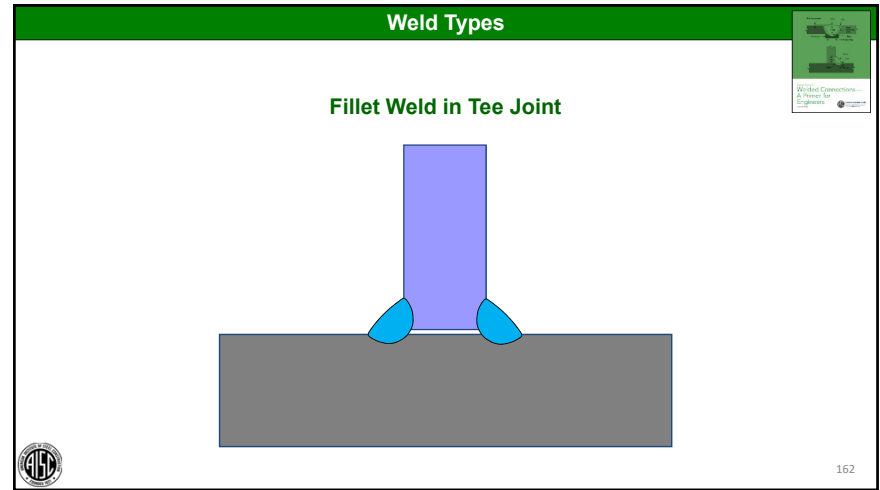
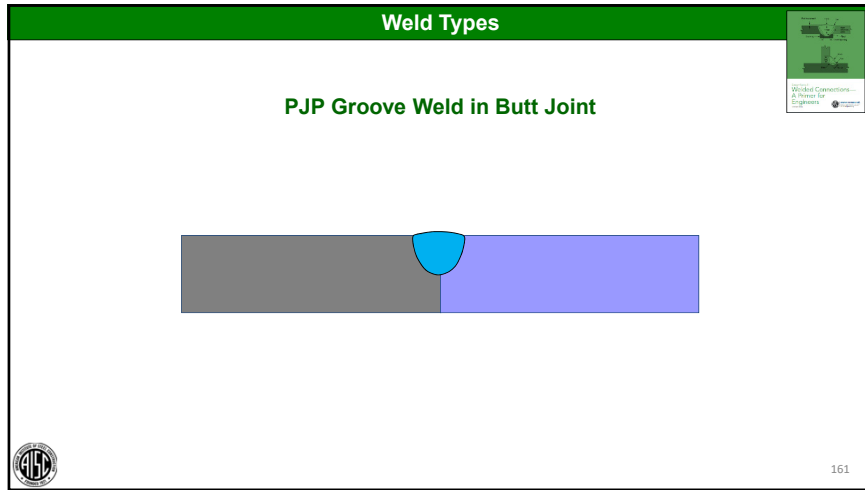
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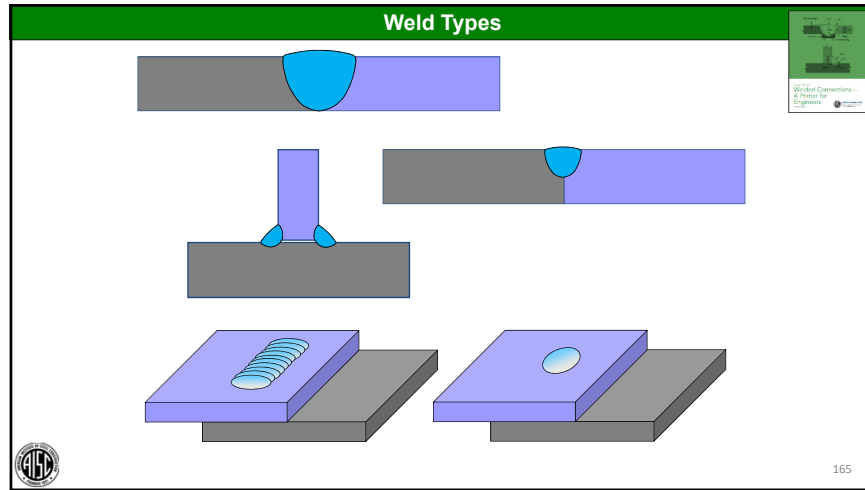
Weld Types

CJP Groove Weld in Butt Joint



160

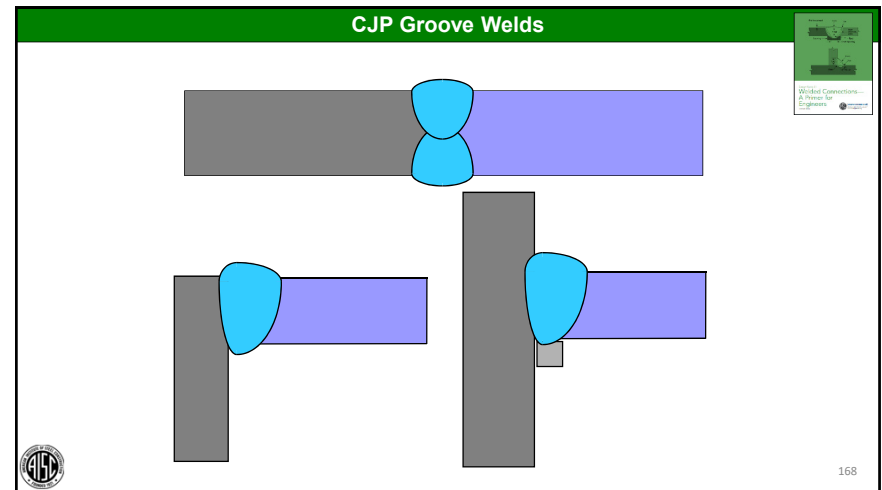
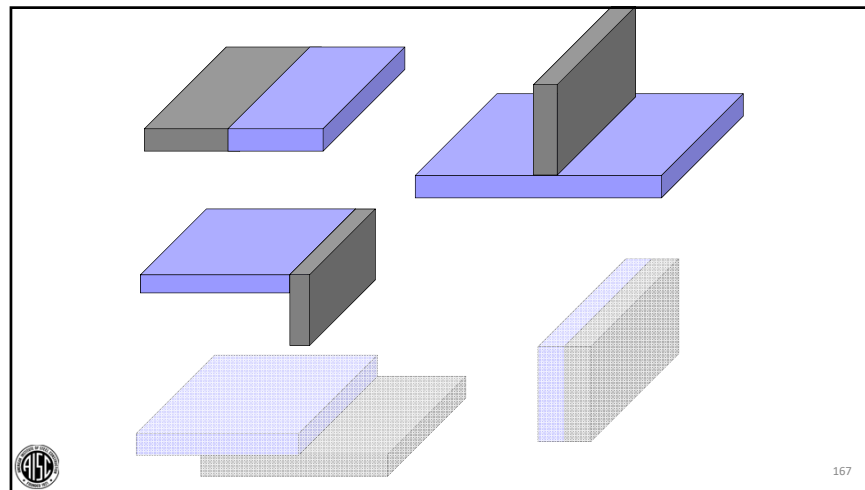




