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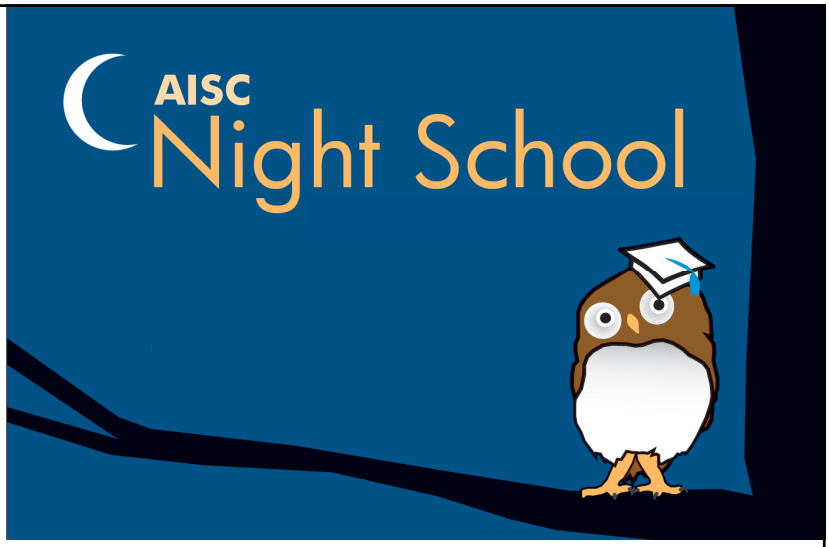

Welded Connections

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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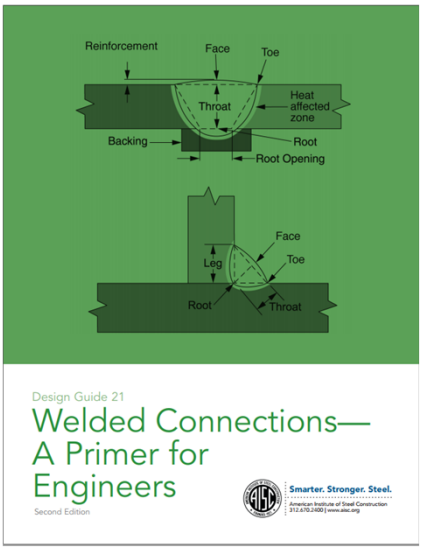
AISC Design Guide 21, 2nd Edition

Welded Connections–

A Primer for Engineers



10

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

11

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

12

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

13

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

14

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

15

WELDED CONNECTION BASICS

Outline

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

16

WELDED CONNECTION BASICS

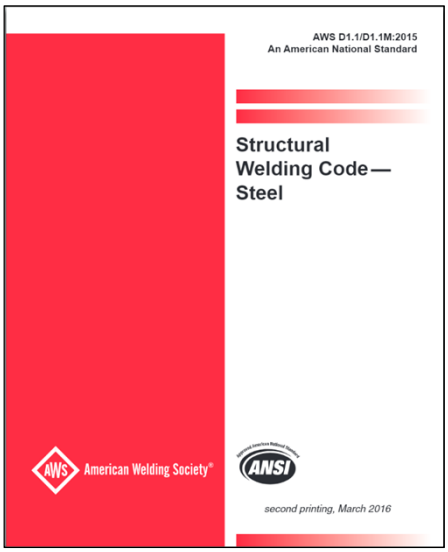
Outline

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

17

AWS D1.1

Structural Welding Code – Steel



18

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

19

AWS D1.1: 2015 Structural Welding Code – Steel

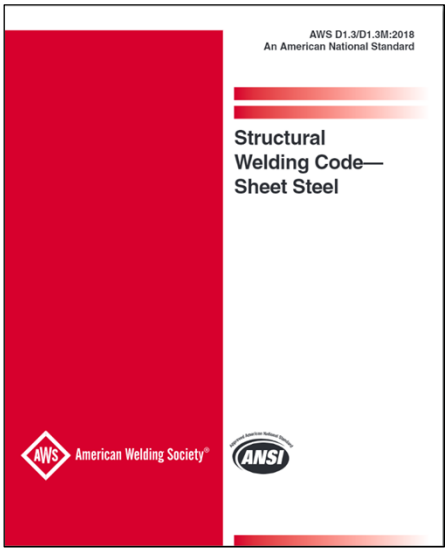
Major sections of AWS D1.1 include the following:

- 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.

20

AWS D1.3

Structural Welding Code –
Sheet Steel



21

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

AWS D1.3 covers:

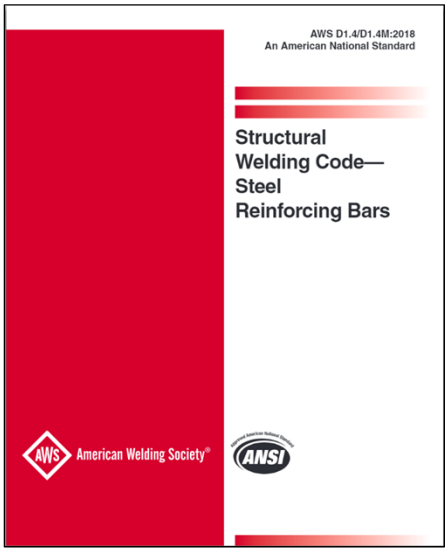
- Welding of structural sheet and strip steels, including cold-formed members equal to or less than 3/16 in. [5mm] thick.
- The primary purpose for structural steel applications: welding sheet steel decking to supporting members with puddle welds.

22

AWS D1.4

Structural Welding Code –

Steel Reinforcing Bars



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

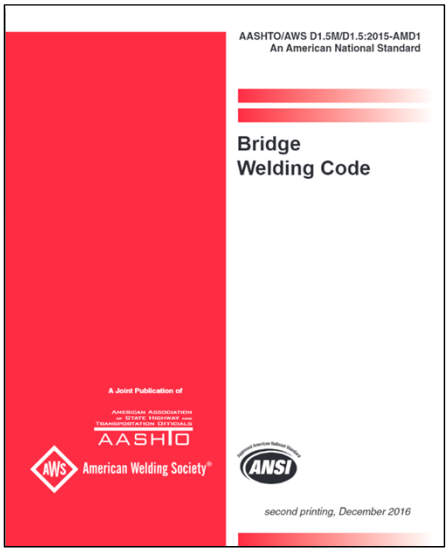
AWS D1.4 covers:

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

24

AASHTO/AWS D1.5

Bridge Welding Code



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AASHTO/AWS D1.5: 2015 Bridge Welding Code

AASHTO/AWS D1.5:

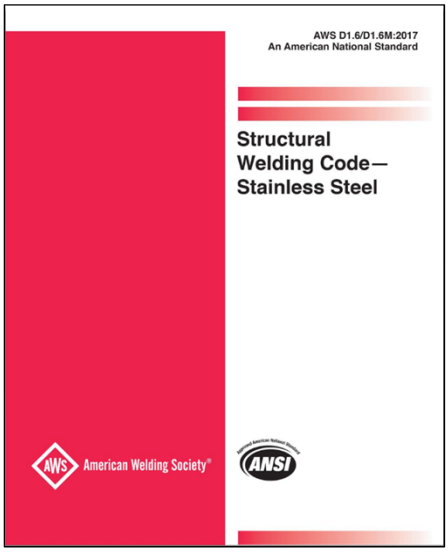
- Joint standard of the AWS and the American Association of State Highway Transportation Officials (AASHTO)
- Generally requires that WPS be qualified by test, with a few exceptions
- Qualification testing involves Charpy V-notch (CVN) specimens and all weld metal tensile specimens
- Nondestructive testing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

26

AWS D1.6

Structural Welding Code –

Stainless Steel



27

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

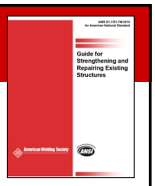
28

AWS D1.7

Guide for Strengthening and Repairing Existing Structures

29

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

30

AWS D1.8

Structural Welding Code –

Seismic Supplement

31

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

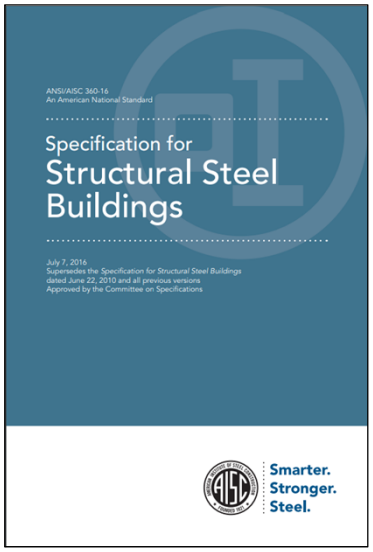
AWS D1.8:

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

32

AISC 360-16

Specification for Structural Steel Buildings



33

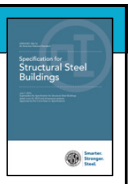
AISC 360-16 Specification for Structural Steel Buildings

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)

34

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

AISC 341-16

Seismic Provisions for Structural Steel Buildings

36

AISC 341-16 Seismic Provisions for Structural Steel Buildings

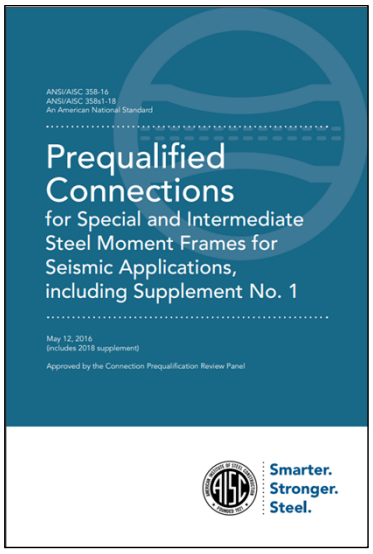
AISC 341:

- 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

37

AISC 358-16

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



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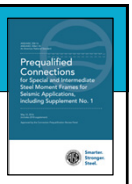
AISC 358-16 Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications



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)

39

AISC 303-16

Code of Standard Practice for Steel Buildings and Bridges

40

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)

41

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*

42

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*

43

WELDED CONNECTION BASICS

Outline

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

44

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.

45

Arc Welding Processes

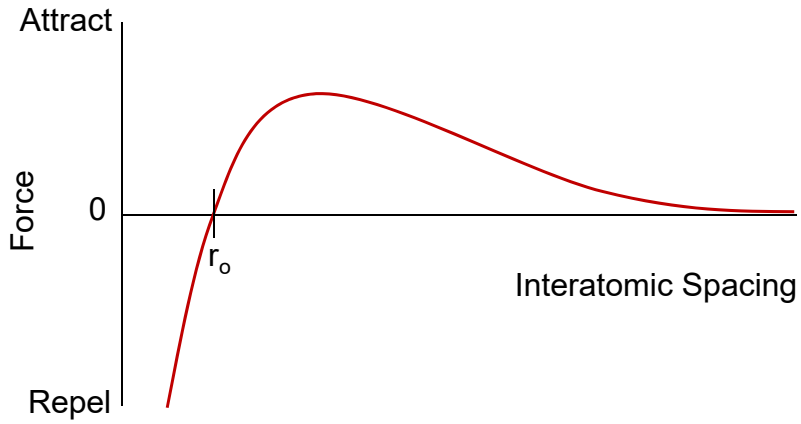
Requirements for fusion:

- Atomic closeness
- Atomic cleanliness

46

Arc Welding Processes

Atomic Closeness

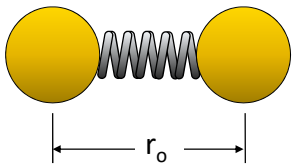


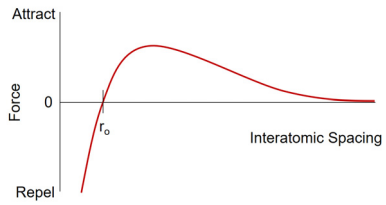
Adapted from W.F. Savage, as presented in *Weld Imperfections*, 1968

47

Arc Welding Processes

Atomic Closeness





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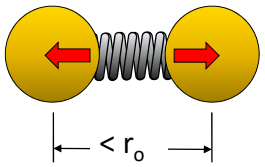
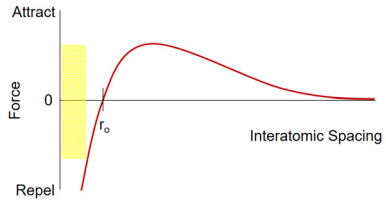
Arc Welding Processes

Atomic Closeness





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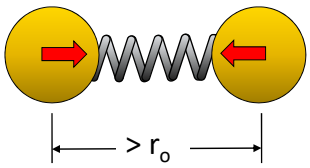
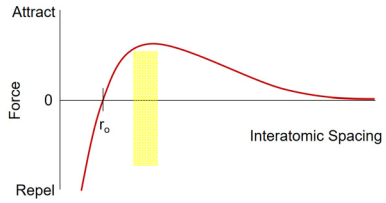
Arc Welding Processes

Atomic Closeness





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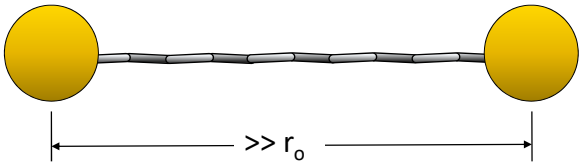
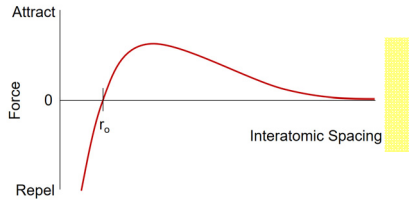
Arc Welding Processes

Atomic Closeness





51

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)

52

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)

53

Arc Welding Processes

Atomic Cleanliness:

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

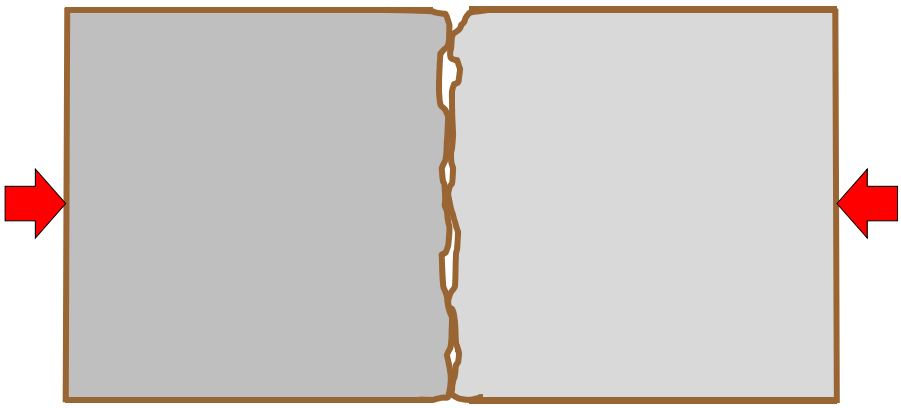
54

Arc Welding Processes

How to Achieve Atomic Cleanliness:

