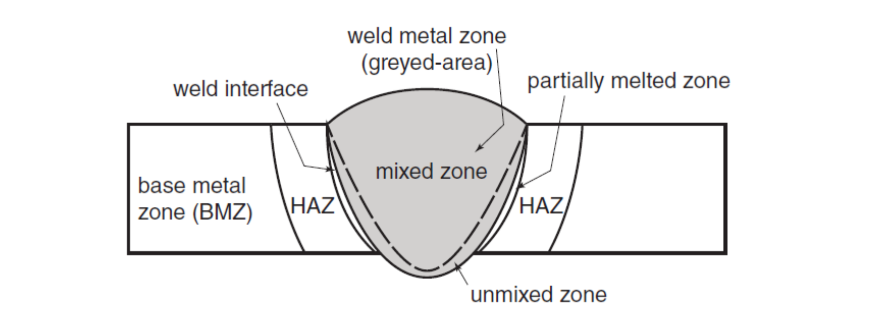
Welding Fundamentals CSA & ASME Section IX

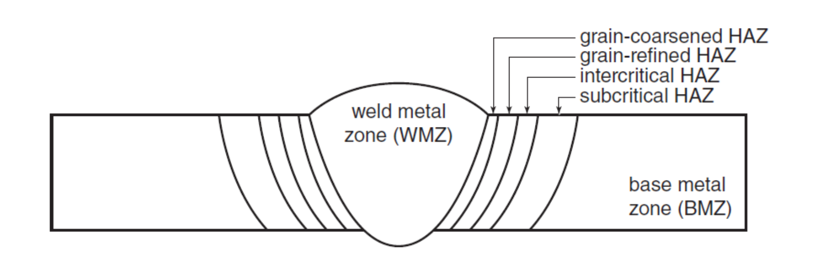
By: Gregory Lightheart, P.Eng.

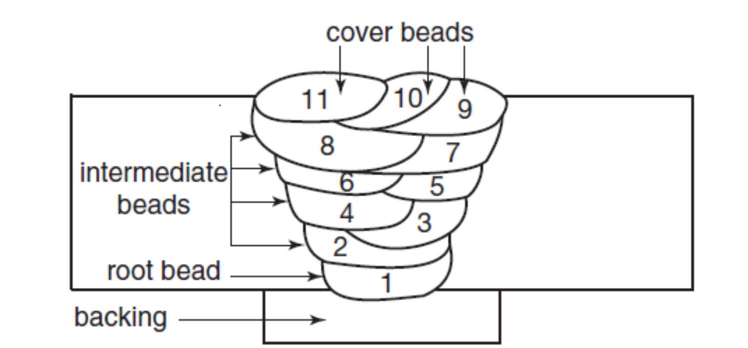
Agenda

- Overview
- Topics Covered
- How does welding apply to the midstream pipelines and oil and gas industry?
- Examples (WPS, PQR, WQR, Weld Details)
- Key Take Aways
- Wrap Up