Groove Welds



- Applied to butt, tee, corner joints
- CJP = full strength (for statically loaded connections)
- PJP = partial strength
- Tension vs. compression vs. shear

The slide contains a list of bullet points and a small diagram in the top right corner showing a groove weld. The AISC logo is in the bottom left corner, and the number 166 is in the bottom right corner.



CJP Groove Welds

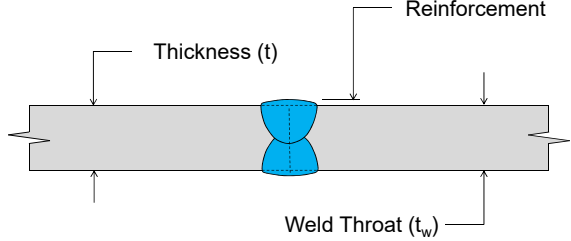
- Throat = plate thickness



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CJP Groove Welds


Weld Throat Dimension (t_w)



Thickness (t)

Reinforcement



Weld Throat (t_w)



170

CJP Groove Welds

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


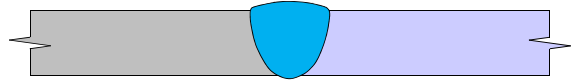


171

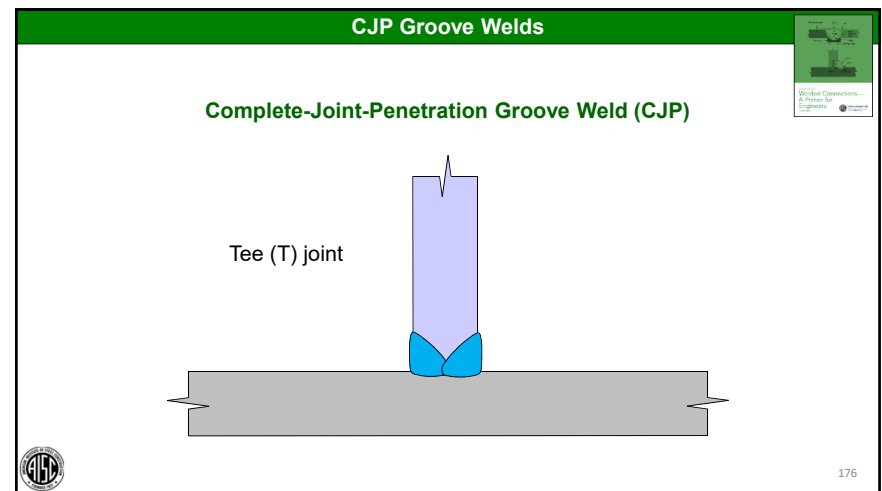
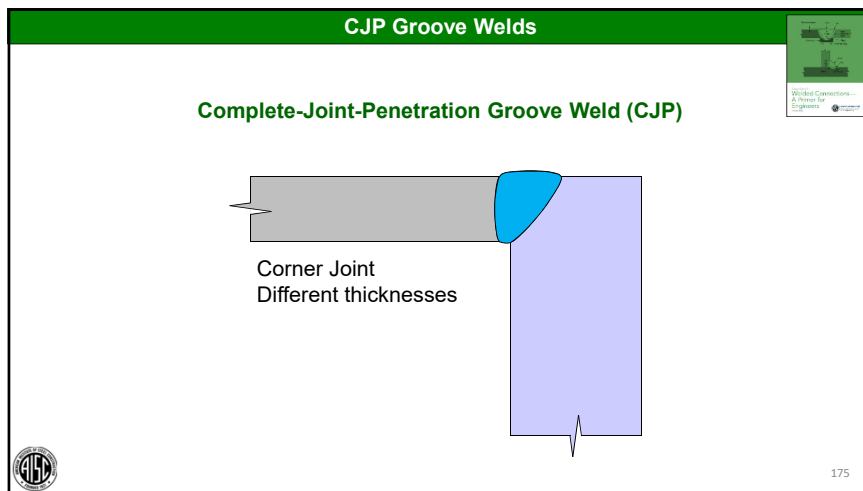
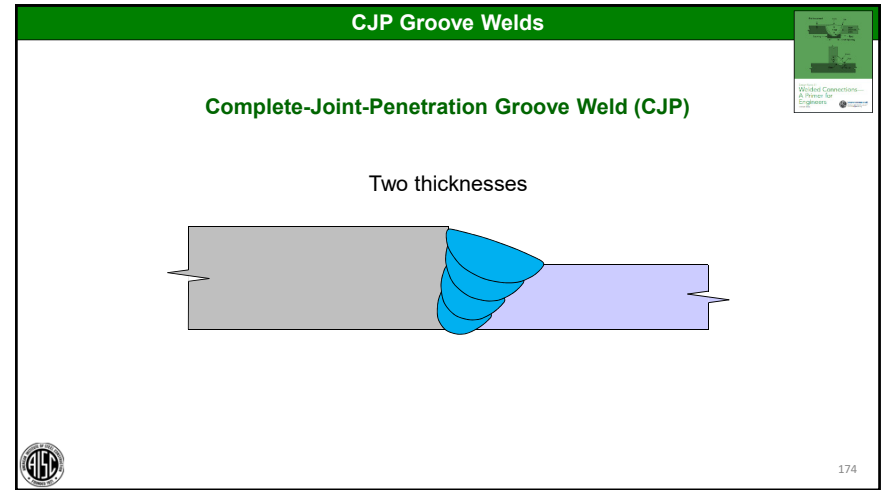
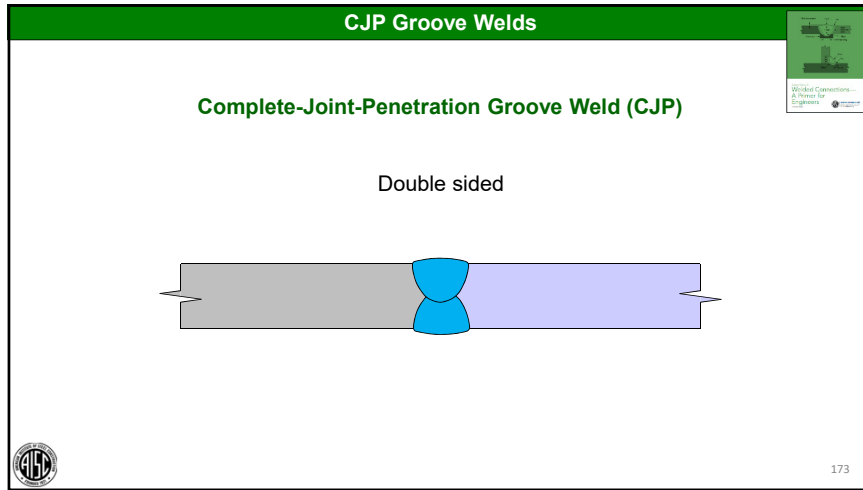
CJP Groove Welds

