# *Laser Beam Welded*

# *Vs*

# *Gas Tungsten Arc Welded*

# *Tubing*

# Commonly Used Welding Methods

## Fusion

- Shielded Metal Arc (SMAW / Stick Electrode)
- Submerged Arc
- Metal Inert Gas (MIG)
- Gas Tungsten Arc (TIG)
- Plasma Arc (PAW)
- Laser Beam (LBW)
- Electron Beam (EBW)

## Solid State

- High Frequency (HFW)
- Electric Resistance (ERW)
  - Spot
- Friction
- Ultrasonic
- Explosive

Brazing (not a welding process)

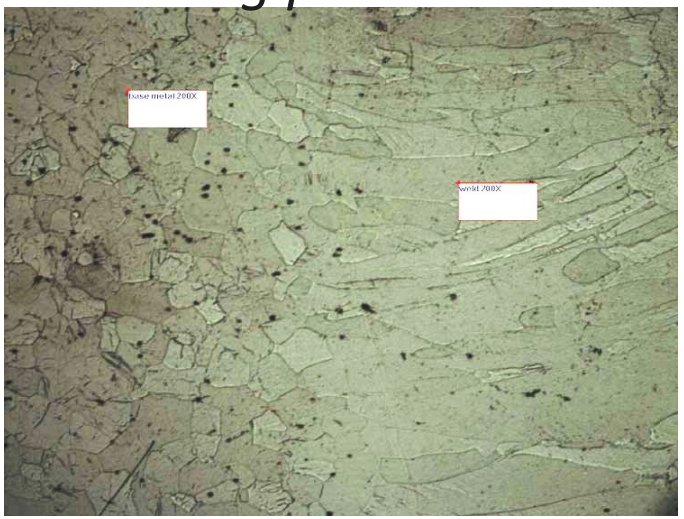
# Commonly Used Welding Methods

## Fusion Welding:

"The melting together of filler metal and base metal (substrate), or of base metal only which results in coalescence" *(ANSI / AWS A3. 0 Standard Welding Terms and Definitions)*

*Think of fusion welding as miniature, continuous casting*

- *Melt metal to a liquid physical state*
- *Mixing of elements from both contributing pieces*
- *Alloy segregation*
- *Columnar grain structure*



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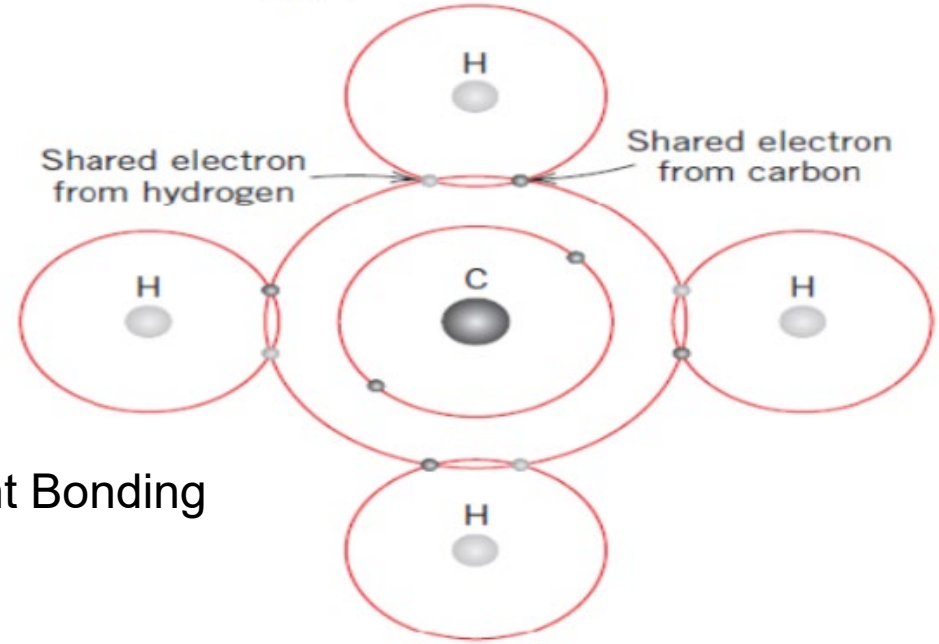
LBW v GTAW

# Commonly Used Welding Methods

## Fusion Welding:

Fusion occurs when atomic bonding of the metals occurs. The molecules of each separate piece of metal (and the filler metal) bond together when you have 1) atomic cleanliness and 2) atomic closeness . This occurs with welding such that the atoms of each piece of metal bond together with shared electrons to become one solid or homogeneous piece of metal.