Defining the Weld & Weld Metallurgy





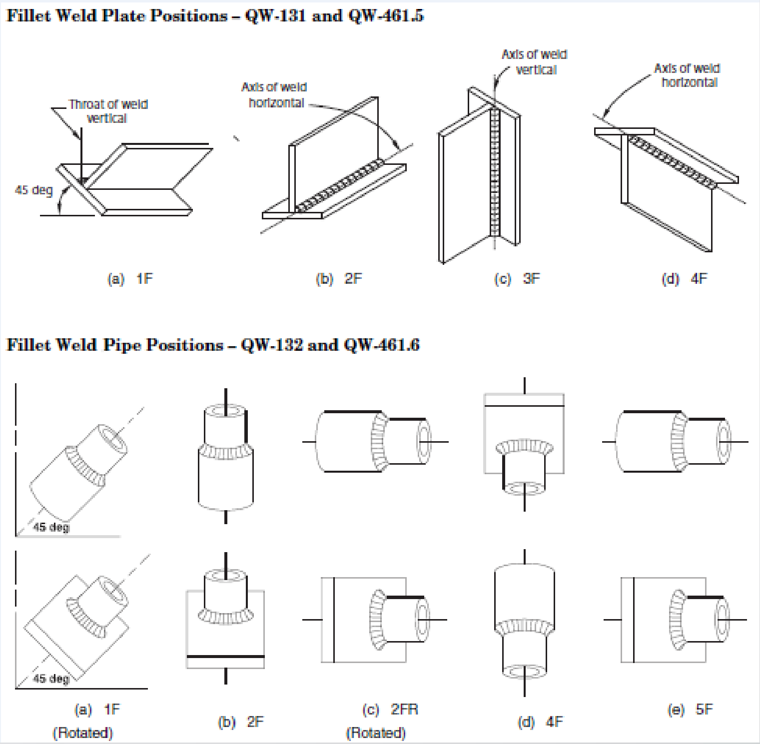


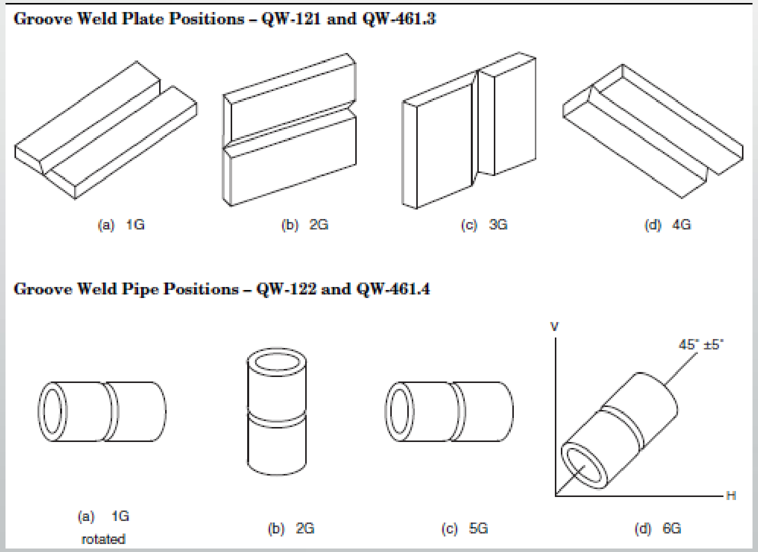
Weld Pass and Weld Bead

- Various Weld Zones:
  1. Weld Metal Zone
     - Mixed Zone
     - Un-Mixed Zone
  2. Weld Interface
  3. Partially Melted Zone
  4. Heat Affected Zone (HAZ)
     - Grain-Coarsened HAZ
     - Grain-Refined HAZ
     - Intercritical HAZ
     - Subcritical HAZ
  5. Base Metal Zone (BMZ)
- Weld Sequence:
  - Root Pass / Backing Weld
  - Single Hot Pass
  - Fill Passes
  - Cap / Cover Passes
  - Back Weld (if applicable)

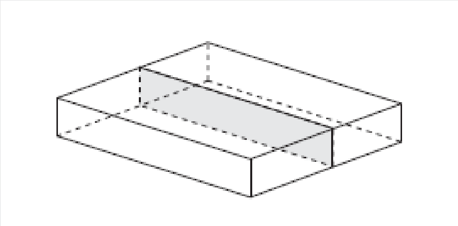
Weld Positions

- All welds can be simplified into a number of common weld positions
  - (eg. Flat, horizontal, vertical, overhead)
- When welding in vertical position, changing weld progression (vertical up/vertical down) is of particular importance – as opposed to other weld positions