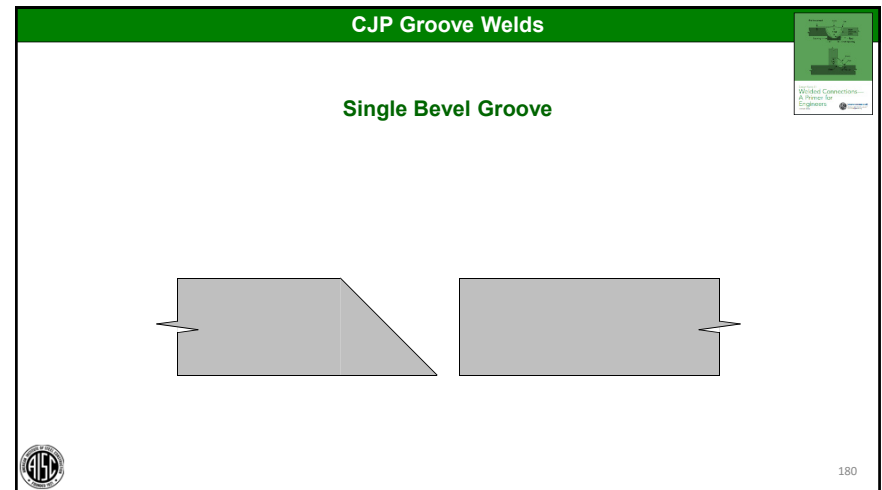
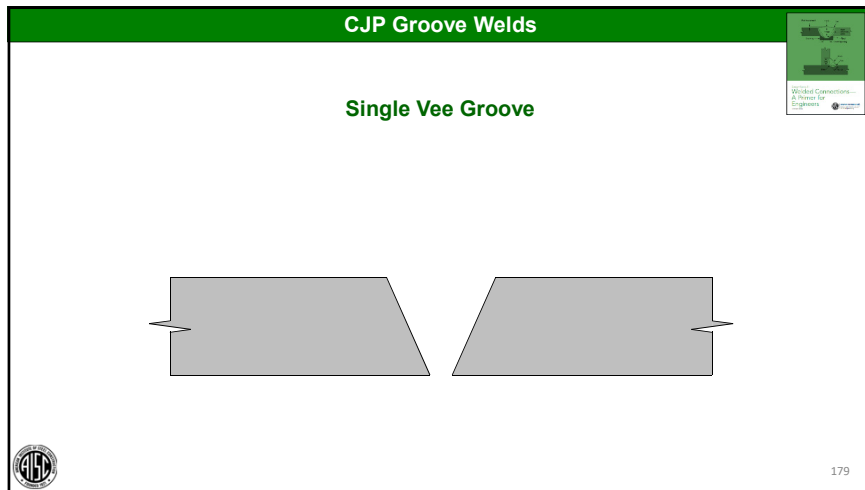
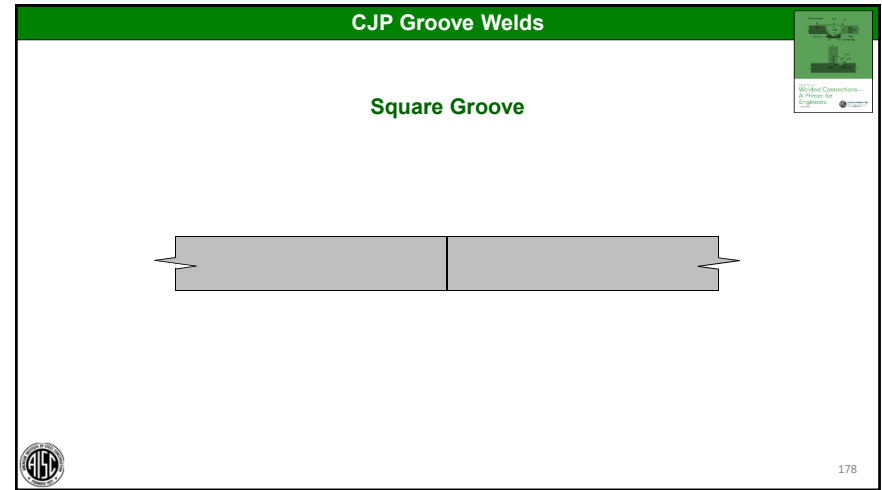
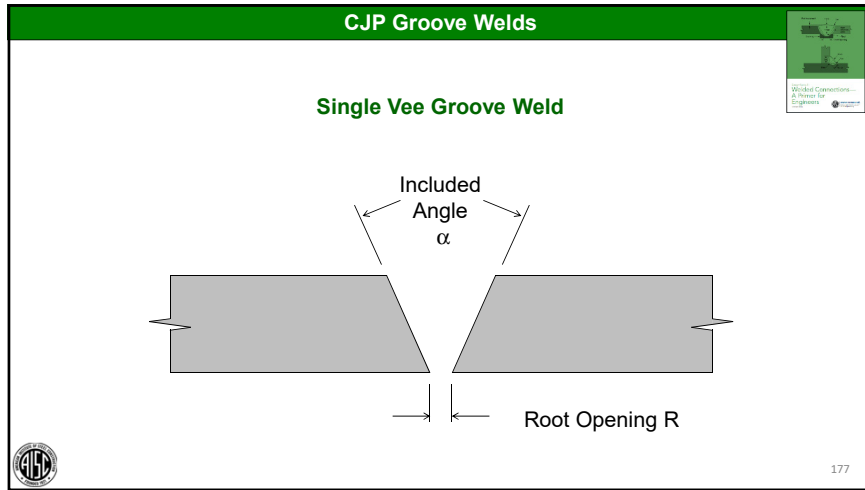
Complete-Joint-Penetration Groove Weld (CJP)