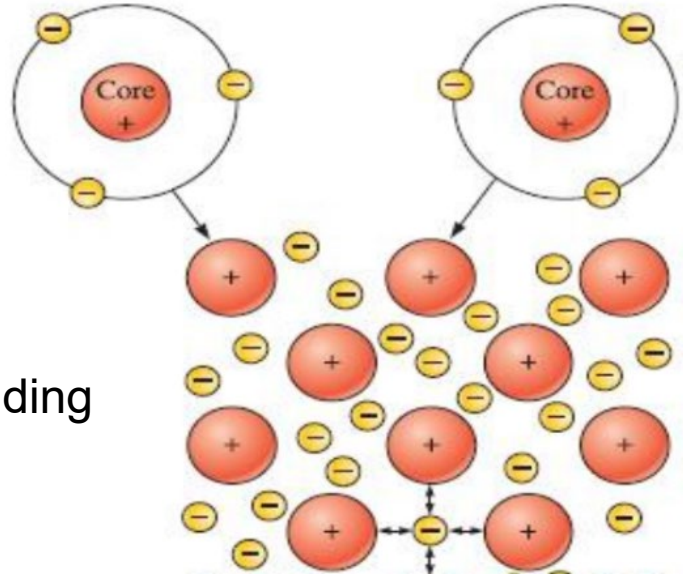



Covalent Bonding

# Commonly Used Welding Methods

## Solid State Welding:

Solid-state welding refers to the joining of similar and dissimilar materials below their melting temperature. In this process, the weld formation occurs due to the intermolecular diffusion in which the interface molecules of workpieces flow from higher concentration regions to lower concentration regions due to applied pressure. Solid-state welding and its applications: A methodological review; *Hemika Jadav Badavath; Somnath Chattopadhyay; Sachindra Shankar*

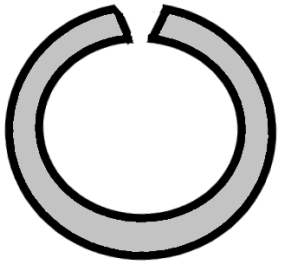



Metallic Bonding

# Commonly Used Welding Methods

## GTAW = Gas Tungsten Arc Welding

- Uses an electric arc with a non-consumable tungsten electrode
- Is a low energy density process - conductive
- May use filler metal, but most austenitic stainless steel tubes, specifications require autogenous welds (no filler metal allowed)
- Comparatively slow travel / production speeds
  - 1 – 12 ft/min
- Joint typically V-shaped, may be tight butt joint for thinner steel (< 1 mm)