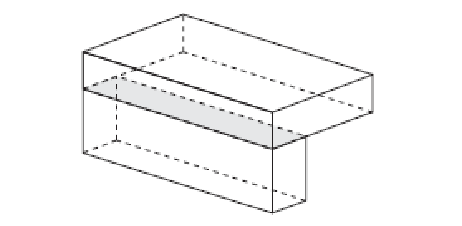




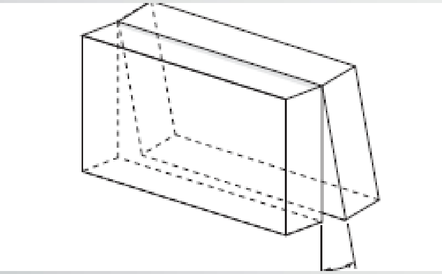
Weld Joint Types



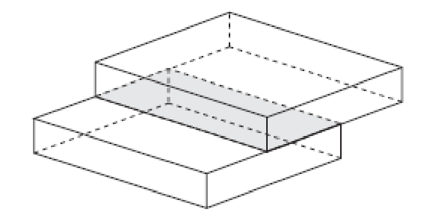
- BUTT JOINT



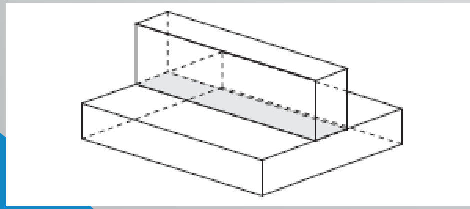
- CORNER JOINT



- EDGE JOINT



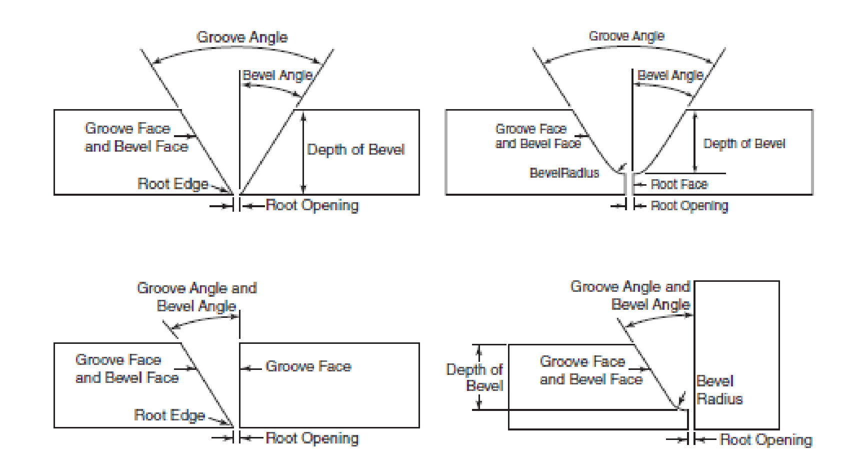
- LAP JOINT

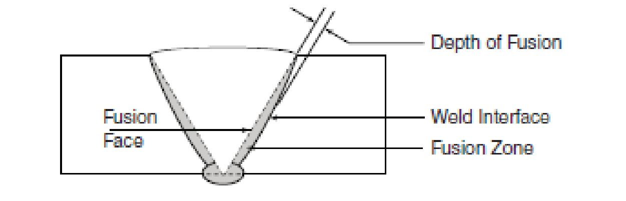


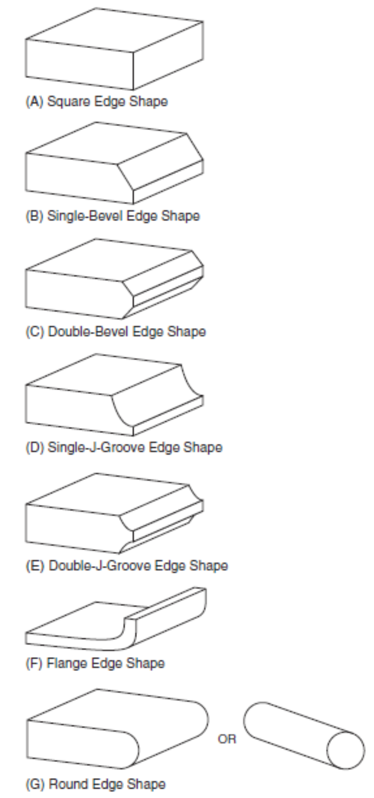
- T JOINT

- Selecting the correct joint type considers:
  - Minimum weld metal required to fill the joint
  - Weld process & available equipment
  - Accessibility & weld position
  - Plate thickness & preparation equipment available

Edge Preparation & Joint Design Geometry





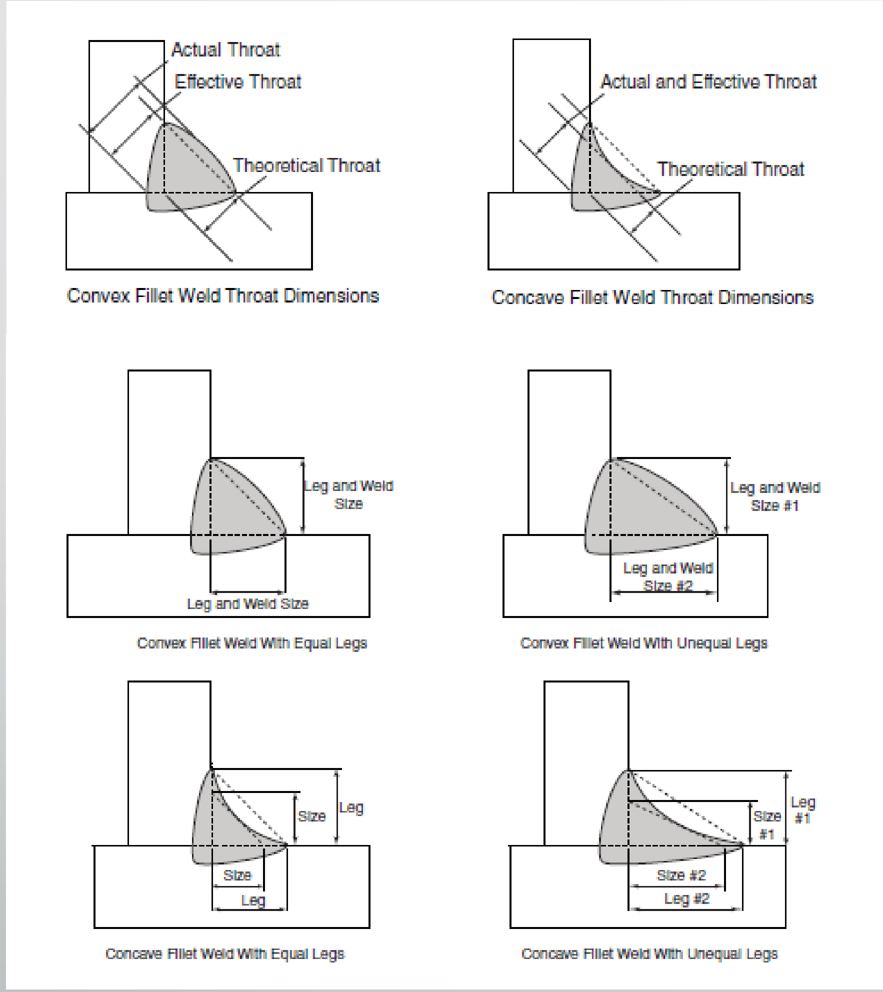


Common Edge Shapes

Standard welding terms to describe the type of weld joints

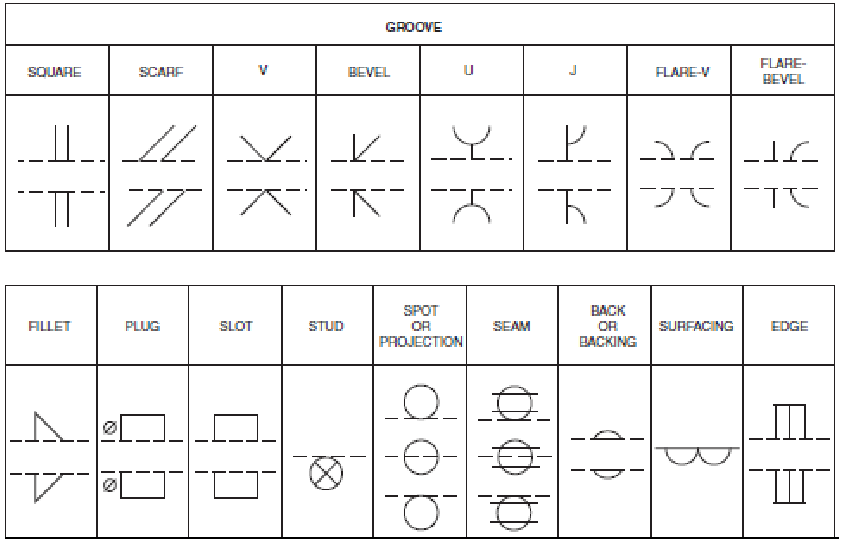
A well designed end preparation will increase overall weld quality, efficiency, and minimize costs.