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

55



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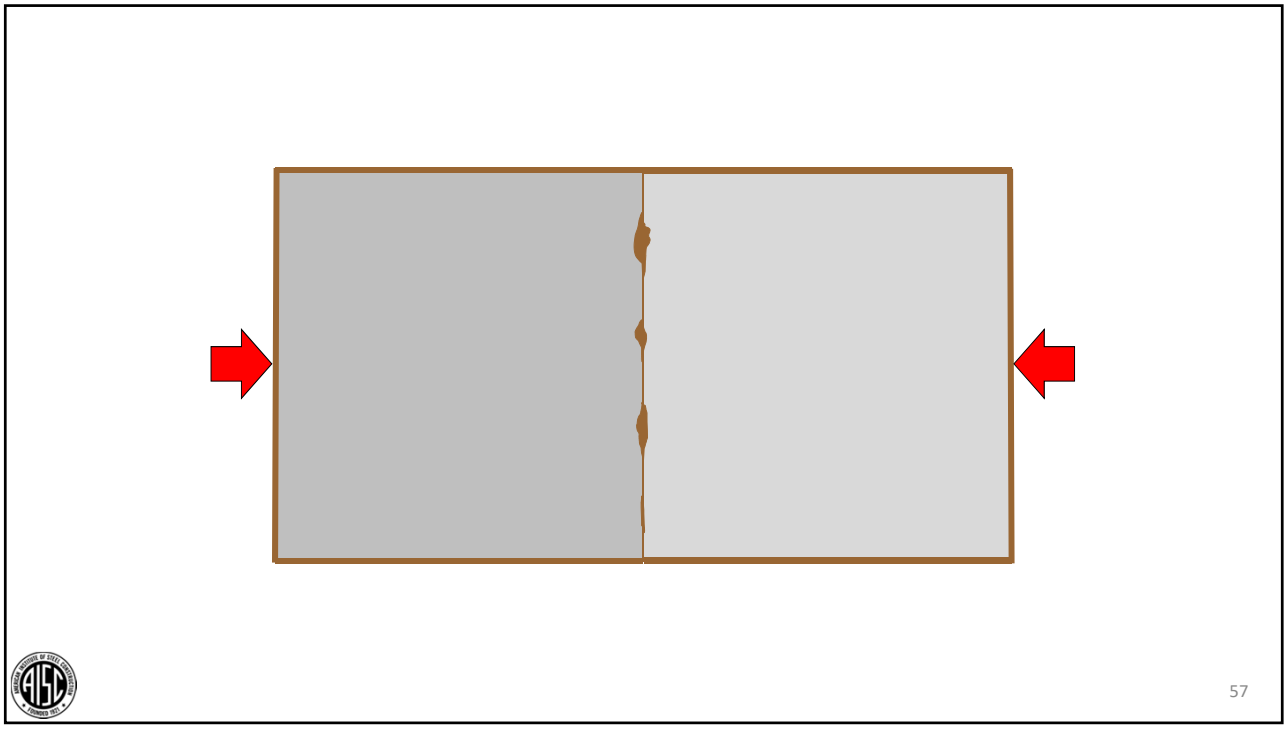

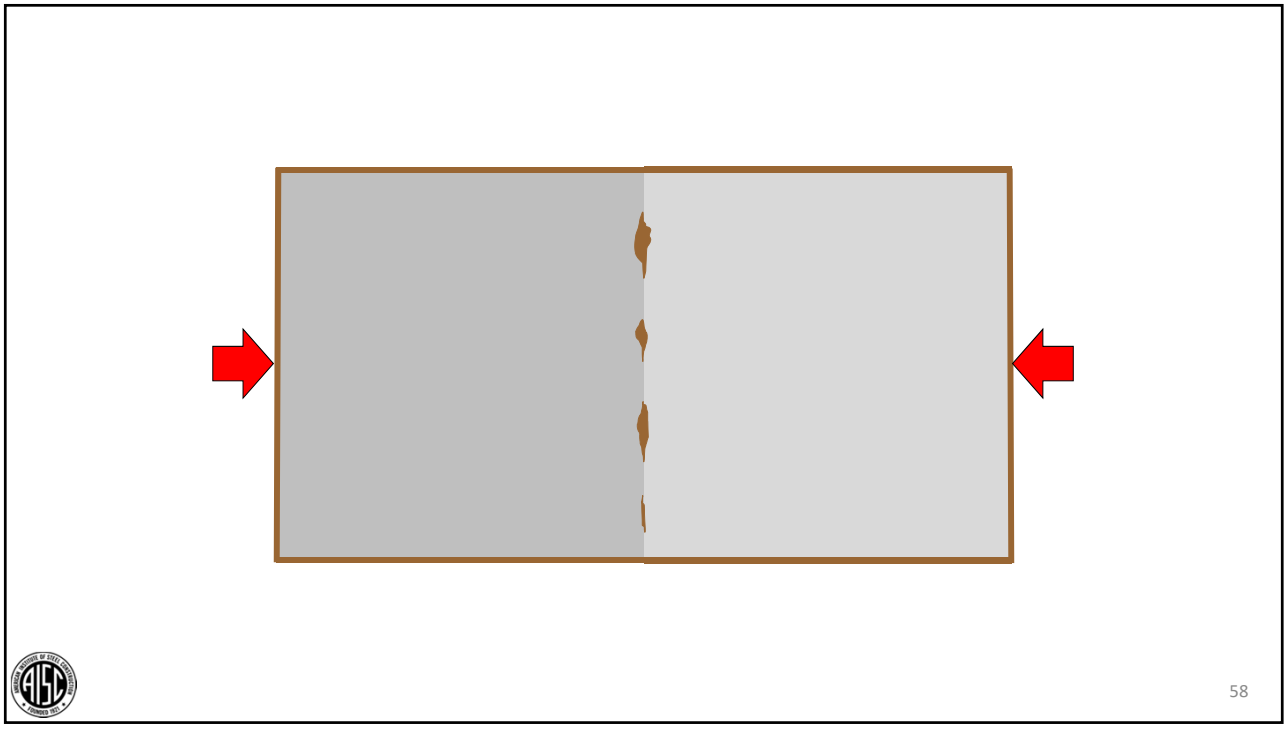

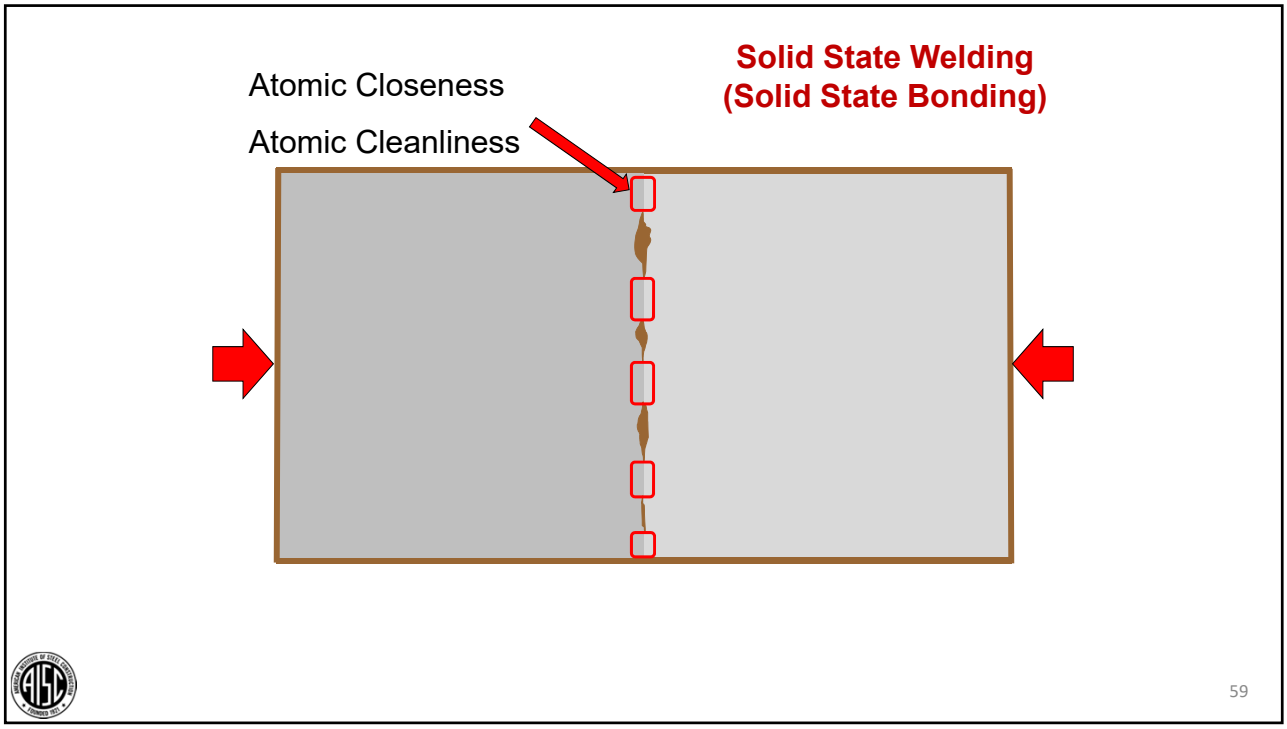

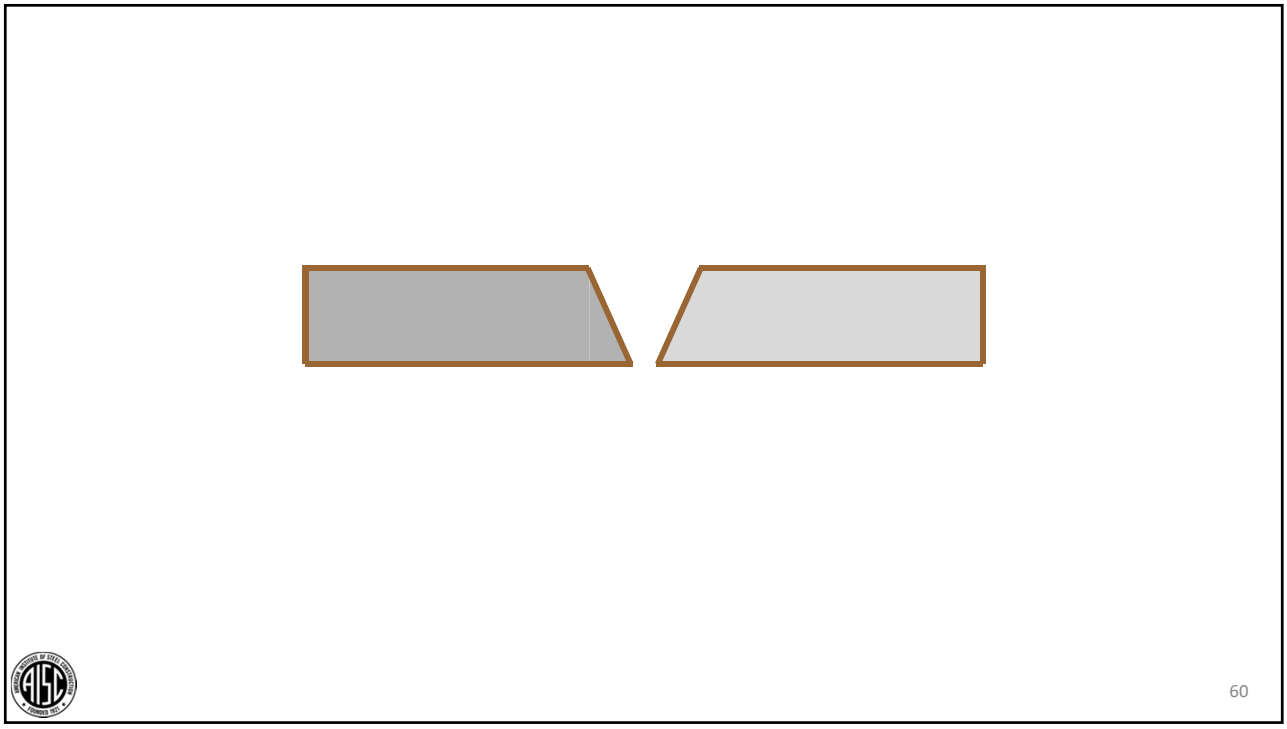

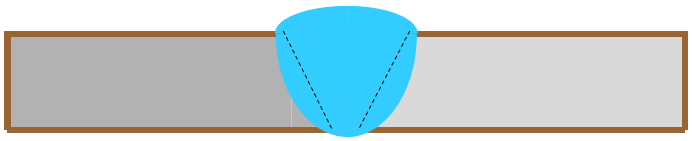

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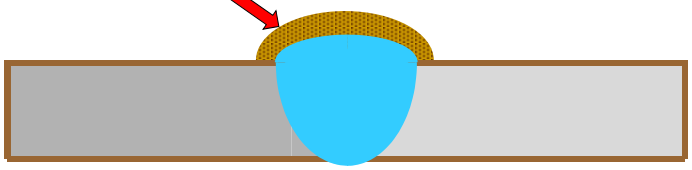
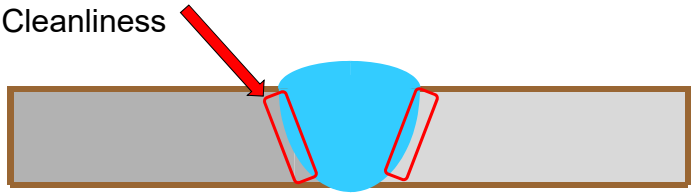


62

Fusion Welding

Atomic Closeness

Atomic Cleanliness



63

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.

64

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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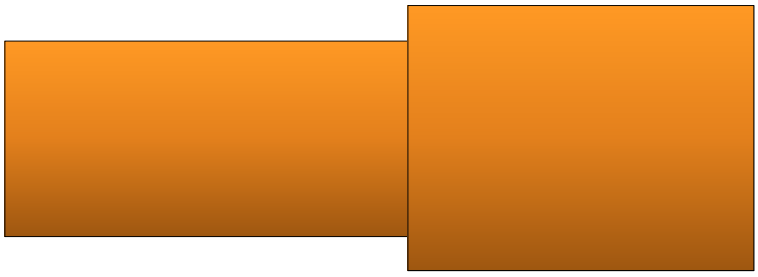

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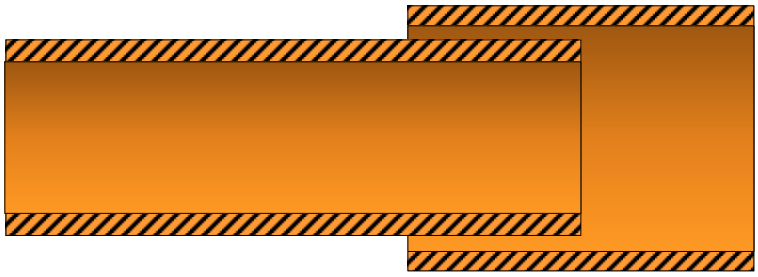
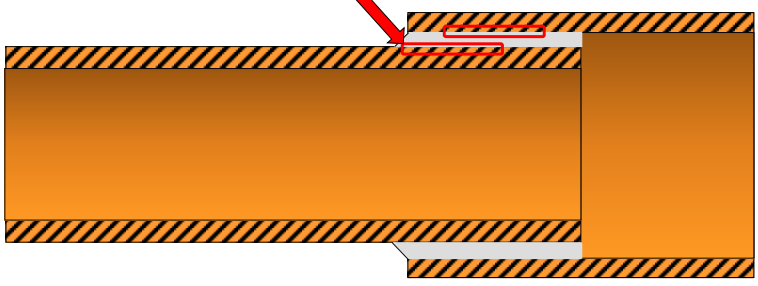


67

Soldering, Brazing

Atomic Closeness

Atomic Cleanliness



68

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.

69

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.

70

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

71

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)

72

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

73

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)

74

Arc Welding Processes

Major thermal cutting processes:

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

75

WELDED CONNECTION BASICS

Outline

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

76

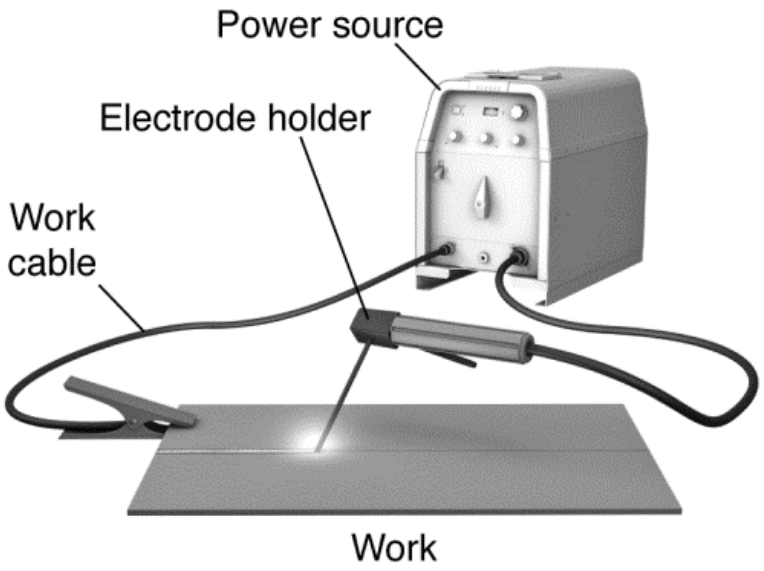
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

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.