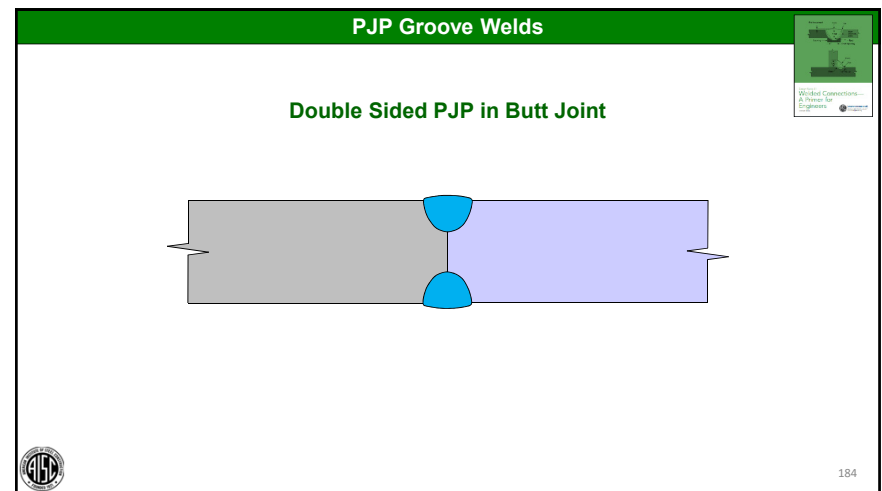
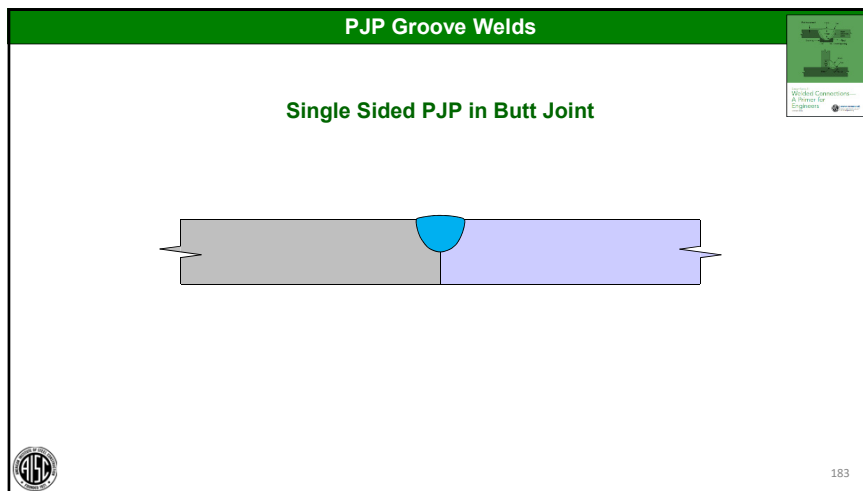
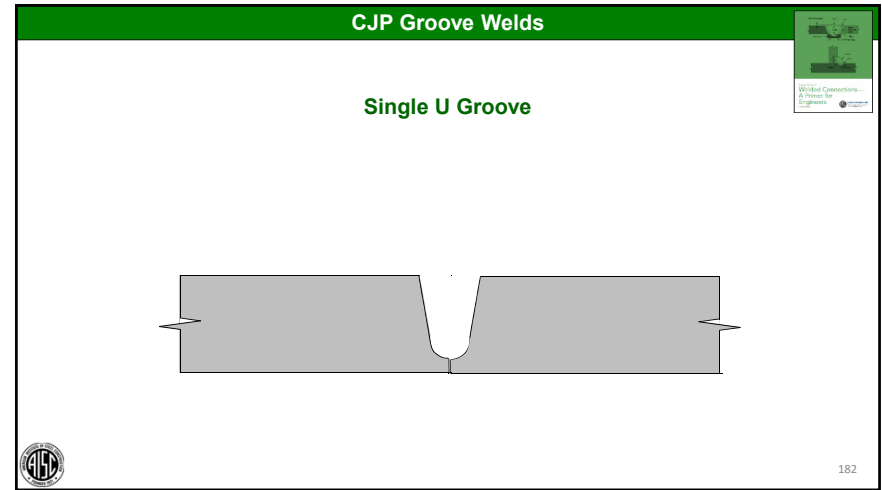
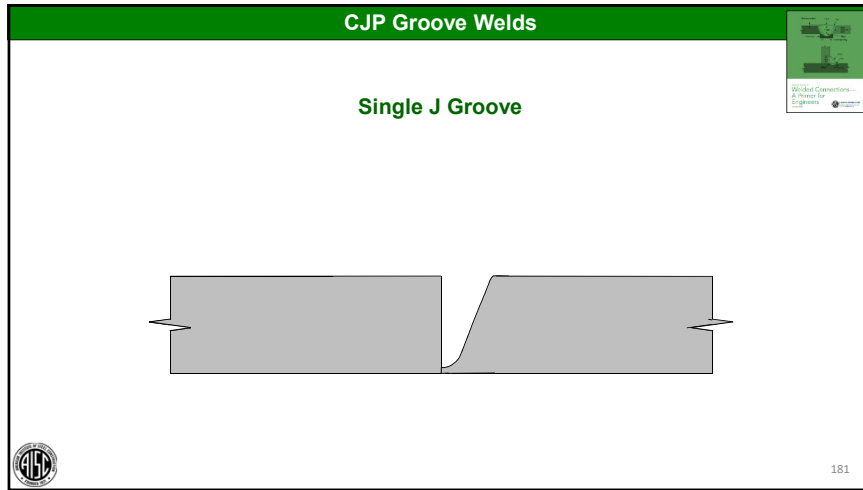