Fillet Weld – Joint Geometry

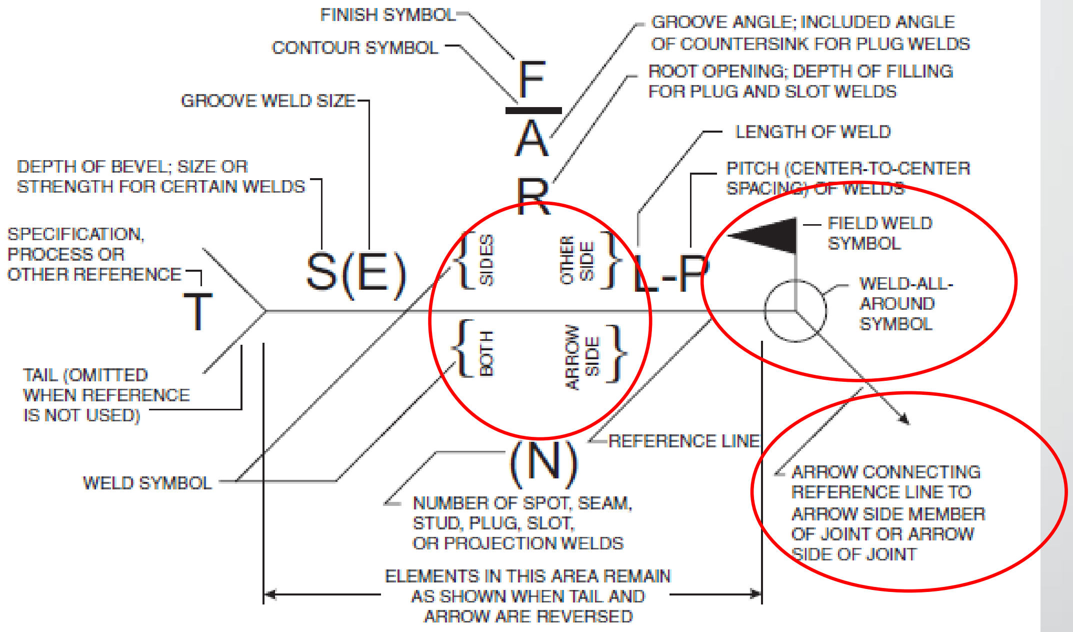


- Fillet welds are sized by their LEG length
- Can be slightly convex or concave
- Theoretical throat is used for design purposes