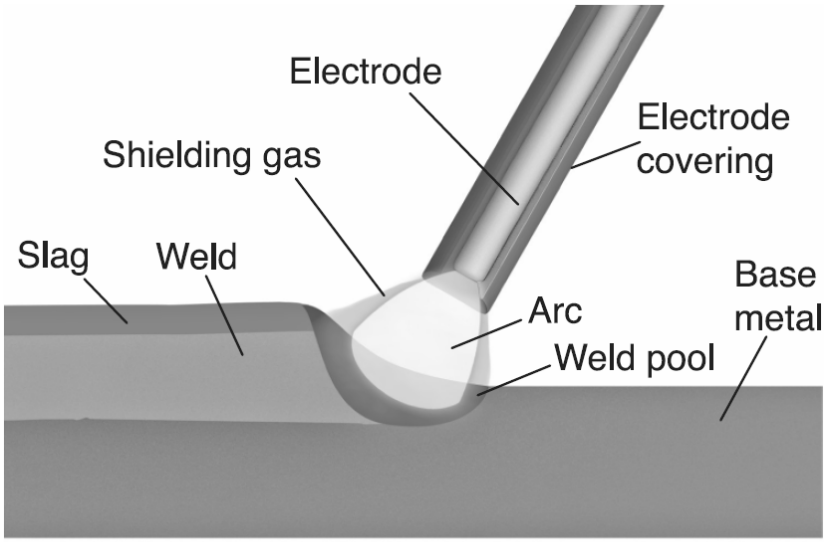
77

Arc Welding Processes: SMAW



78

Arc Welding Processes: SMAW



80

Arc Welding Processes: SMAW

Advantages:

- Simplicity
- Flexibility
- Familiarity

82

Arc Welding Processes: SMAW

Limitations:

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

83

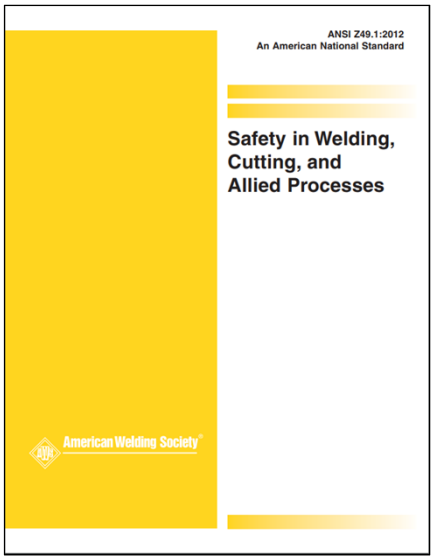
ANSI Z49.1

Safety in Welding, Cutting, and Allied Processes

Available by free download from AWS

aws.org

www.aws.org/technical/facts

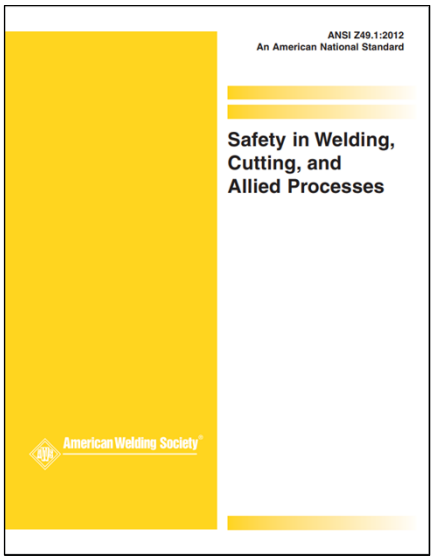


84

The big four:

- Arc
- Fire
- Electrical
- Fume

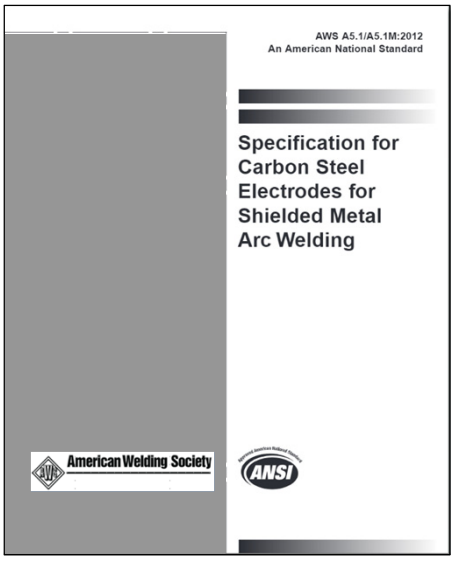
Not comprehensive.
See Z49.1 for a complete listing



85

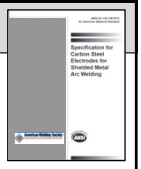
AWS A5.1

Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding



86

AWS 5 Filler Metal Specifications

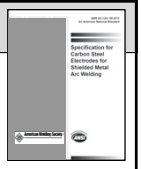


E7018

Electrode
70 ksi minimum specified tensile strength
1 = Position of welding
8 = Coating type, mechanical properties

87

AWS 5 Filler Metal Specifications



E4918

Electrode
490 MPa min. specified tensile strength
1 = Position of welding
8 = Coating type, mechanical properties

88

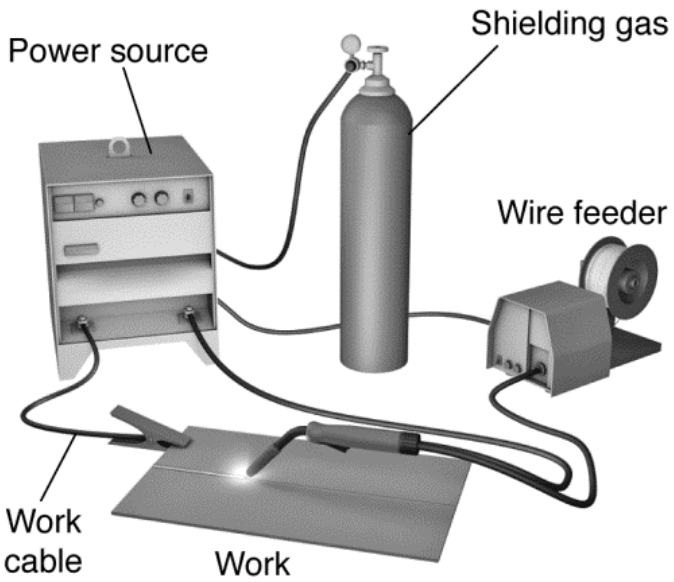
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

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.

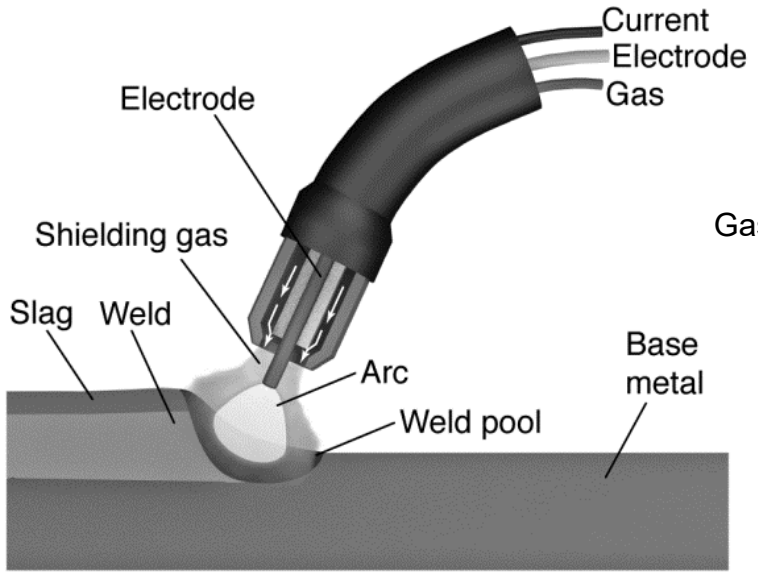
89

Arc Welding Processes: FCAW



90

Arc Welding Processes: FCAW-G



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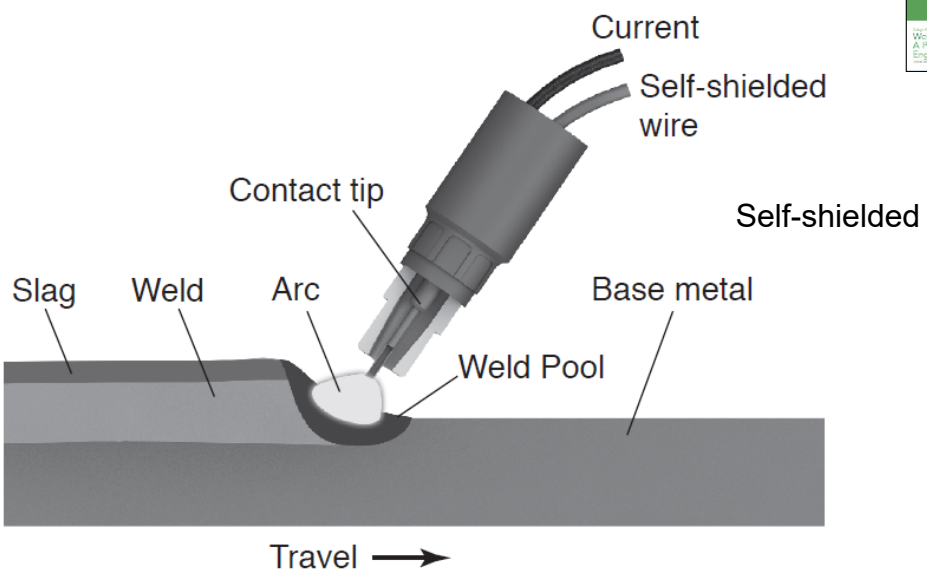
92

Arc Welding Processes: FCAW-S



93

94

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

95

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

96

Arc Welding Processes: FCAW

Limitations:

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

97

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)

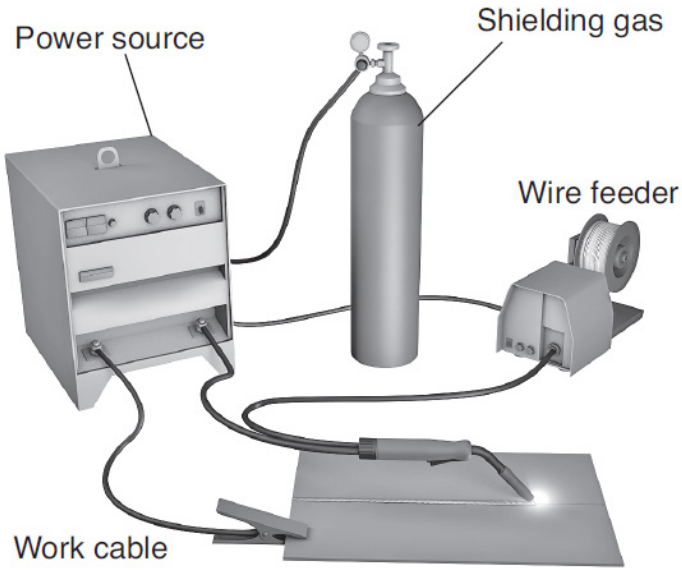
gas metal arc welding (GMAW).

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.

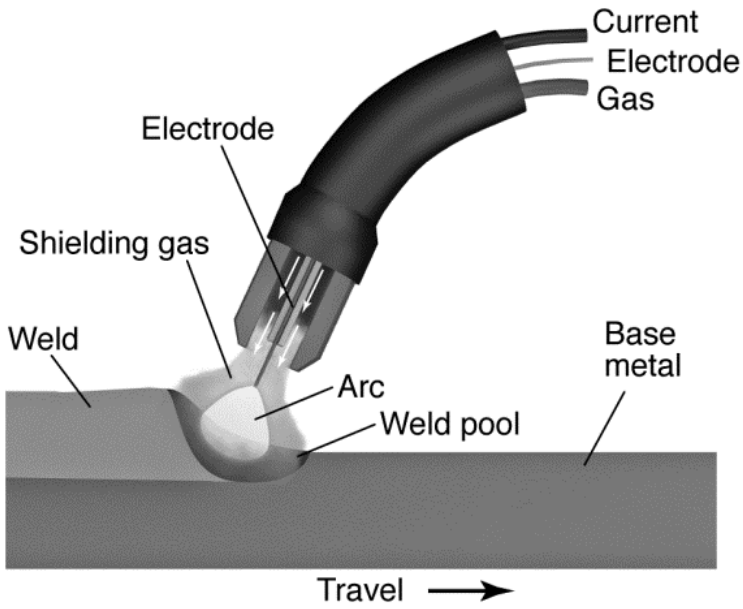
102

Arc Welding Processes: GMAW



103

Arc Welding Processes: GMAW



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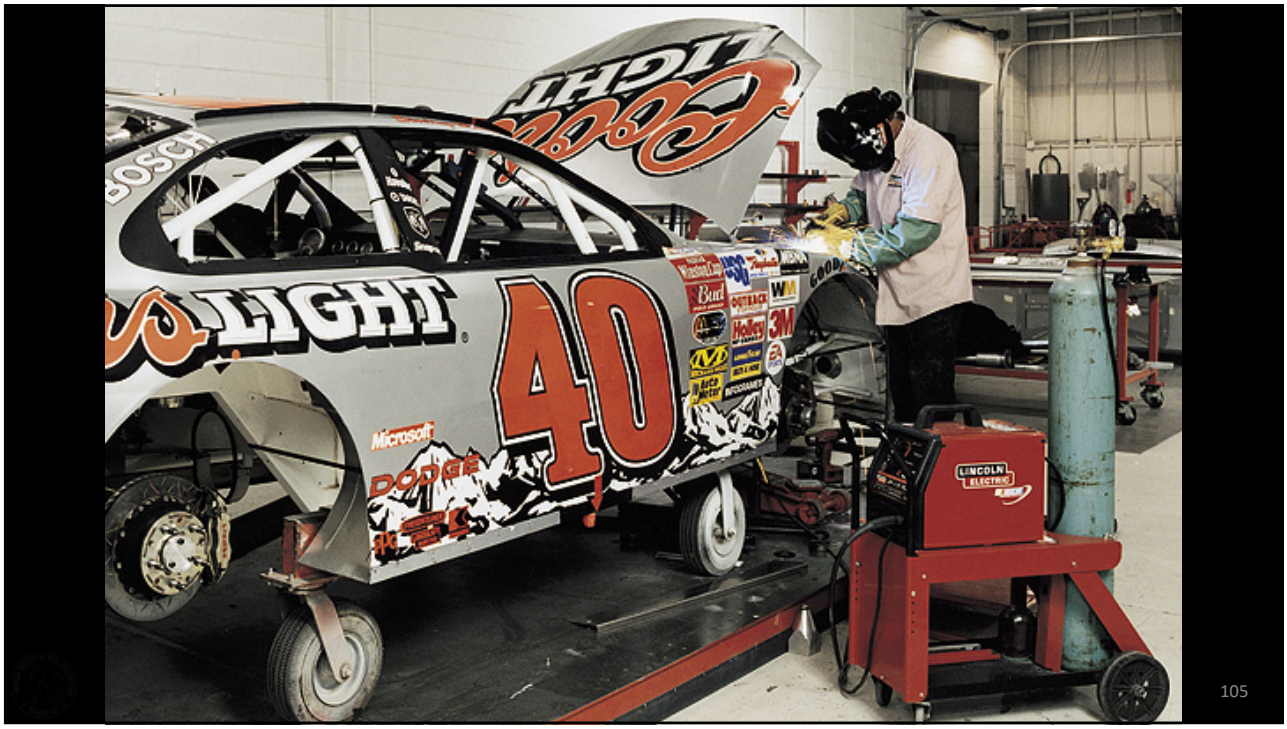