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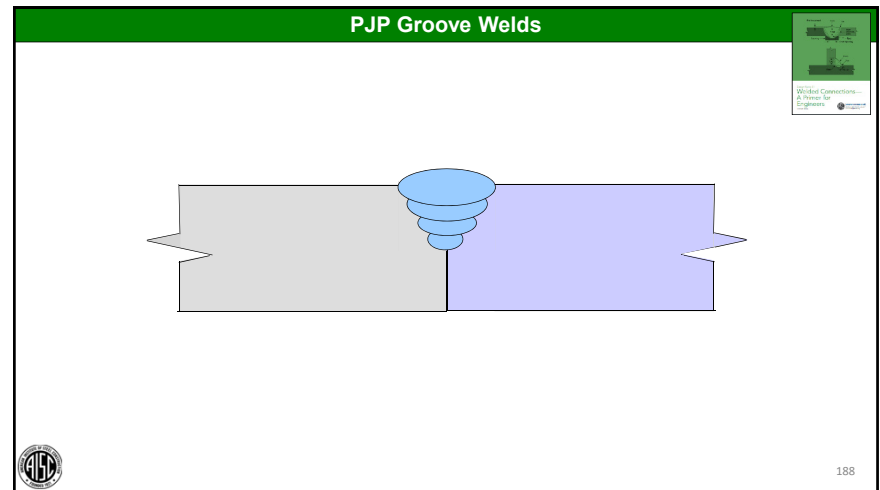
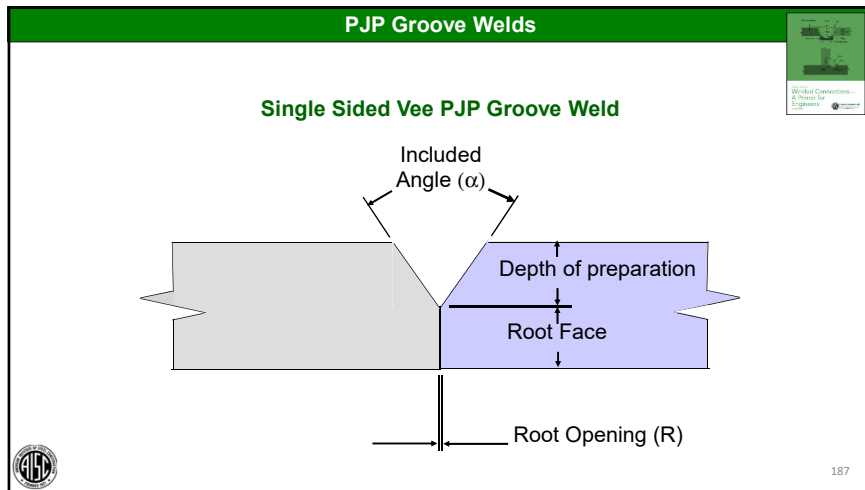
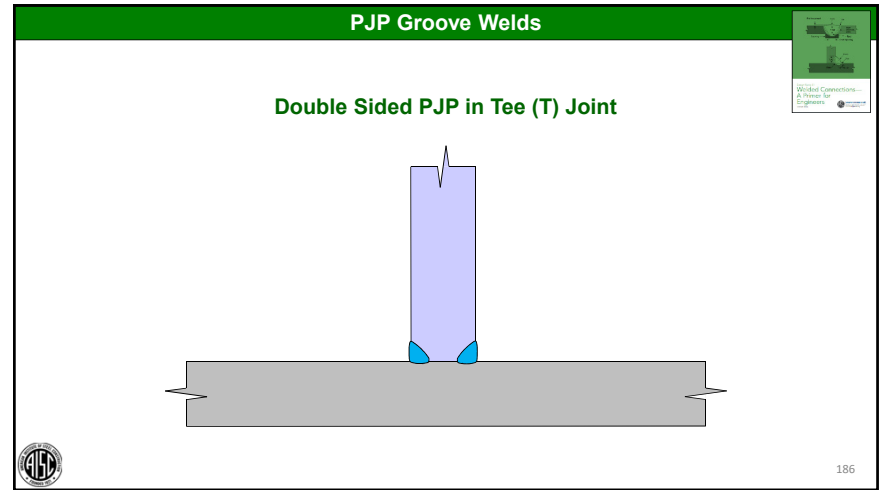
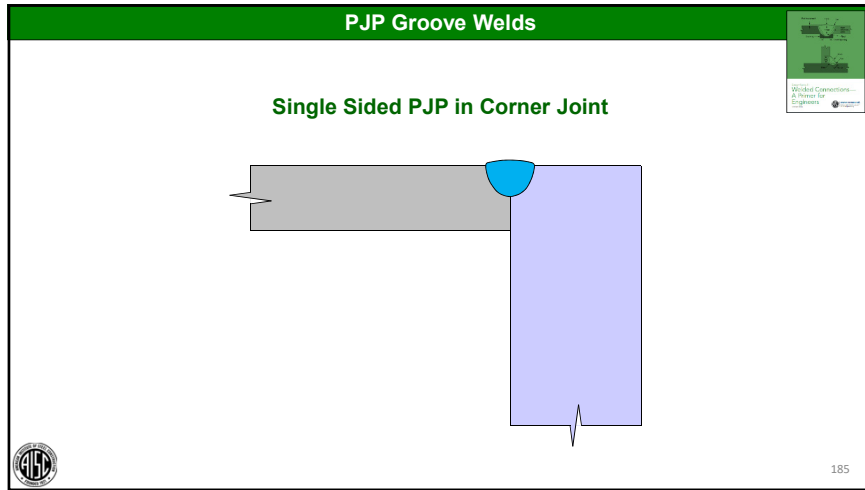