Weld Symbols

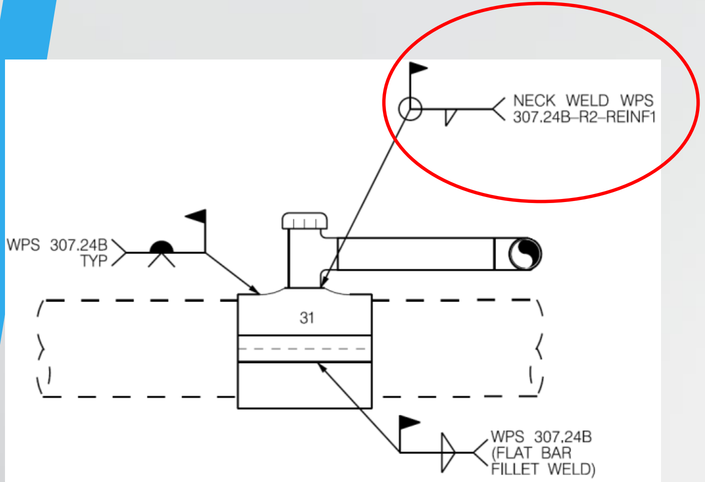


Basic Weld Symbols Used



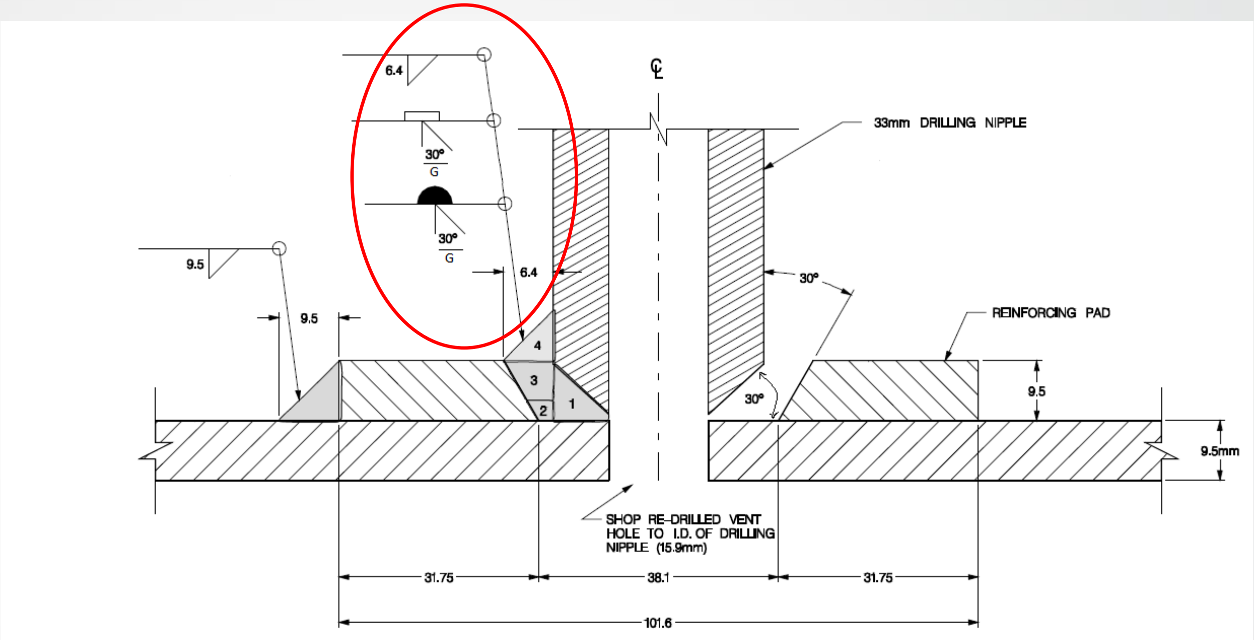
Vertical Line is always to the LEFT!

Examples - #1



Q1: Describe the Highlighted Weld

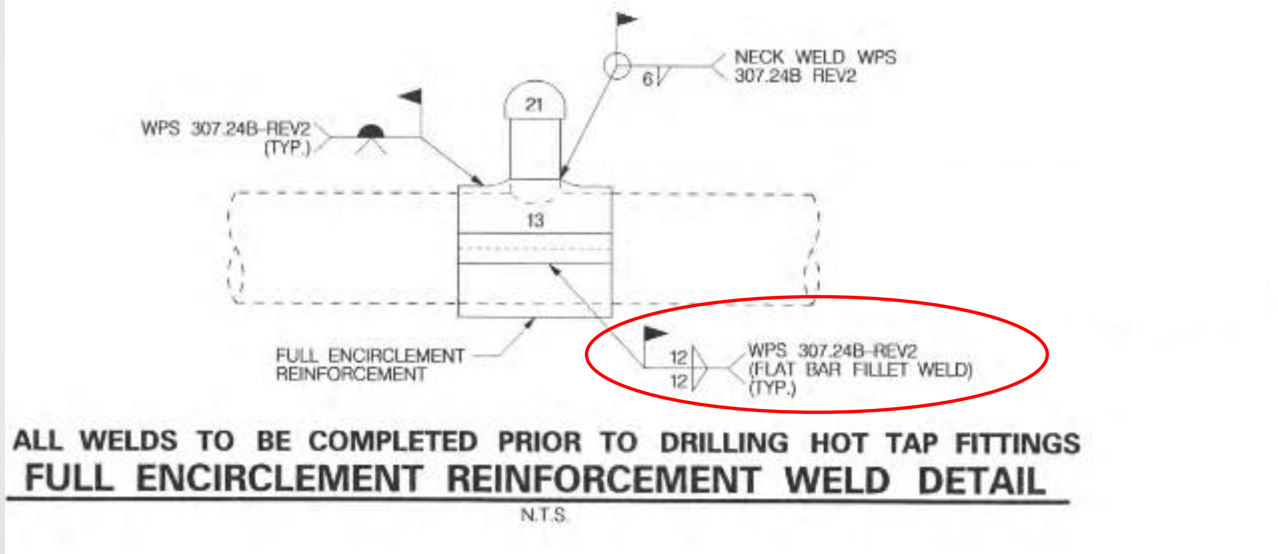
- -Single fillet weld on arrow side
- -Weld all-around
- -Field weld
- -Weld using WPS 307.24B-R2-REINF1



Q2: Describe the Highlighted Weld
(Hint: start with symbol closest to the arrow)

1. Single 30° bevel weld w/ melt-through, on arrow side, all-around, grind flat (weld item 1)
2. Single 30° bevel weld w/ backing, arrow side, all-around, grind flat (weld items 2 and 3)
3. Single 6.4 mm leg length (size) fillet weld, arrow side, all around (weld item 4)