105

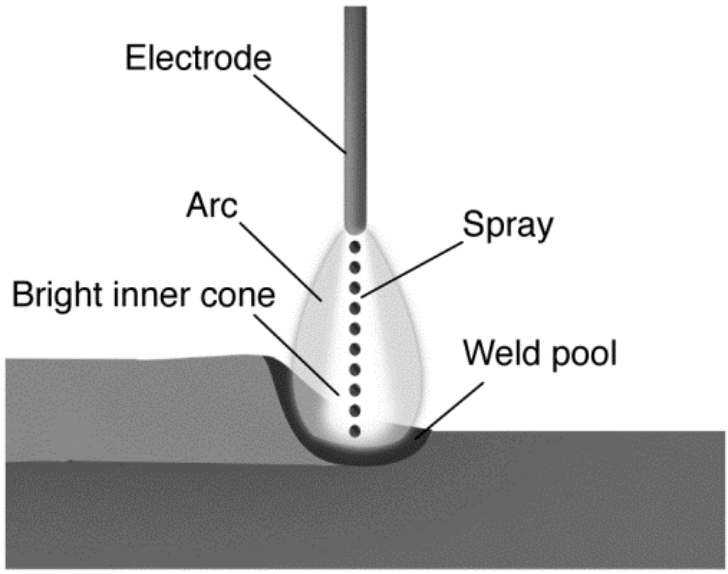
Arc Welding Processes: GMAW

GMAW Modes of Metal Transfer

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

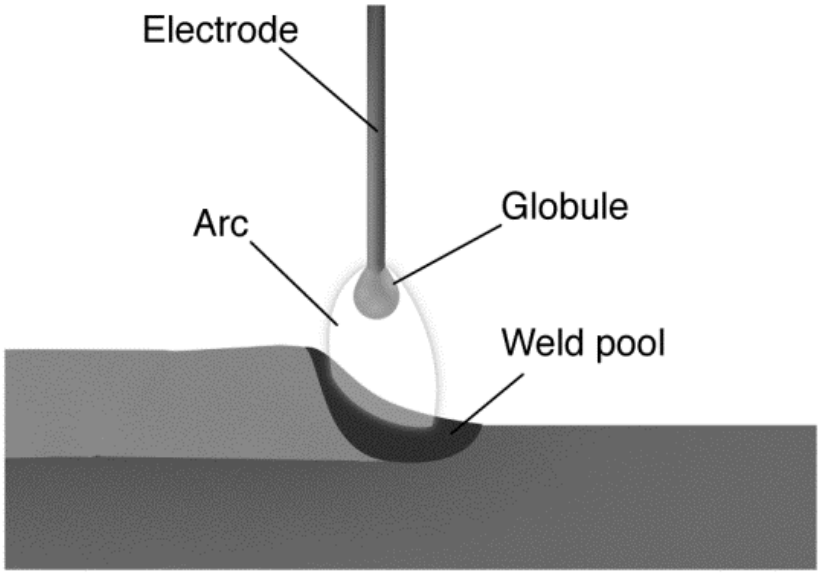
106

Arc Welding Processes: GMAW Spray



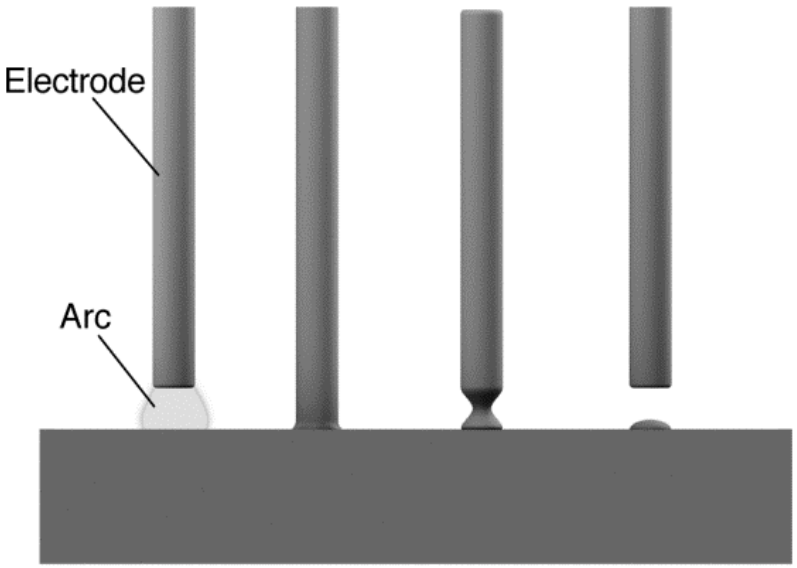
107

Arc Welding Processes: GMAW Globular



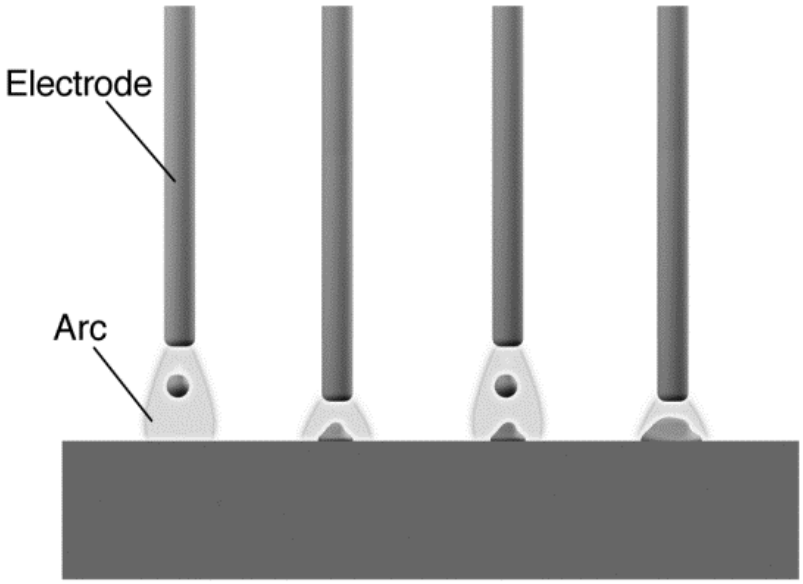
108

Arc Welding Processes: GMAW Short-Circuiting



109

Arc Welding Processes: GMAW Pulsed



110

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

111

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

112

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

114

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

115

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

116

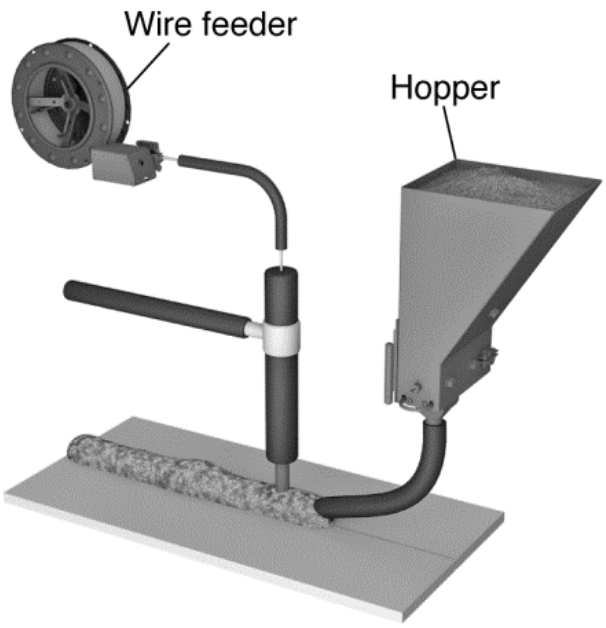
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

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).

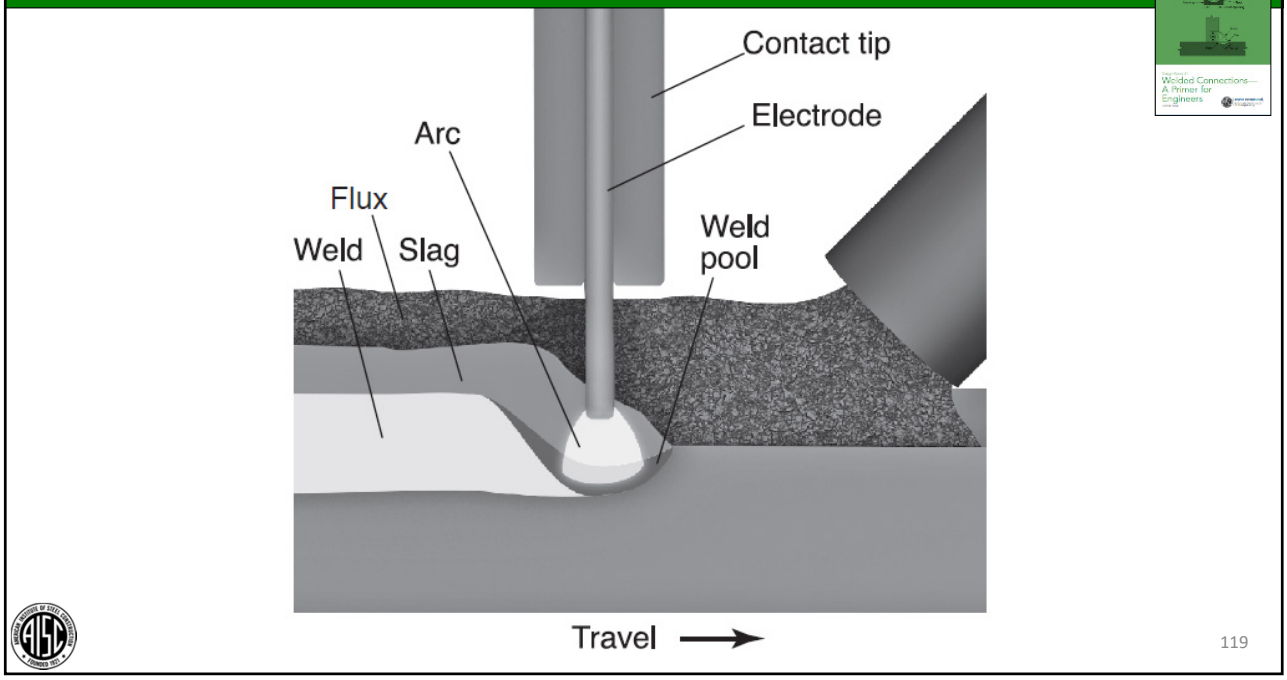
117

Arc Welding Processes: SAW



118

Arc Welding Processes: SAW



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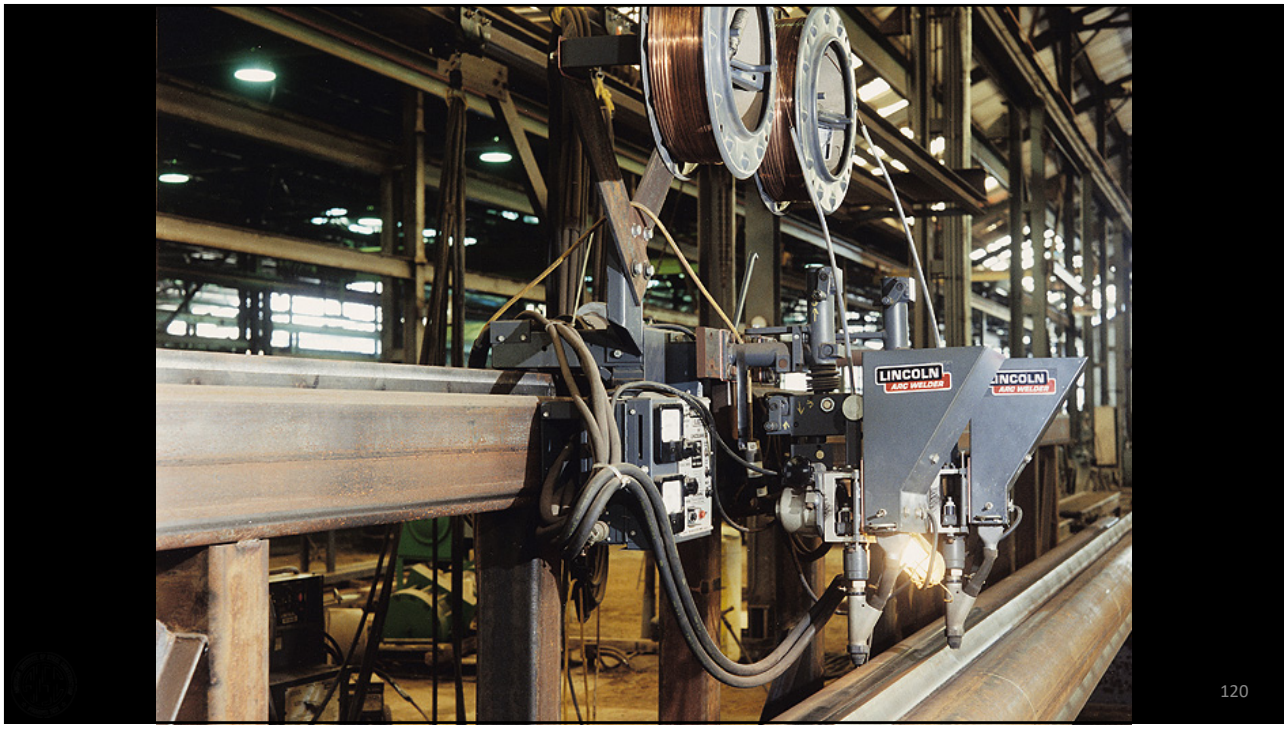


120

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

124

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

126

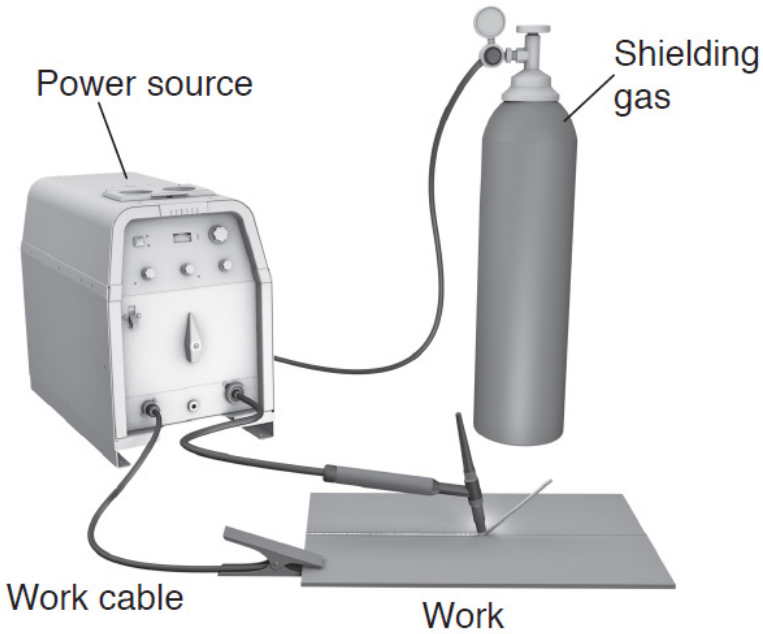
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

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.