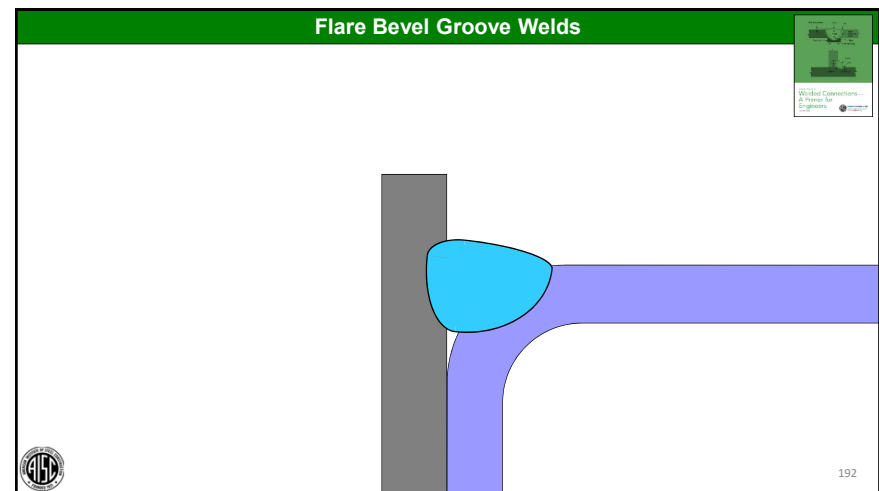
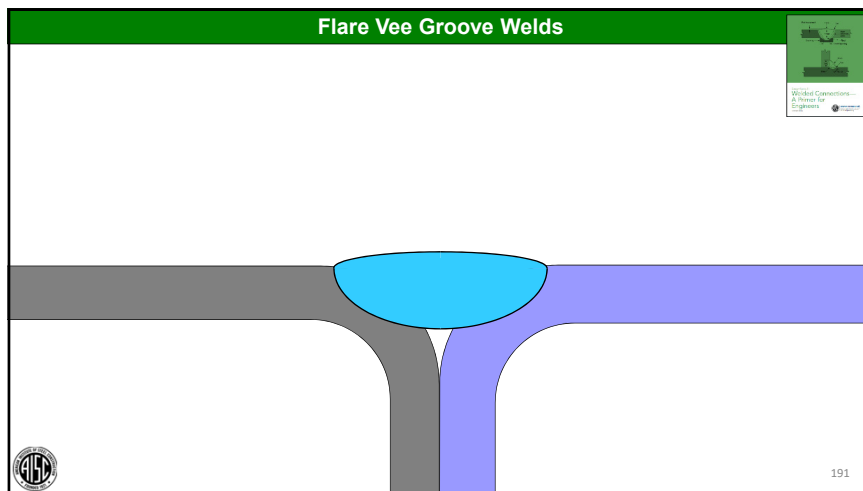
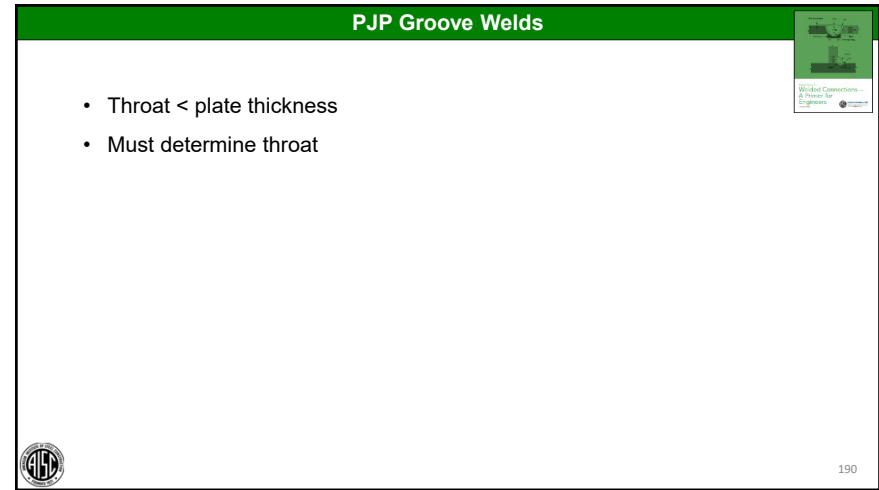
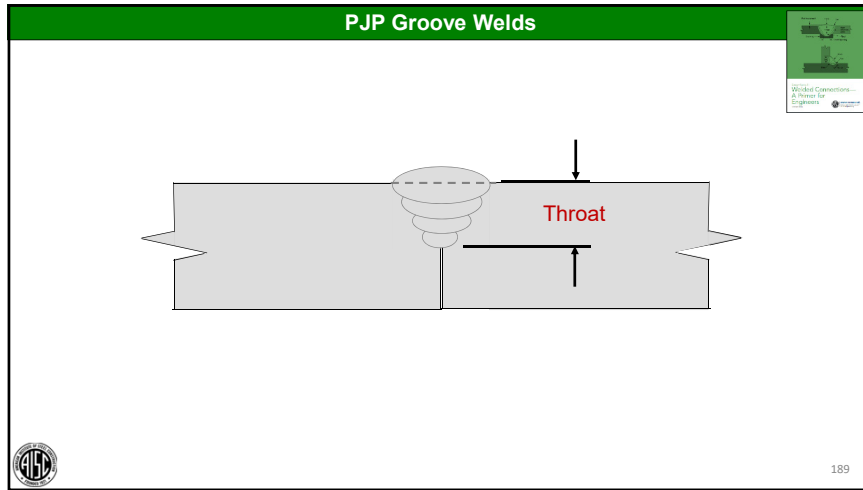