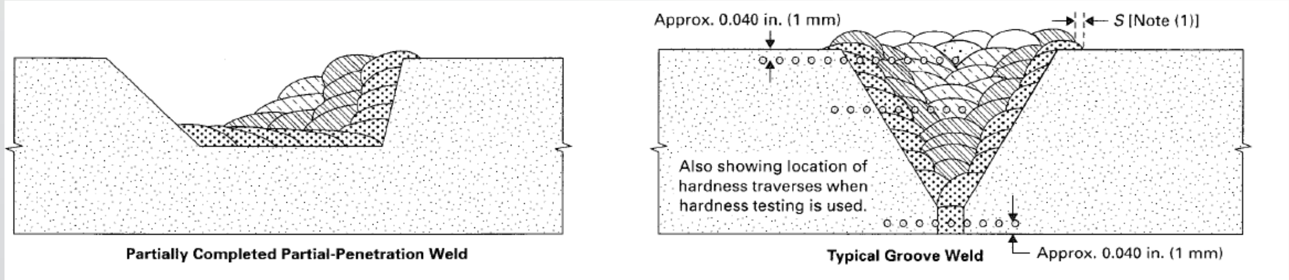
Examples #2

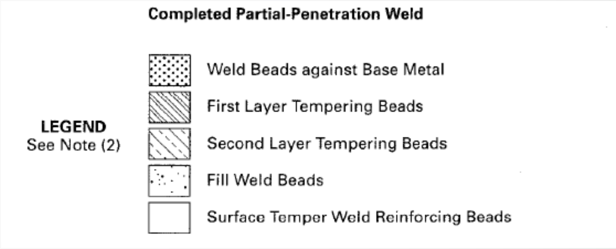


Q3: Describe the Highlighted Weld

- Fillet weld on both sides of bar (arrow side and other side)
- Leg length (size) is 12 mm
- Field weld
- Weld using WPS 307.24B-Rev2

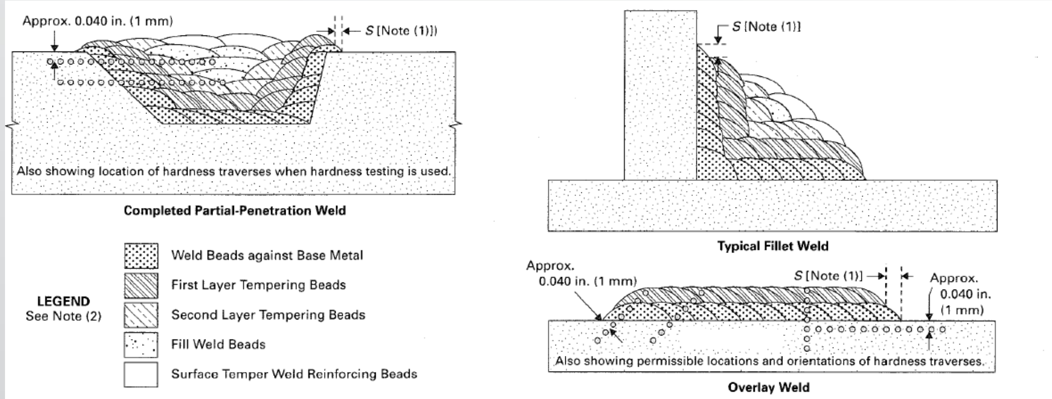
Temper Beading Welding





- Temper Bead Welding:
  - A weld consisting of weld beads placed such that each subsequent weld layer "tempers" the previously deposited weld metal layers
  - Purpose is to achieve desired metallurgical properties of weld metal and heat affected zone

In-Service Welding Using Temper Bead



- Some common applications, such as in-service welding, may utilize Temper Bead Welding
- In-Service Welding Considerations:
  - Cooling Rate - pipe acts as an infinite heat sink, cooling rate becomes a concern
  - Heat Input - ensure no burn-through and maintain certain level of wall thickness in tact

$$Q\left[\frac{J}{in}\right] = \left(\frac{V[volt] * I[amps]}{v\ [travel\ speed, in/min]}\right) * \frac{60\ [sec]}{1\ [min]}$$

Simplified Heat Input Equation

Welding Processes & Cutting Processes

Fusion Weld Processes

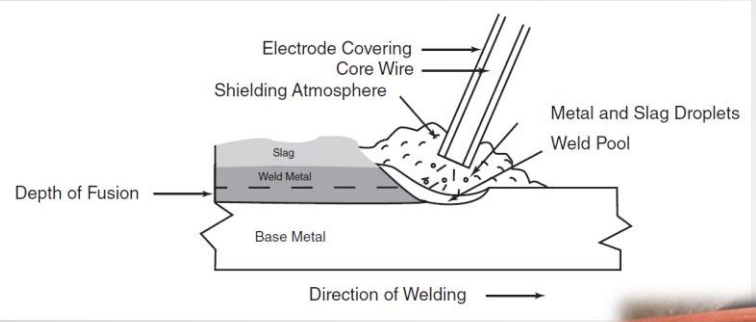
- Shielded Metal Arc Welding (SMAW)
  - Common in pipe joining, manual, referred to as “stick welding”, slag needs to be removed
- Gas Metal Arc Welding (GMAW) or Metal Inert Gas (MIG) Welding
  - Common in shop fabrication, usually semi-automated, wire feed system
- Flux Cored Arc Welding (FCAW)
  - Common in shop fabrication, usually semi-automated, wire feed system, flux turns to slag that needs to be removed
  - Note: Calgary Bow Tower framing was entirely welded using FCAW
- Gas Tungsten Arc Welding (GTAW) or TIG welding
  - Common for welding root pass due to higher precision and control of weld pool, and other welding parameters
- Submerged Arc Welding (SAW)
  - Common in pipe manufacture, mostly entirely automated with a weld operator not a welder
  - Usually in flat (1-G) position as flux needs to sit in weld joint as the longitudinal weld
  - For shop welding using SAW the pipe is rolled while machine stays in position