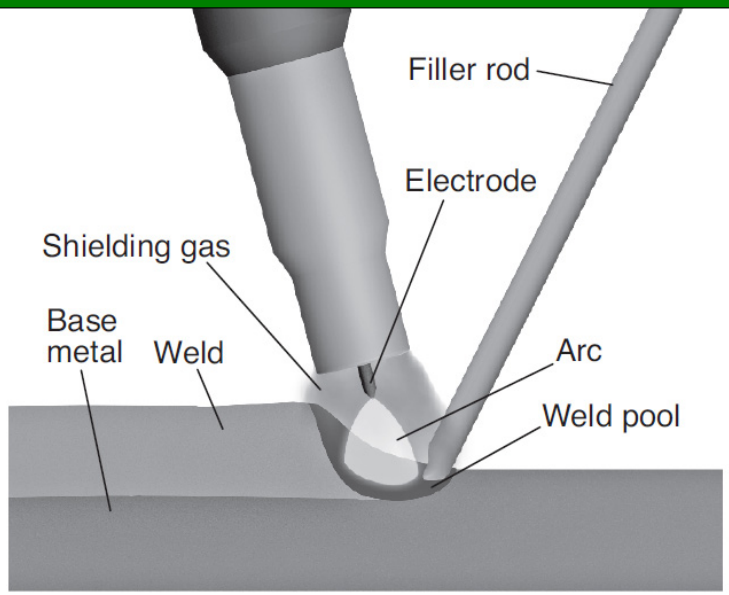
127

Arc Welding Processes: GTAW



128

Arc Welding Processes: GTAW



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130

131

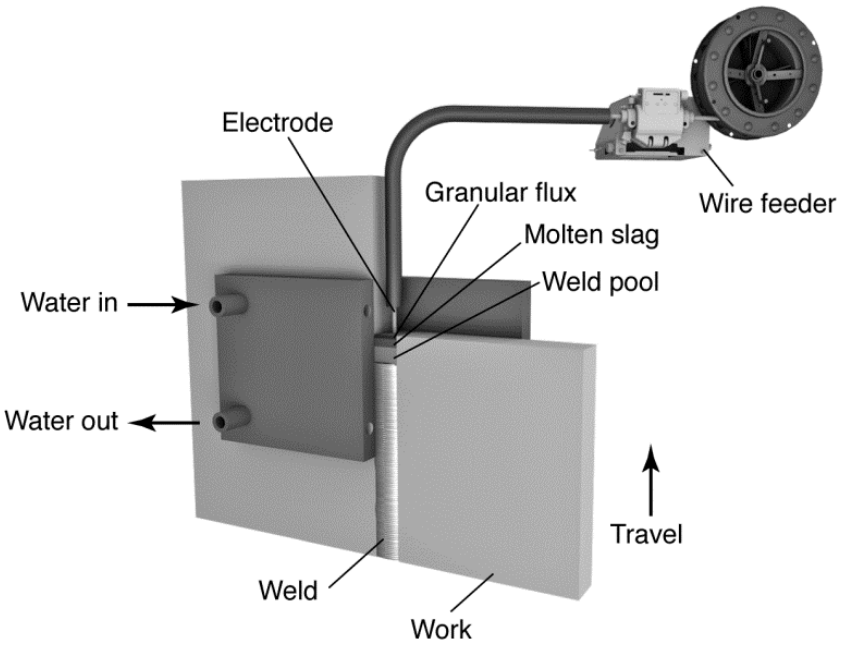
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

electroslag welding (ESW).

A welding process producing calescence 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.

132

Arc Welding Processes: ESW



133

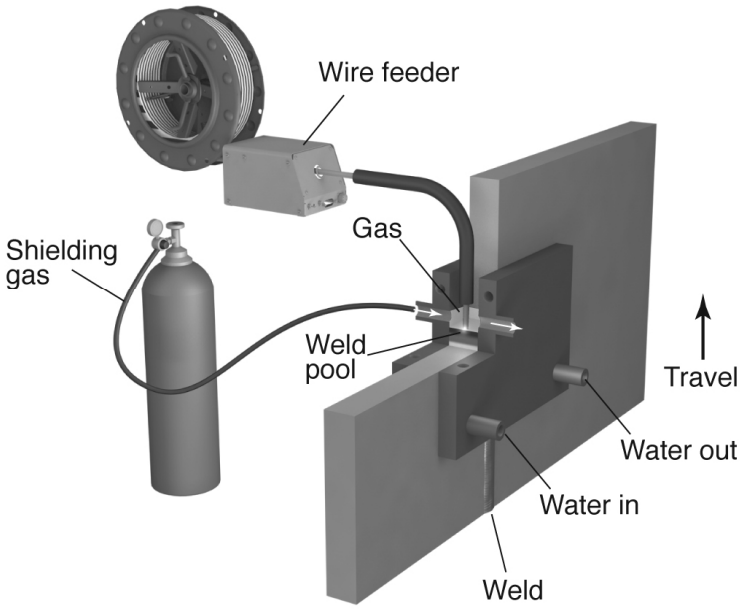
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

electrogas welding (EGW).

An arc welding process using an arc between a continuous filler metal electrode and the weld pool, employing approximately vertical welding progression with backing to confine the molten weld metal. The process is used with or without an externally supplied shielding gas and without the application of pressure.

134

Arc Welding Processes: EGW



135

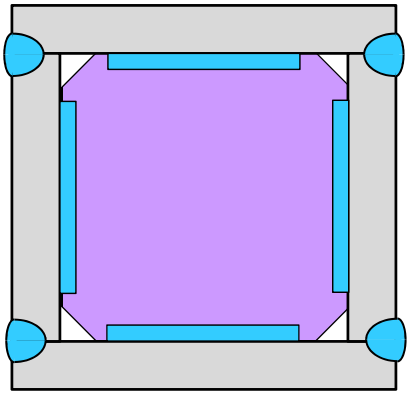
Arc Welding Processes: ESW / EGW

Applications

- "Blind welds" on box column stiffeners

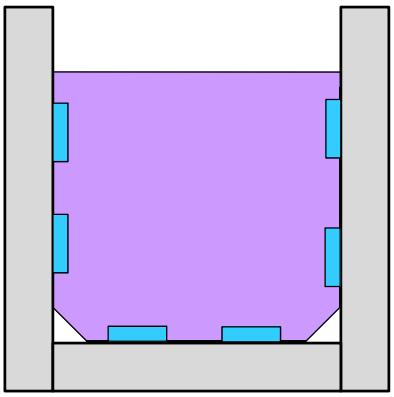
136

Arc Welding Processes: ESW / EGW



137

Arc Welding Processes: ESW / EGW



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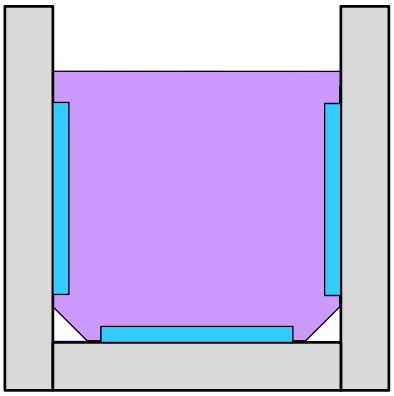
Arc Welding Processes: ESW / EGW



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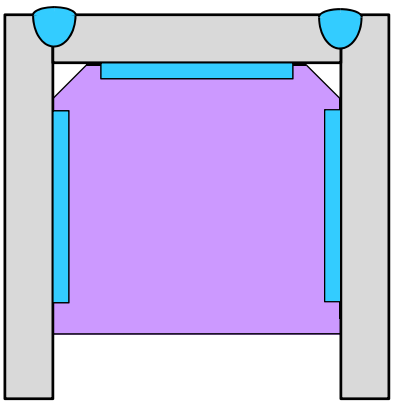
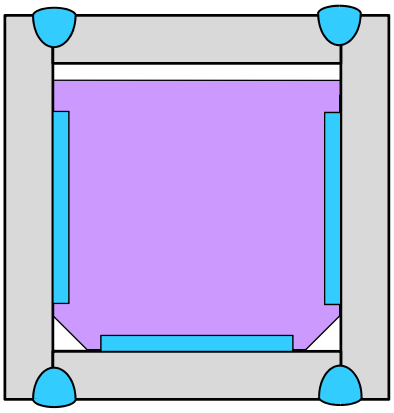
Arc Welding Processes: ESW / EGW



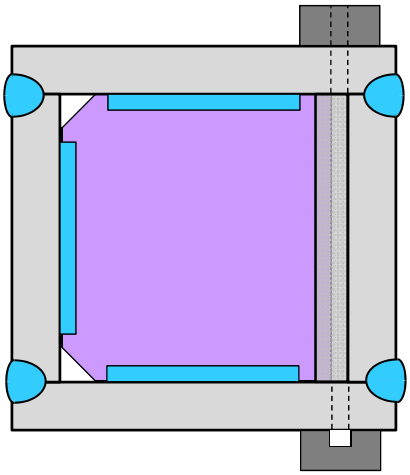
140

Arc Welding Processes: ESW / EGW



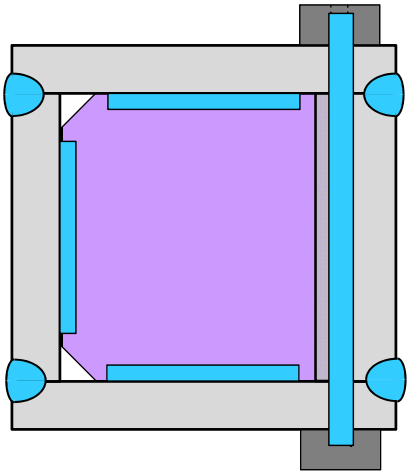
141

Arc Welding Processes: ESW / EGW



142

Arc Welding Processes: ESW / EGW



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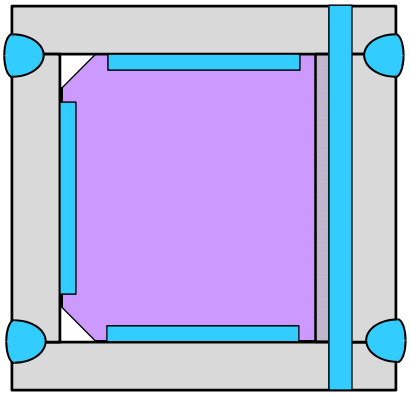
Arc Welding Processes: ESW / EGW



144

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)

145

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

146

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)

147

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

148

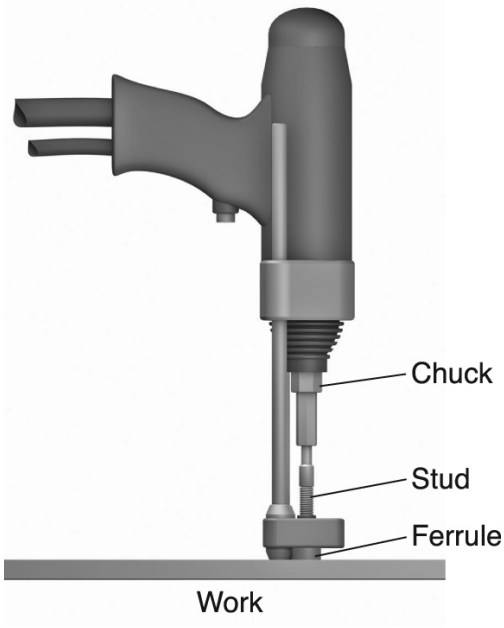
AWS STANDARD WELDING TERMS & DEFINITIONS (A3.0:2010)

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.

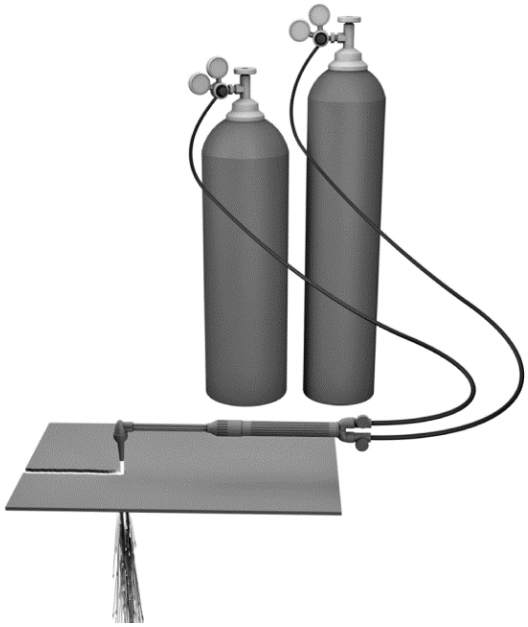
149

Arc Welding Processes: SW



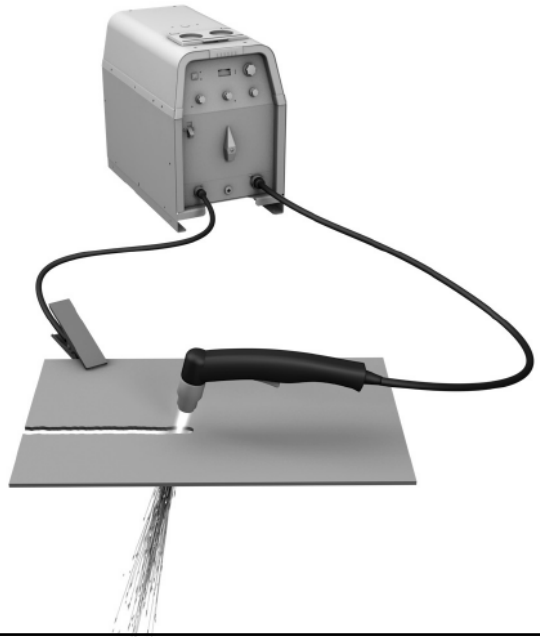
150

Thermal Cutting Processes: Oxyfuel Cutting



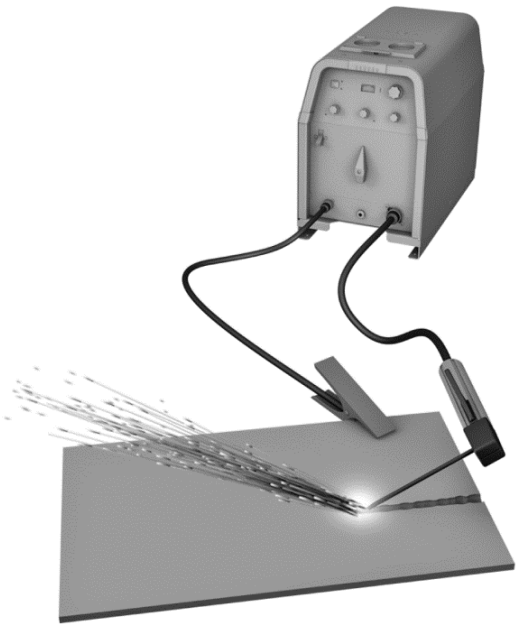
151

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)