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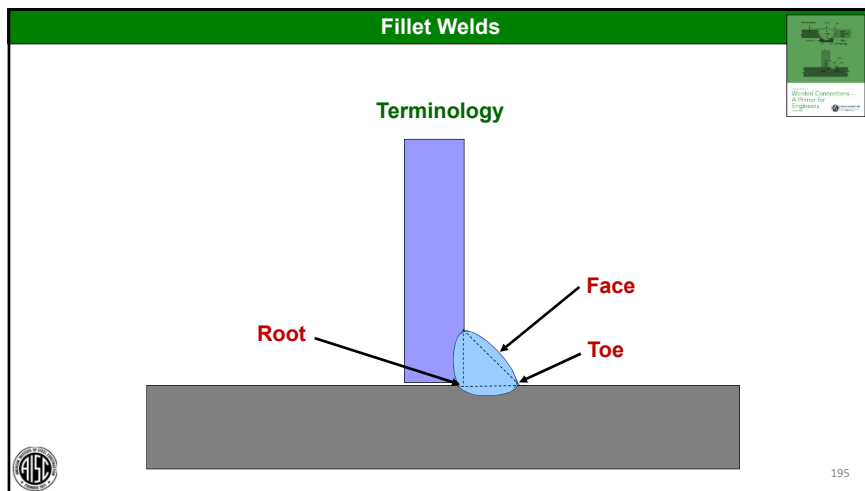
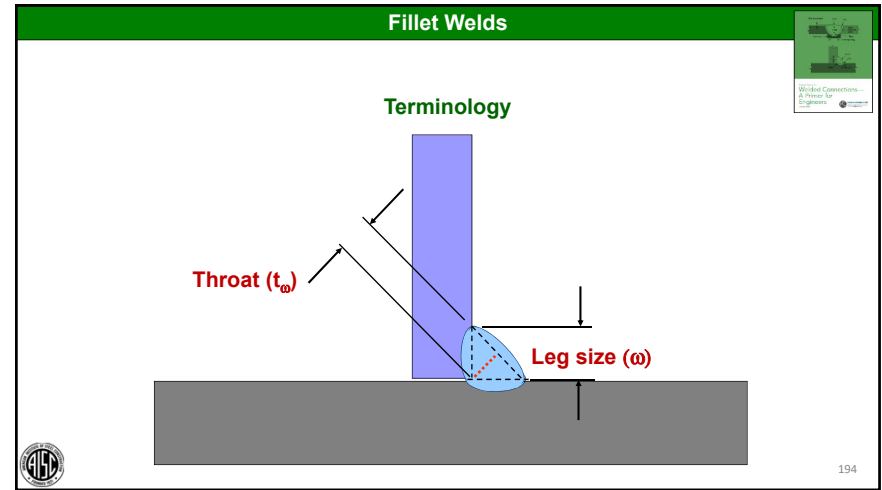
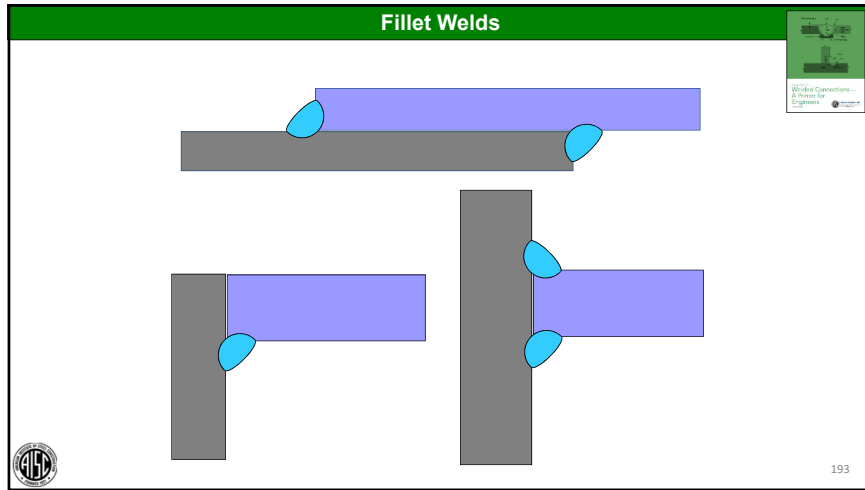