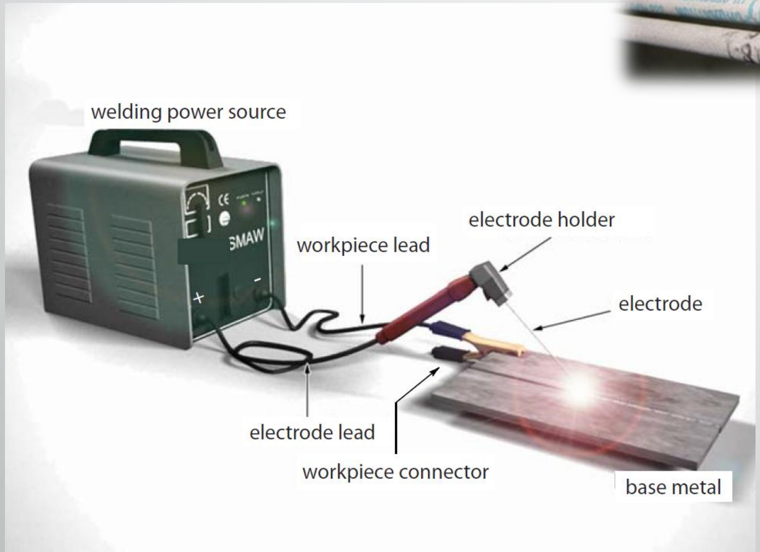
Highlighted processes discussed on next slides

Cutting Processes

- Oxygen Cutting (OC)
- Arc Cutting (AC)

Shielded Metal Arc Welding (SMAW)

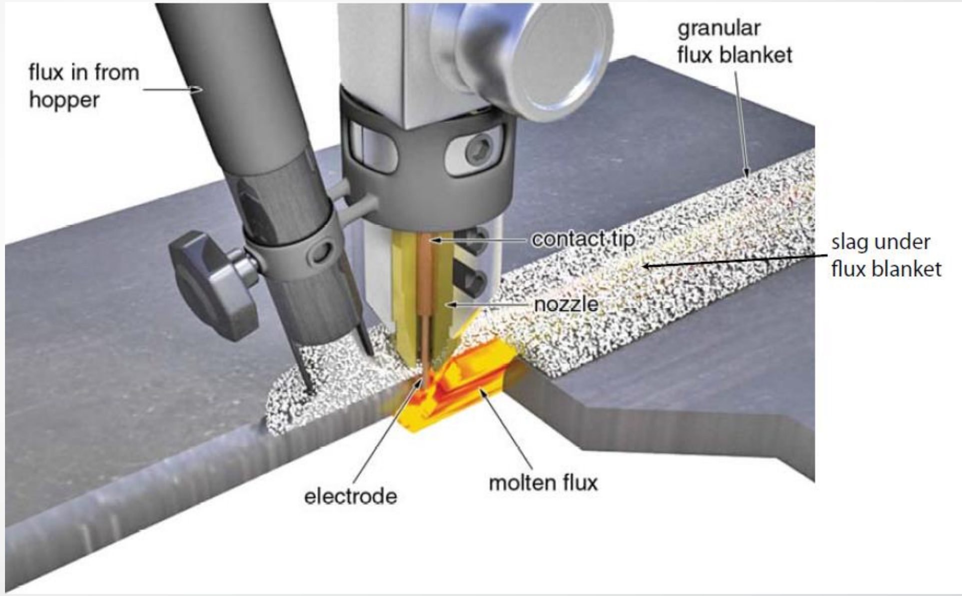




- **Manual Weld Process**
- **Welding electrode contains filler metal core and flux exterior**
- **Consumed electrode produces weld metal, protective slag, and shielding atmosphere**
- **Purpose of flux is to remove impurities from weld pool, provide inert shielding gas, and slag continues to protect weld metal until hardened and physically removed**

Submerged Arc Welding (SAW)

- Automatic / Mechanized Weld Process
- Uses granular flux fed through a hopper
- Weld arc is ‘submerged’ under the granular flux
- Achieves the highest level of weld deposit rates out of any other process, highest productivity but limited to repeatable welds in the flat position



-Unused flux may be recycled
-Small amounts of slag often re-crushed and mixed with new flux before being used

Non-Destructive Testing (NDT)

- Visual Testing (VT)
- Magnetic Particle Testing (MT)
- Liquid Penetrant Testing (PT)
- Ultrasonic Testing (UT)
- Radiographic Testing (RT)
  - Commonly called X-Ray though Gamma-Ray is more often utilized