154

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

155

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

156

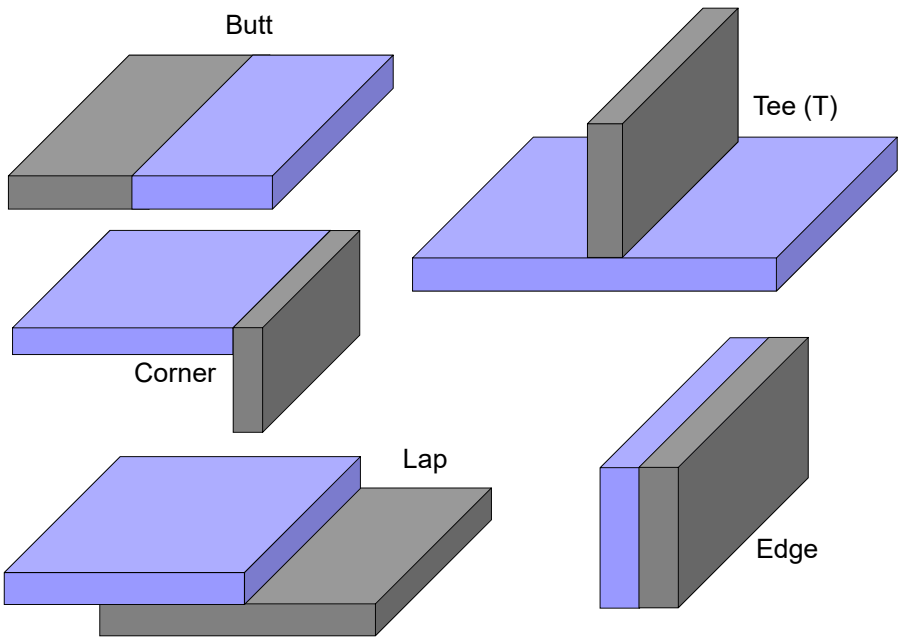
WELDED CONNECTION BASICS

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

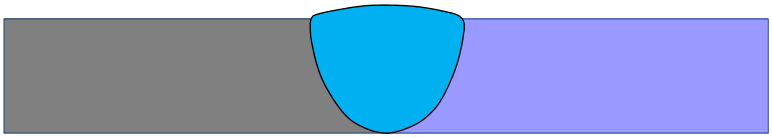
Slot Welds

Plug Welds

159

Weld Types

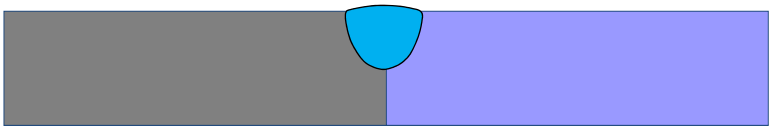
CJP Groove Weld in Butt Joint



160

Weld Types

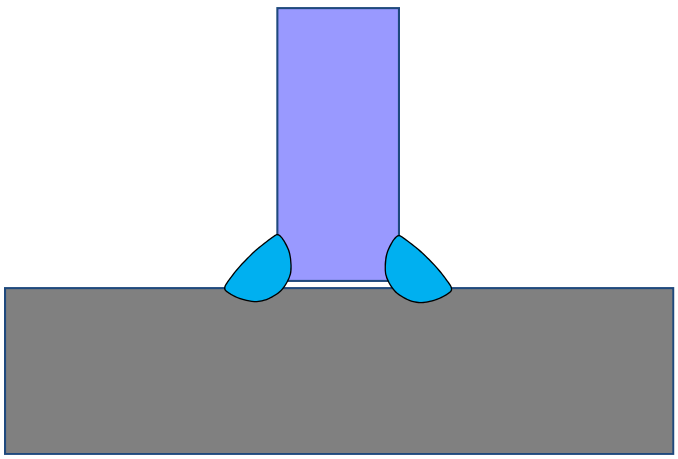
PJP Groove Weld in Butt Joint



161

Weld Types

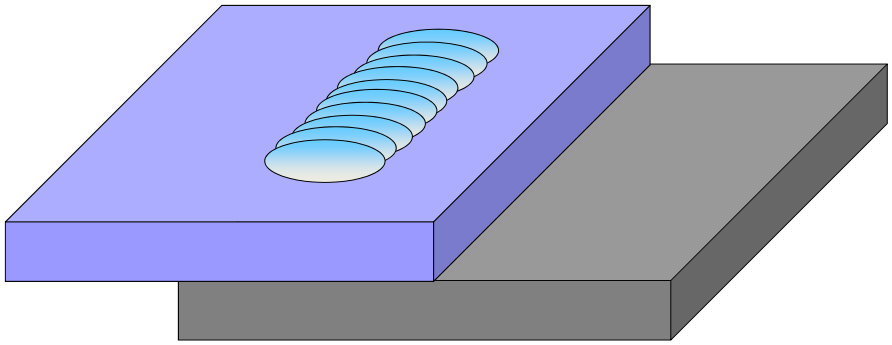
Fillet Weld in Tee Joint



162

Weld Types

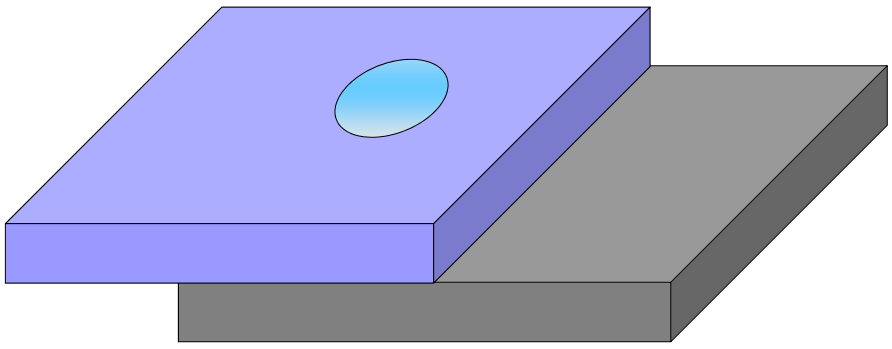
Slot Weld in Lap Joint



163

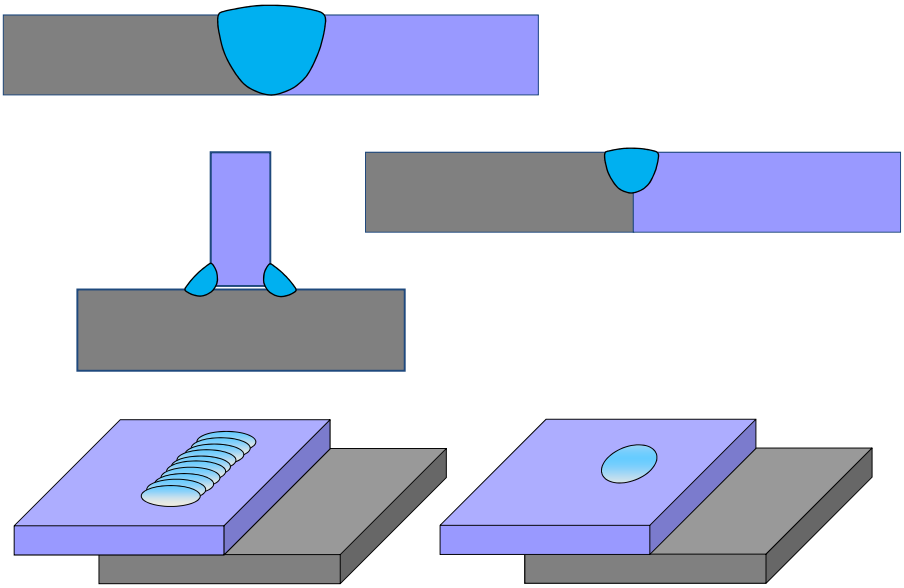
Weld Types

Plug Weld in Lap Joint



164

Weld Types

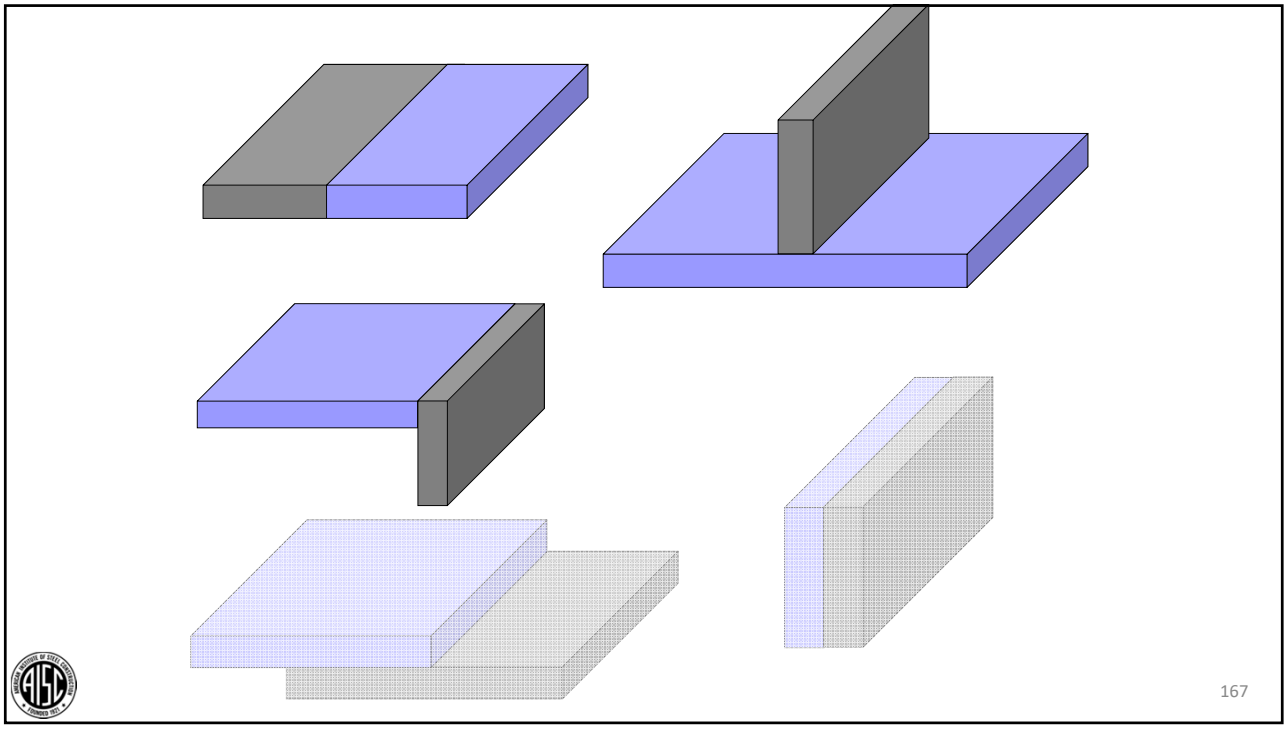


165

Groove Welds

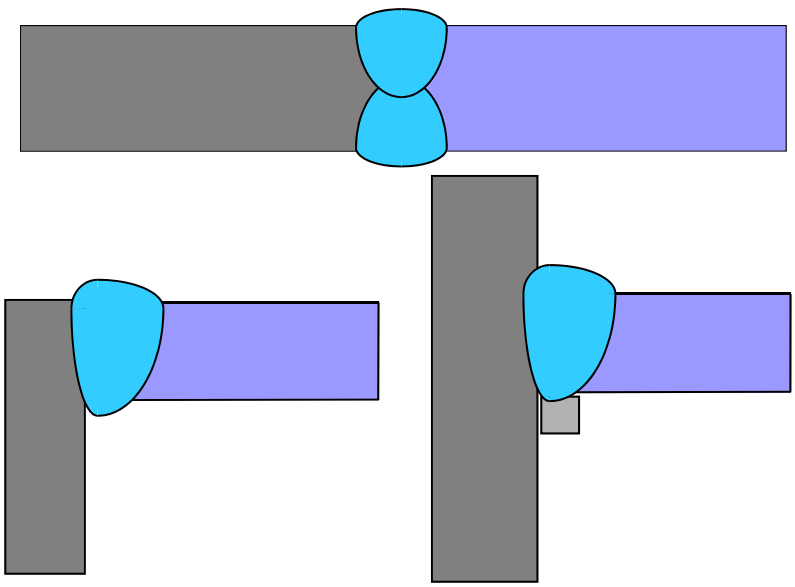
- Applied to butt, tee, corner joints
- CJP = full strength (for statically loaded connections)
- PJP = partial strength
- Tension vs. compression vs. shear

166



167

CJP Groove Welds



168

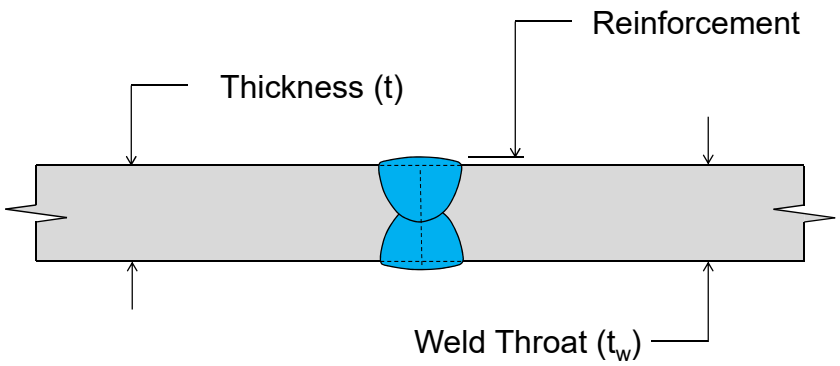
CJP Groove Welds

- Throat = plate thickness

169

CJP Groove Welds

Weld Throat Dimension (t_w)



170

CJP Groove Welds

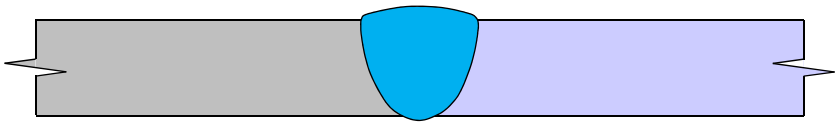
- Throat = plate thickness
- No design calculations are required for statically loaded connections, when “matching” filler metal is used

171

CJP Groove Welds

Complete-Joint-Penetration Groove Weld (CJP)

Single sided

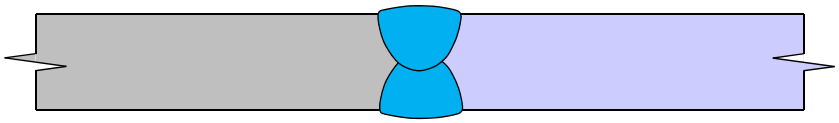


172

CJP Groove Welds

Complete-Joint-Penetration Groove Weld (CJP)

Double sided

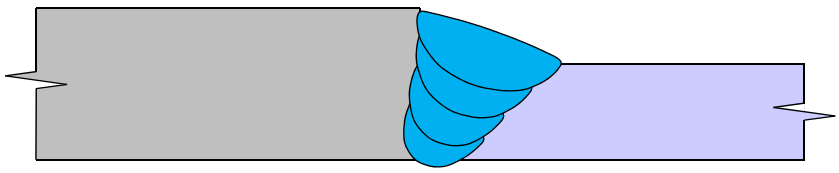


173

CJP Groove Welds

Complete-Joint-Penetration Groove Weld (CJP)

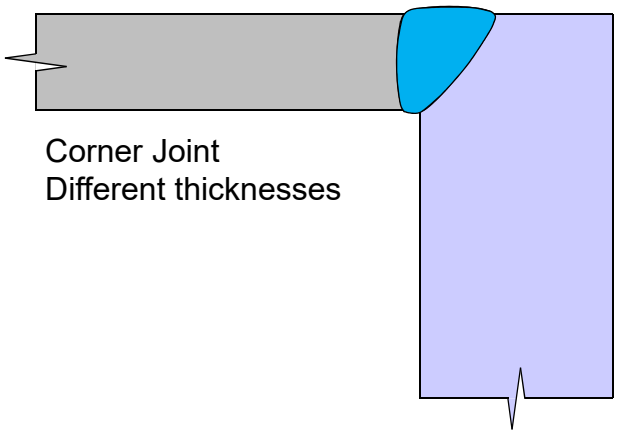
Two thicknesses



174

CJP Groove Welds

Complete-Joint-Penetration Groove Weld (CJP)

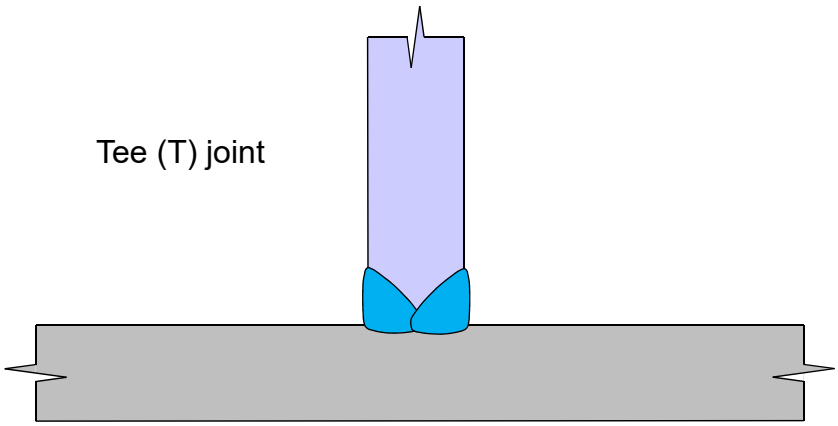


Corner Joint
Different thicknesses

175

CJP Groove Welds

Complete-Joint-Penetration Groove Weld (CJP)