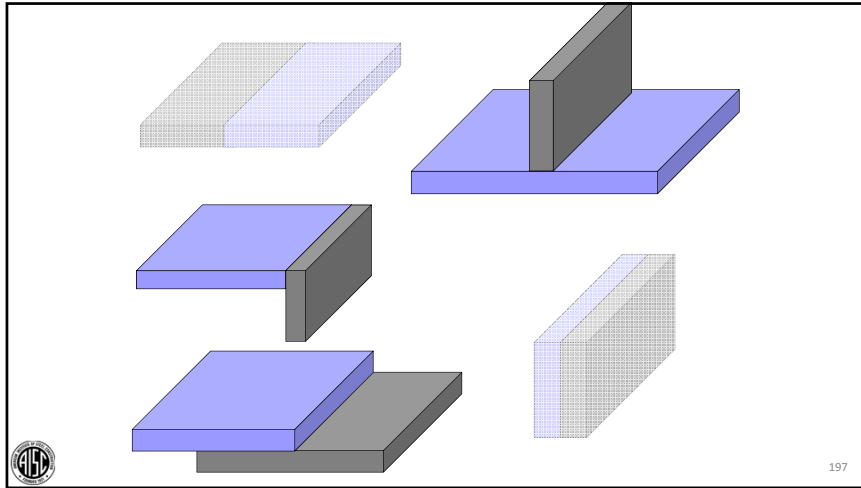








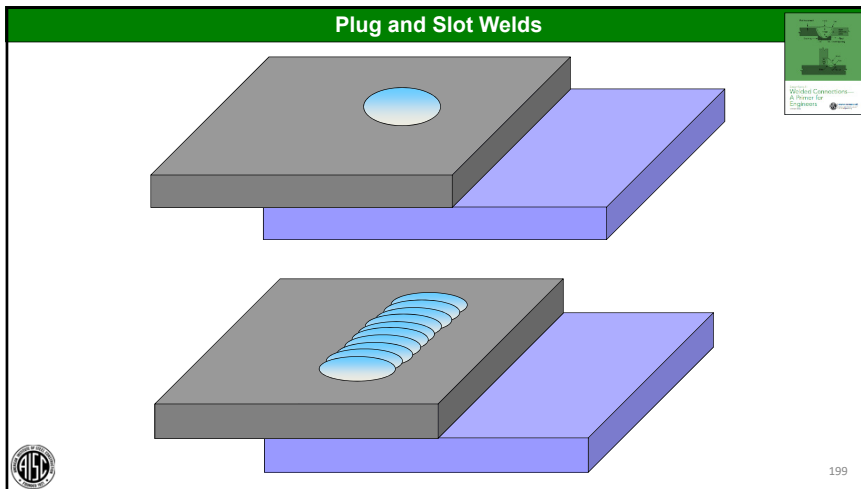




Fillet Welds

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

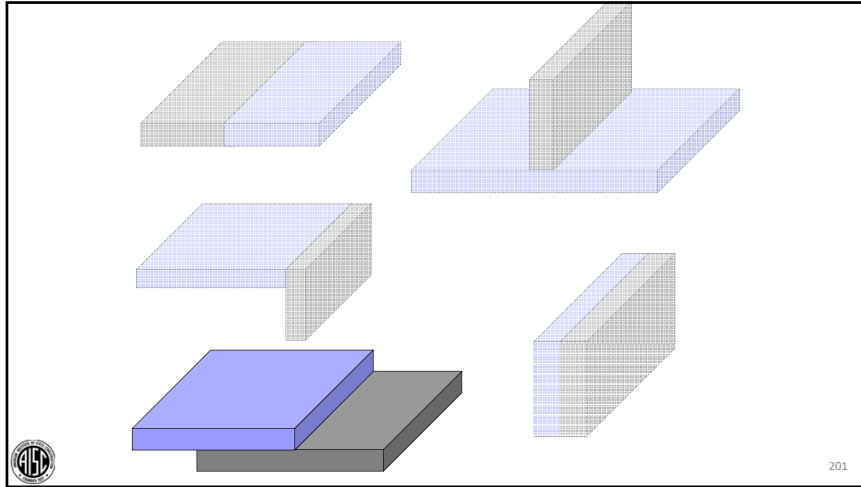
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Plug and Slot Welds


- Applied to lap joints

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Plug and Slot Welds

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



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WELDED CONNECTION BASICS


Outline

- Applicable Codes
- Arc Welding Processes – Overview
- Welding and Thermal Cutting Processes
- Joints and Weld Types

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Thank you!

AISC | Questions?



Smarter.
Stronger.
Steel.

Individual Session Registrants

PDH Certificates

- 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 Session Registrants

PDH Certificates

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



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 Thursday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

Posted Thursday 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 Thursday. 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.

USERNAME

Enter your username

PASSWORD

Enter your password

Remember Me

DON'T HAVE AN ACCOUNT?

My AISC allows you to access Engineering Journal articles and Design Guides you have downloaded from the bookstore.

[REGISTER NOW](#)



8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.

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View online resources for Night School and Live Webinar package registrations.

[VIEW RESOURCES](#)



8-Session Registrants

Night School Resources

AISC > MYASC > COURSE RESOURCES

Course Resources

Event	Start Date
NS 13 8-Session Package-Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 14 8-Session Package-Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM

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8-Session Registrants

Night School Resources

AISC > MYASC > NIGHT SCHOOL RESOURCES > NS13 8-SESSION PACKAGE RESOURCES

Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Videos	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	Videos	Pass Score: 10	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Videos	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Videos	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Videos	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girders Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Videos	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Videos	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Brag Bracing Dev	3/27/2017 7:00:00 PM	Handouts	Videos	Available 03/29/2017 5pm EST	Pending

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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/nightschool21. Scroll down to Quiz and Attendance records.
 - Updated on Thursday mornings.

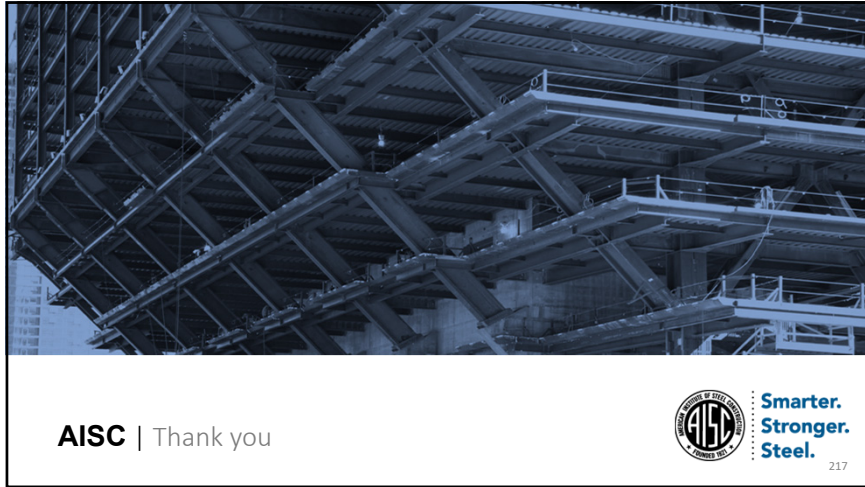
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8-Session Registrants

Night School Resources

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

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AISC | Thank you



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