Weld Imperfections vs. NDT Method

Imperfection vs Type of NDT Method

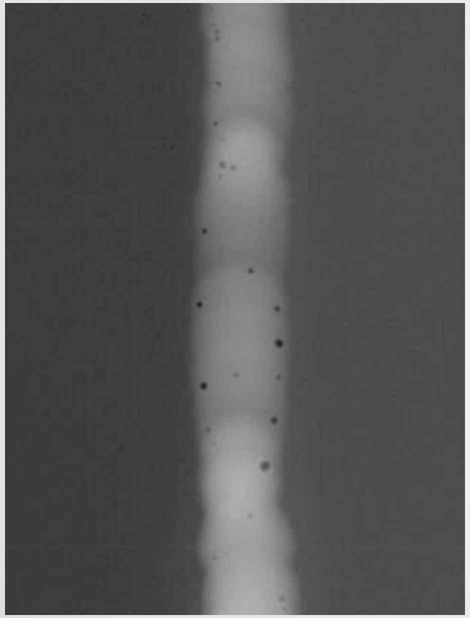
	Surface [Note (1)]		Sub-surf. [Note (2)]		Volumetric [Note (3)]				
	VT	PT	MT	ET	RT	UTA	UTS	AE	UTT
Welding Imperfections									
Burn Through	◉	. . .	. . .	. . .	◉	⊛	. . .	. . .	◎
Cracks	◎	◉	◉	⊛	⊛	◉	◎	◉	. . .
Excessive/Inadequate Reinforcement	◉	. . .	. . .	. . .	◉	⊛	◎	. . .	◎
Inclusions (Slag/Tungsten)	. . .	. . .	⊛	⊛	◉	⊛	◎	◎	. . .
Incomplete Fusion	⊛	. . .	⊛	⊛	⊛	◉	⊛	⊛	. . .
Incomplete Penetration	⊛	◉	◉	⊛	◉	◉	⊛	⊛	. . .
Misalignment	◉	. . .	. . .	. . .	◉	⊛	. . .	. . .	. . .
Overlap	⊛	◉	◉	◎	. . .	◎	. . .	. . .	. . .
Porosity	◉	◉	◎	. . .	◉	⊛	◎	◎	. . .
Root Concavity	◉	. . .	. . .	. . .	◉	⊛	◎	◎	◎
Undercut	◉	⊛	⊛	◎	◉	⊛	◎	◎	. . .

Legend:

AE — Acoustic Emission
ET — Electromagnetic (Eddy Current)
MT — Magnetic Particle
PT — Liquid Penetrant
RT — Radiography
UTA — Ultrasonic Angle Beam
UTS — Ultrasonic Straight Beam
UTT — Ultrasonic Thickness Measurements
VT — Visual

◉ — All or most standard techniques will detect this imperfection under all or most conditions.
⊛ — One or more standard technique(s) will detect this imperfection under certain conditions.
◎ — Special techniques, conditions, and/or personnel qualifications are required to detect this imperfection.

What Type of Weld Defect?



Q1

POROSITY

Q2

SLAG INCLUSIONS

WPS / PQR / WPQR

- Weld Procedure Specification (WPS)
  - Defines weld variables & parameters to adhere to during welding
  - Some variables (called non-essential variables) may be changed by the company without re-qualification (as defined in ASME BPVC Section IX), but the changes MUST be documented and approved by the company based on good engineering judgment (e.g. straight vs. weaving weld progression)

RECIPE

- Procedure Qualification Record (PQR)
  - Record qualifying a WPS
  - Includes non-destructive and destructive test results (e.g. guided bend test, tensile)

TASTE TEST

- Welder Performance Qualification Record (WPQR)
  - Record qualifying of a welder performing a certain weld procedure to specification

ANOTHER CHEF'S ABILITY TO REPLICATE THE SAME RECIPE

WPS/PQR/WPQR

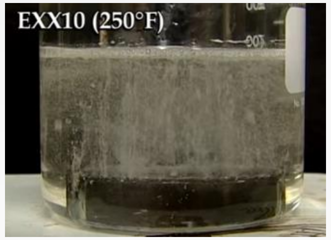
Review WPS Examples

Industry Transition & Lessons Learned

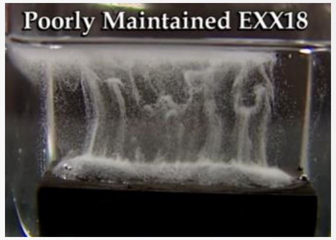
<u>Pipelines Continuous Improvement</u>

- Assess value for increased use of low-hydrogen electrodes to reduce probability of HIC (Hydrogen Induced Cracking)
- Evaluate NDT methods and select best NDT methods based on imperfection modes (UT / RT)
- Evaluate chosen weld process to be used based on weld quality, efficiency, and costs. (SMAW vs GMAW, etc.)

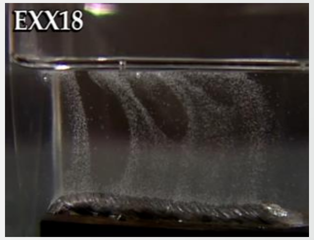
Diffused Hydrogen Comparison



Standard Electrode



Low-Hydrogen Electrode (poorly stored)



Low-Hydrogen Electrode

NDT is critical – Don't Do THIS!

References

- CASTI “Welding Fundamentals” Course Handbook
- ASME BPVC - Section V “Non-Destructive Examination”, 2010 Edition
- ASME BPVC - Section IX “Welding and Brazing Qualifications”, 2010 Edition

Interested in More?

Courses available:

- Program offered by ‘Codes and Standards Training Institute’ (CASTI) “Welding Fundamentals” & “ASME Section IX”
- Targeted towards: Engineers, QA/QC Personnel, Inspectors, Welders, and Project Managers
- Beneficial for people with various degrees of welding knowledge and experience
- Paths to become qualified **W47.1 Weld Engineer** and **ABSA Weld Examiner** by trade

https://www.absa.ca/examination-and-certification/welders-welding-examiners/welding-examiner-welding-examiner-in-training/welding-examiner/

QUESTIONS?