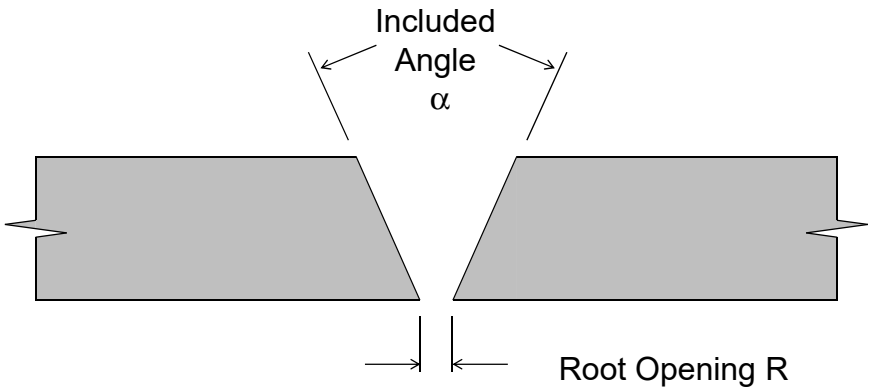


Tee (T) joint

176

CJP Groove Welds

Single Vee Groove Weld



177

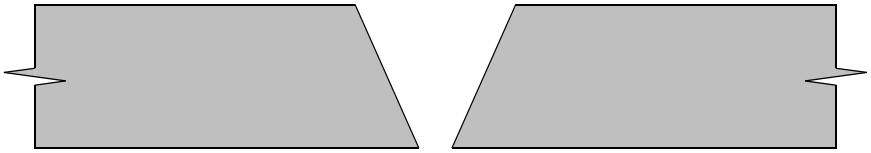
CJP Groove Welds

Square Groove

178

CJP Groove Welds

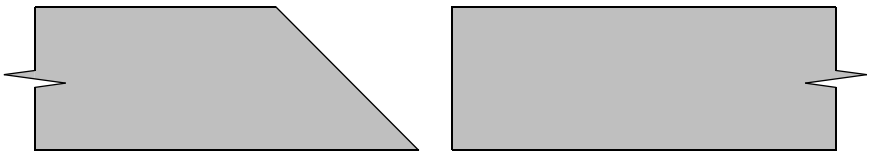
Single Vee Groove



179

CJP Groove Welds

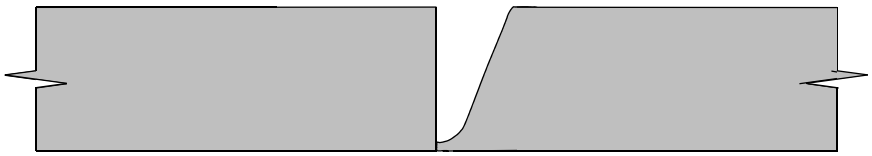
Single Bevel Groove



180

CJP Groove Welds

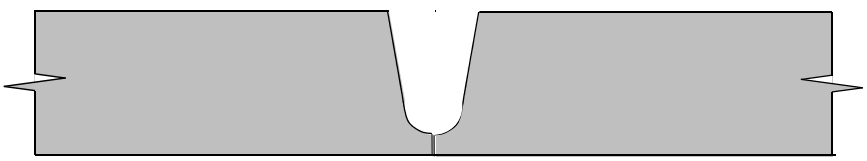
Single J Groove



181

CJP Groove Welds

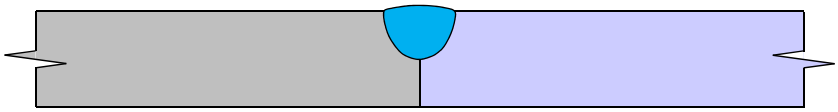
Single U Groove



182

PJP Groove Welds

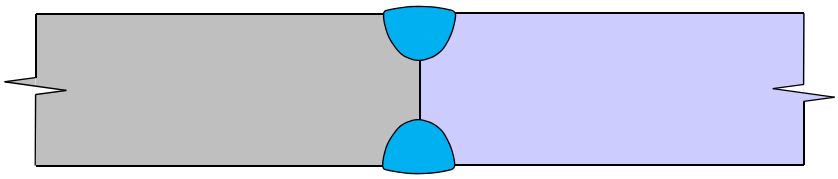
Single Sided PJP in Butt Joint



183

PJP Groove Welds

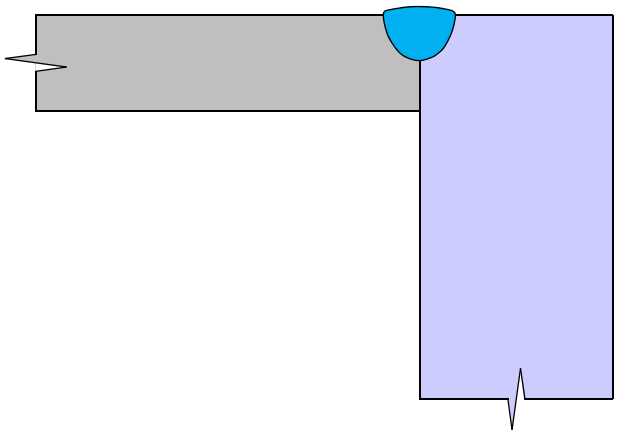
Double Sided PJP in Butt Joint



184

PJP Groove Welds

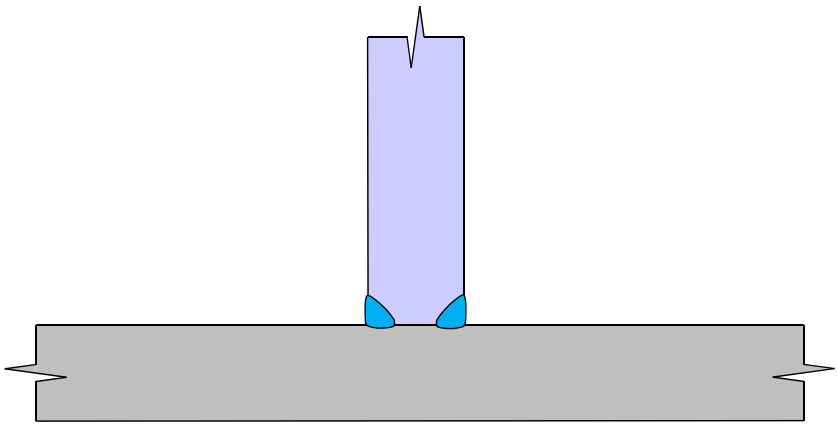
Single Sided PJP in Corner Joint



185

PJP Groove Welds

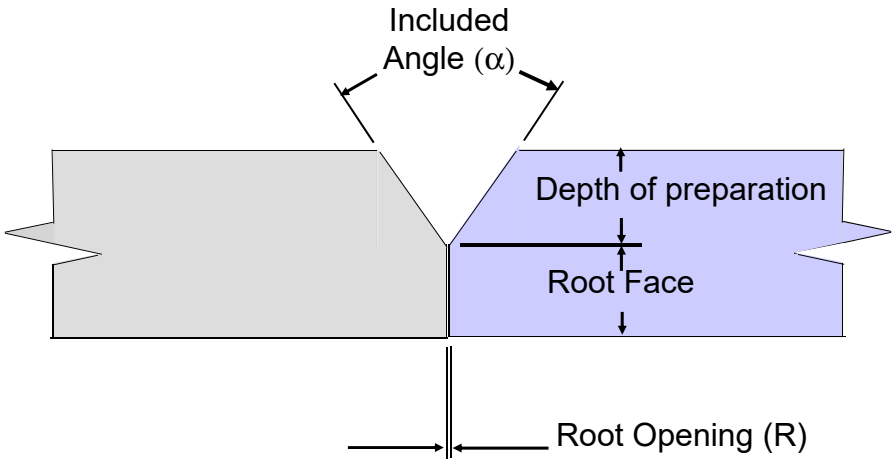
Double Sided PJP in Tee (T) Joint



186

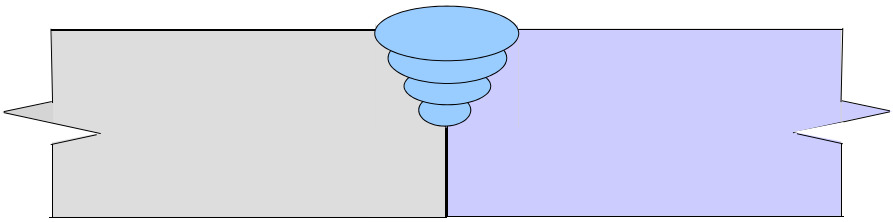
PJP Groove Welds

Single Sided Vee PJP Groove Weld



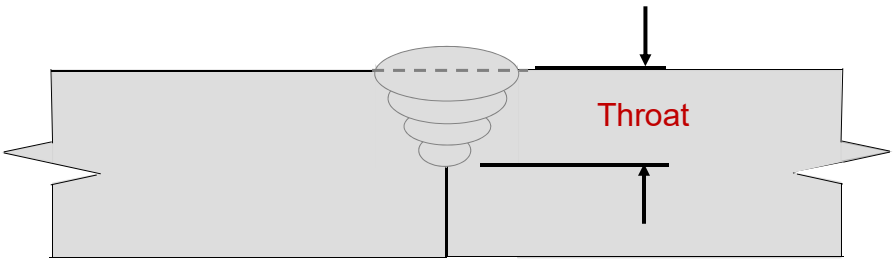
187

PJP Groove Welds



188

PJP Groove Welds



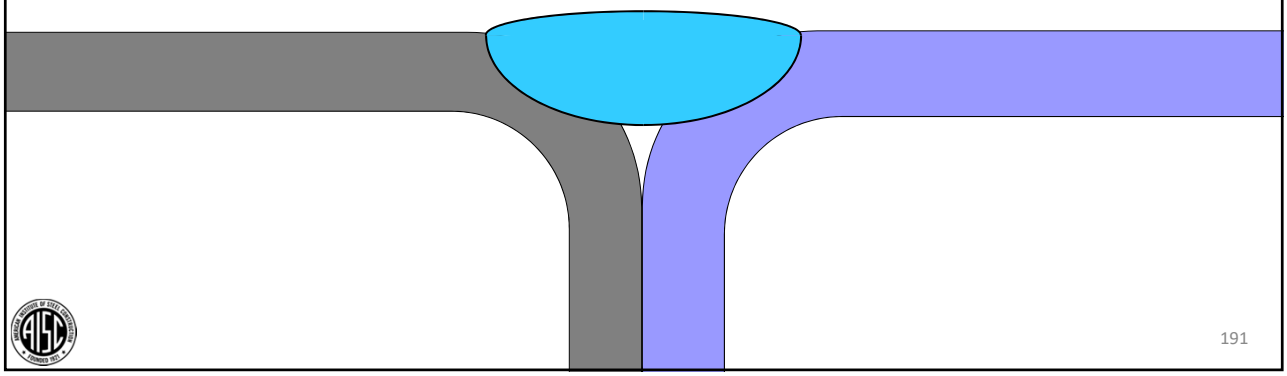
189

PJP Groove Welds

- Throat < plate thickness
- Must determine throat

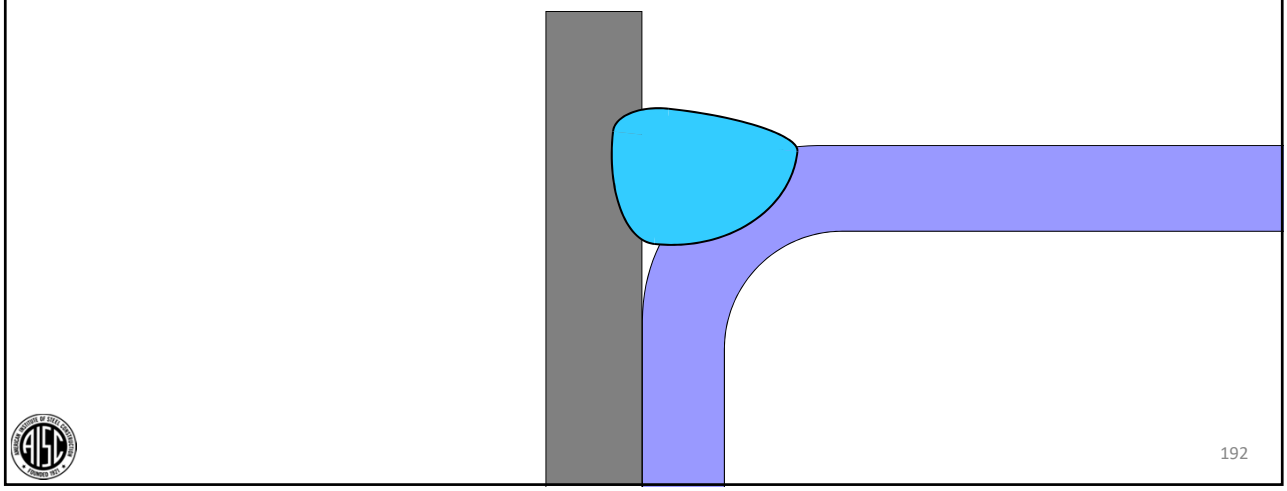
190

Flare Vee Groove Welds



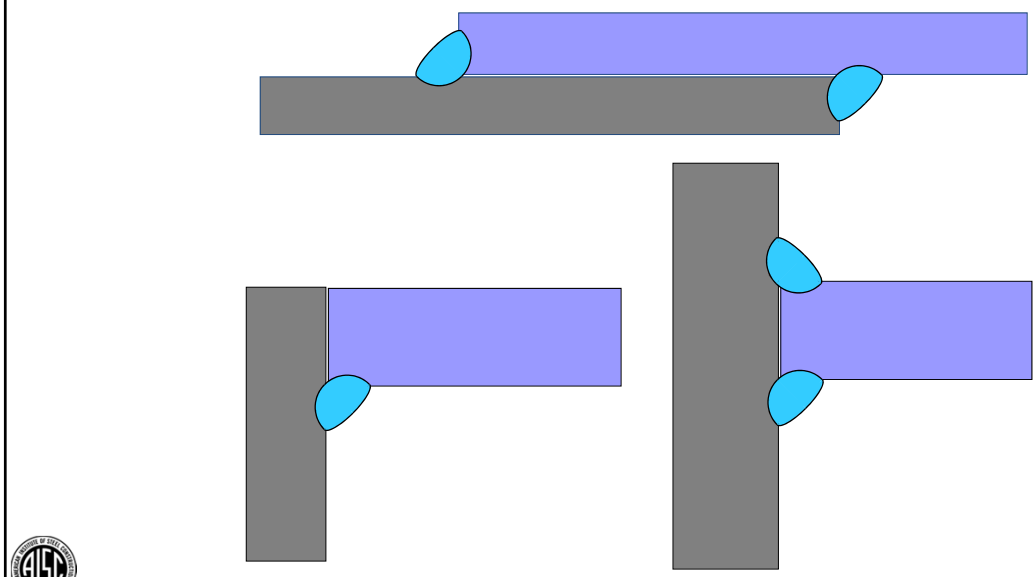
191

Flare Bevel Groove Welds



192

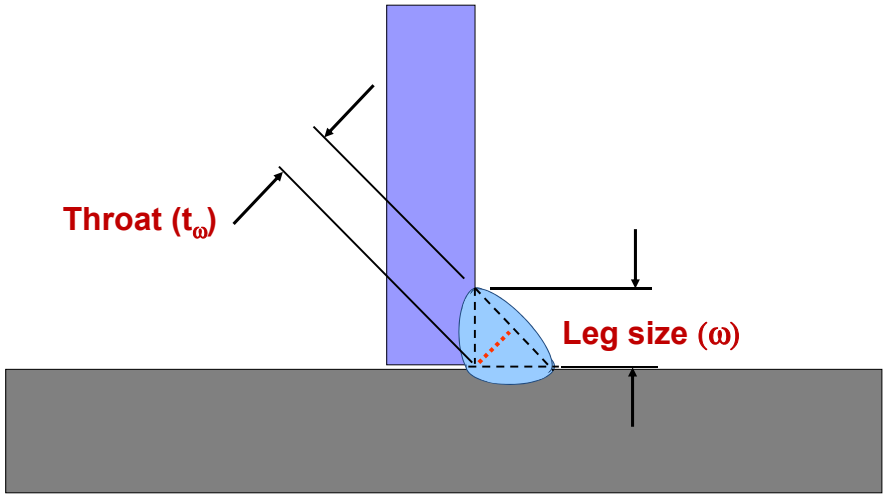
Fillet Welds



193

Fillet Welds

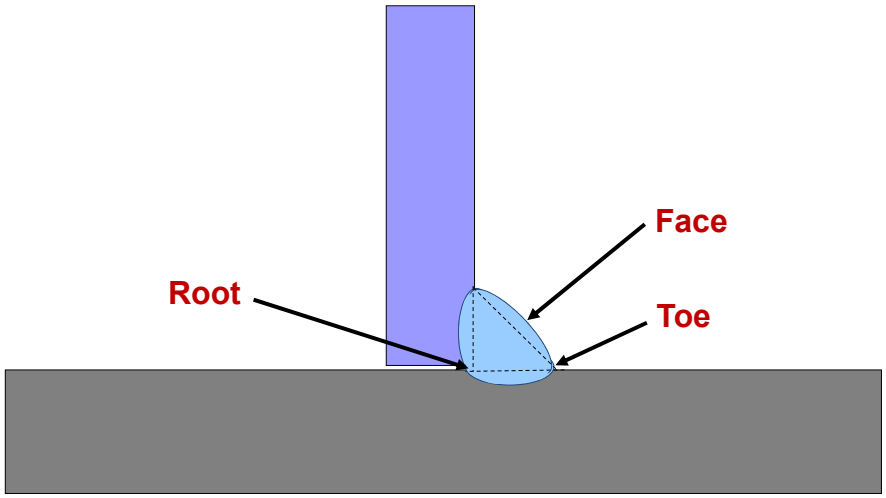
Terminology



194

Fillet Welds

Terminology

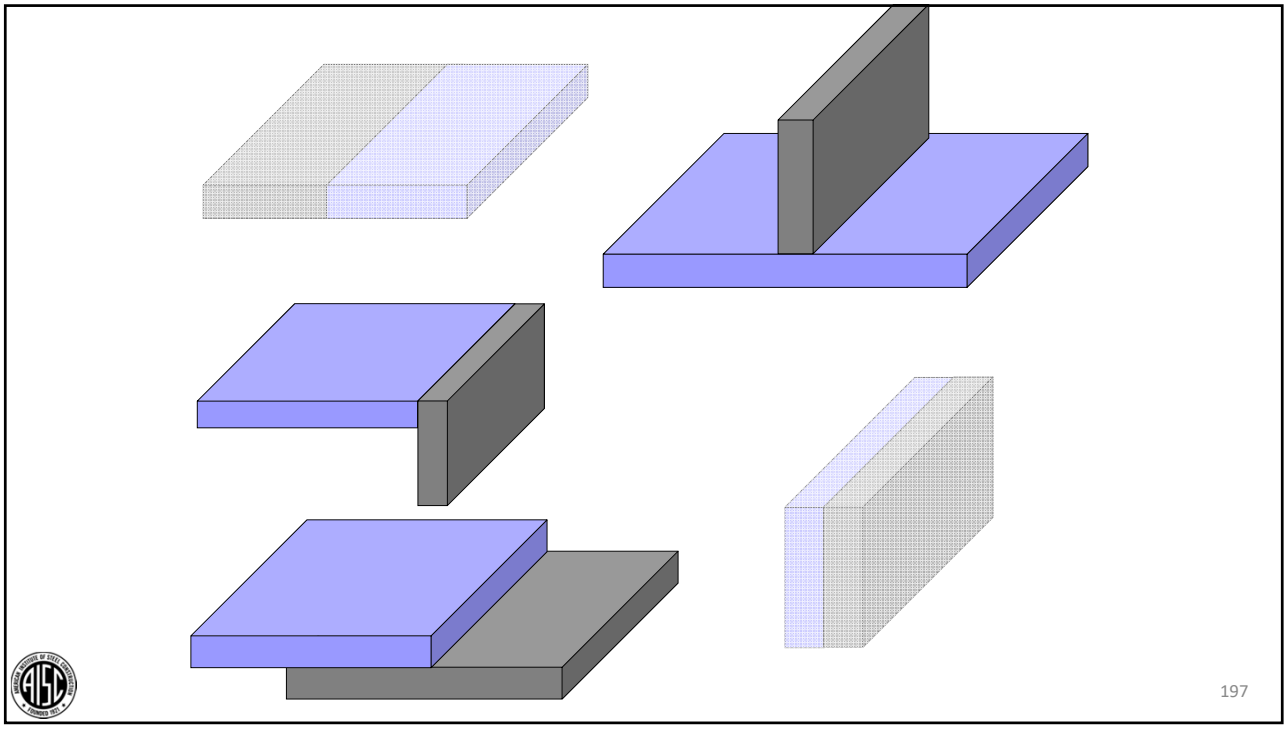


195

Fillet Welds

- Applied to tee, corner, lap joints

196



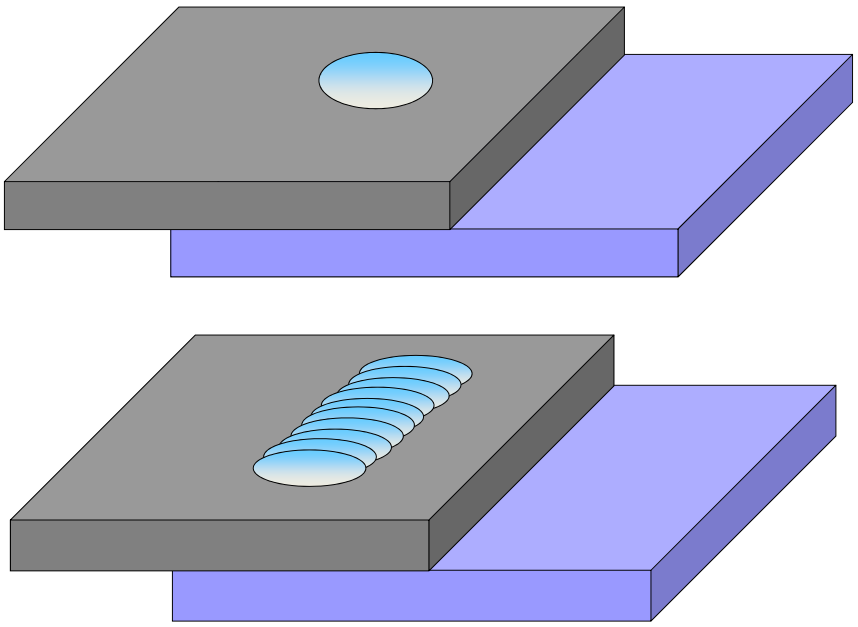
197

Fillet Welds

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

198

Plug and Slot Welds

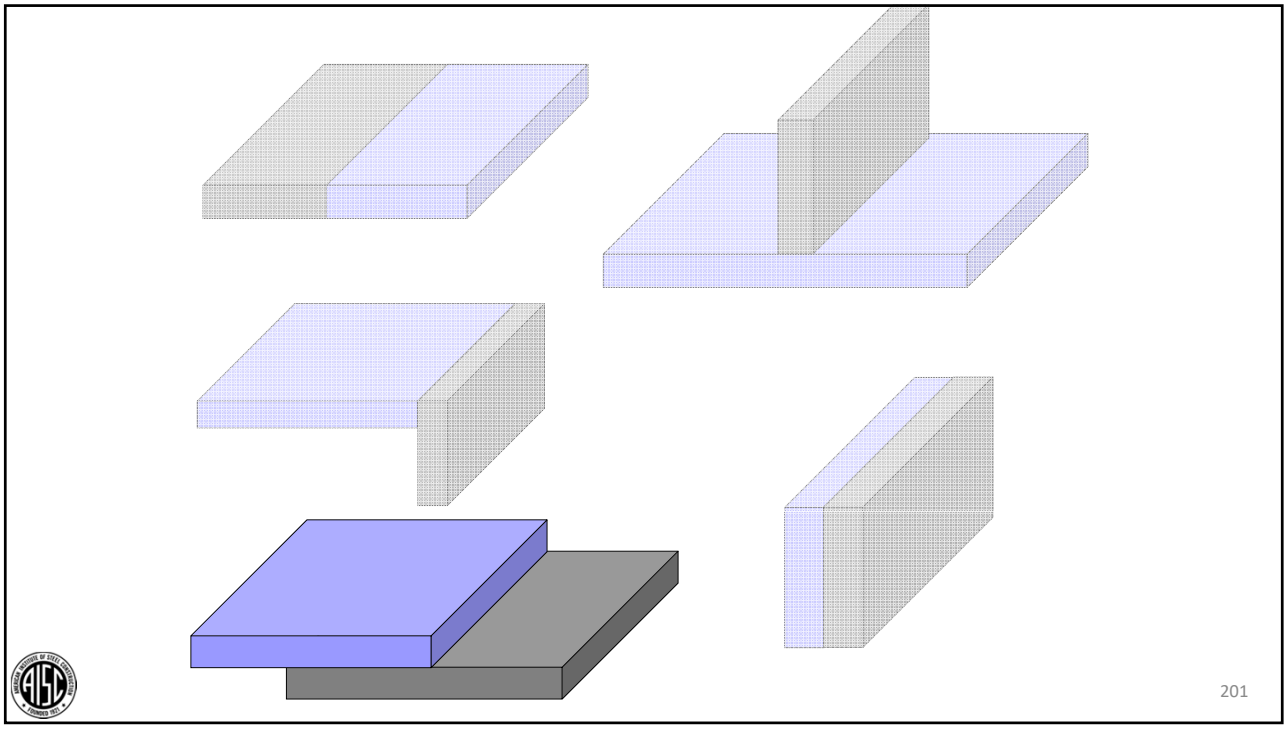


199

Plug and Slot Welds

- Applied to lap joints

200



201

Plug and Slot Welds

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

202

WELDED CONNECTION BASICS

Outline

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

Thank you!

AISC | Questions?

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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!

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205

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.

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206

8-Session Registrants

PDH Certificates

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

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207

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

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208

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.

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209

8-Session Registrants

Night School Resources

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

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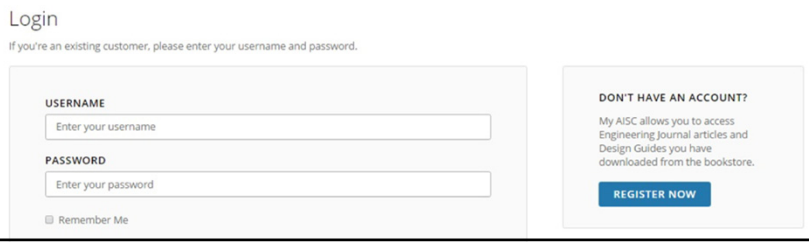
210

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



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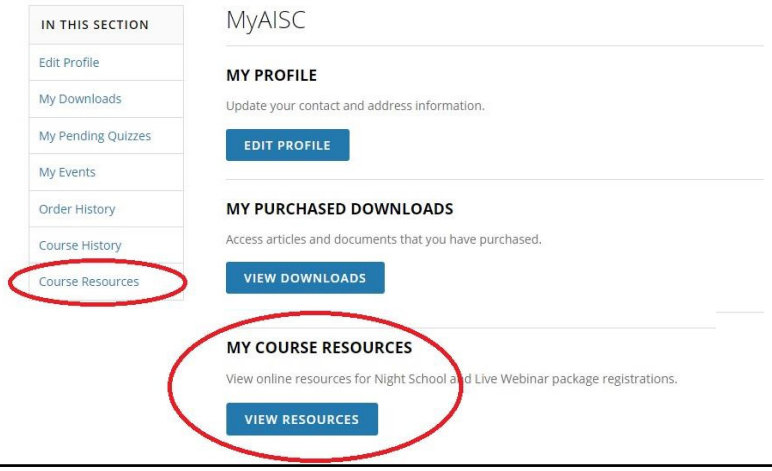
211

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



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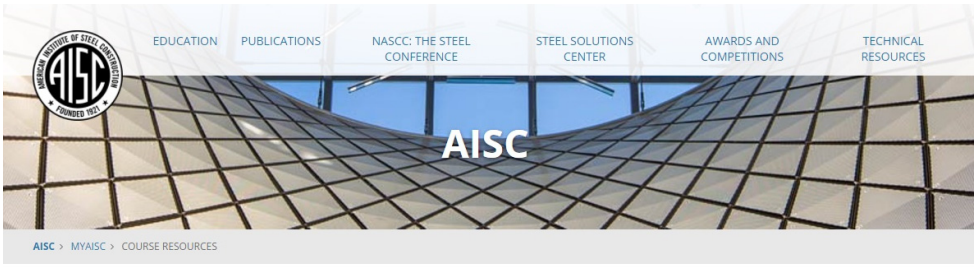
212

8-Session Registrants

Night School 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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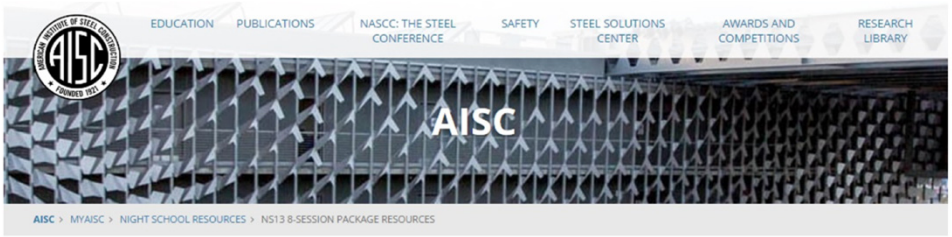
213

8-Session Registrants

Night School Resources



Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending

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214

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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215

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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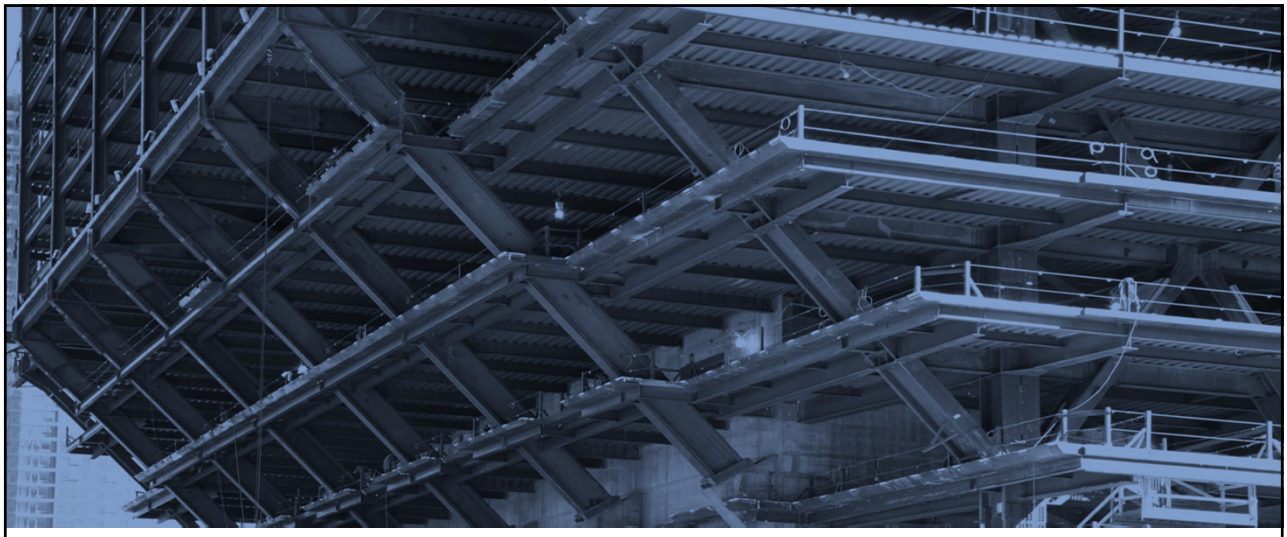
216



AISC | Thank you

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217