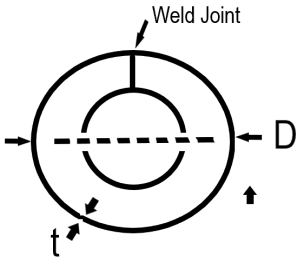


# Commonly Used Welding Methods

## LBW = Laser Beam Welding

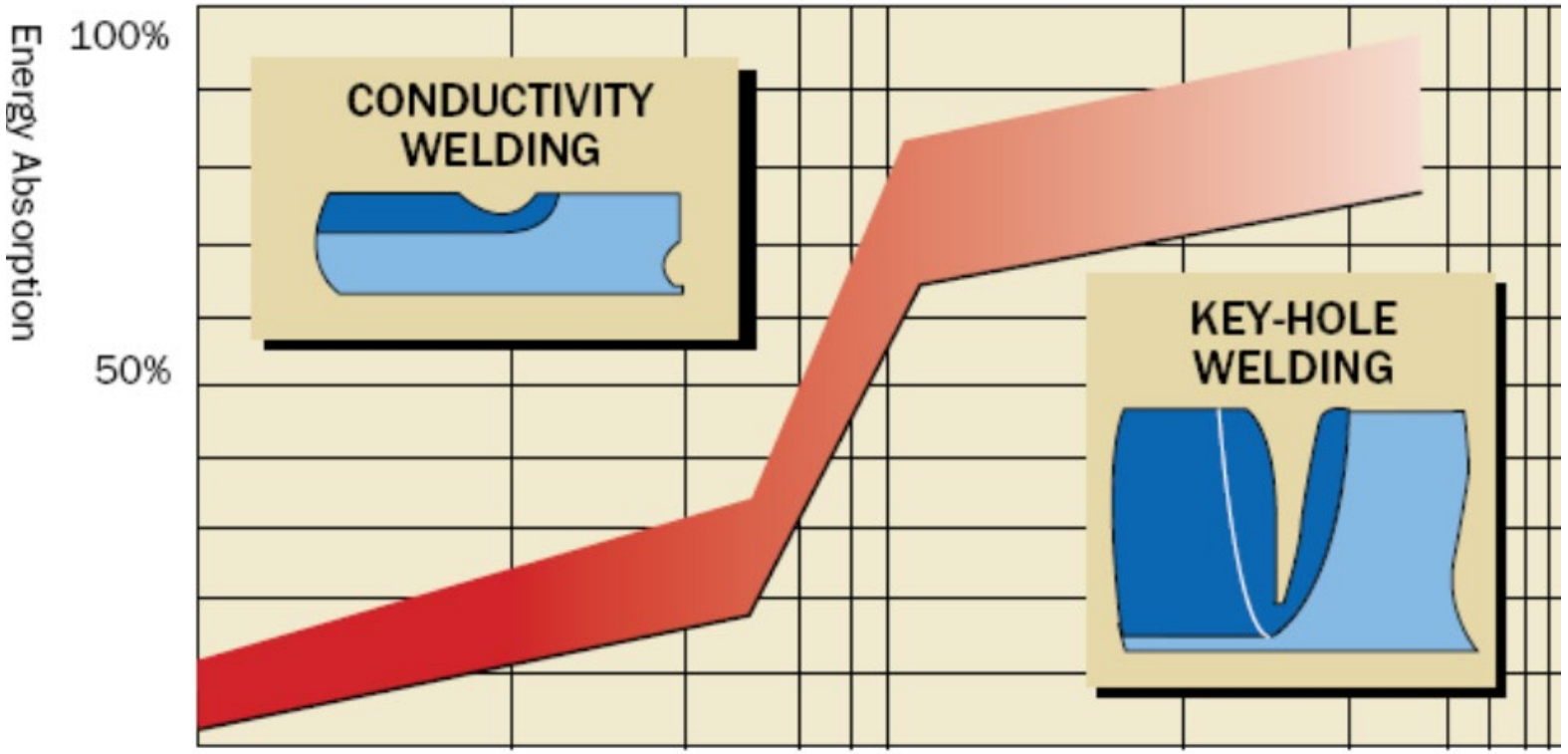
- Uses only a focused beam of coherent light
- Is a high energy density process – key hole
- May use filler metal, but most austenitic stainless steel tubes, specifications require autogenous welds (no filler metal allowed)
- Faster travel / production speeds – 5-30 ft/min
- Narrow weld bead + HAZ – hour glass

1 mm 1 mm each side




- Full Penetration <u>not</u> subject minor chemical element variations (S)
- Tube seam welds require post-weld solution anneal heat treat

# Weld Penetration Profiles




Low energy density /
High total energy input

High energy density /
Low total energy input

# Weld Penetration Profiles

- LBW
  - Extreme high energy causes metal to vaporize, molten metal fills in behind & solidifies
    - Low total energy
      - Heat energy not conducted away from joint >>
      - Rapid solidification >>
      - Finer grain Size >>
      - Improved Ductility + Corrosion Resistance
  - Smaller melt volume >> less weld slag + inclusions

# Weld Penetration Profiles

- GTAW
  - High total energy
    - Heat energy is conducted away from joint

      Slower solidification >>

      Larger solidification grain Size >>

      Longer diffusion distances for homogenization require longer heat treat

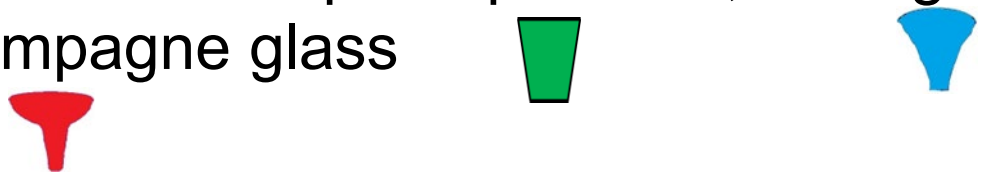
      Reduced Ductility + Corrosion Resistance

      Larger melt volume >> more weld slag + inclusions

# Commonly Used Welding Methods

## GTAW

- Large weld bead + Heat Affected Zone (HAZ)
  - 1.5 mm root/3 mm face  2 – 3 mm each side
- Weld bead shape trapezoidal, wine glass or champagne glass

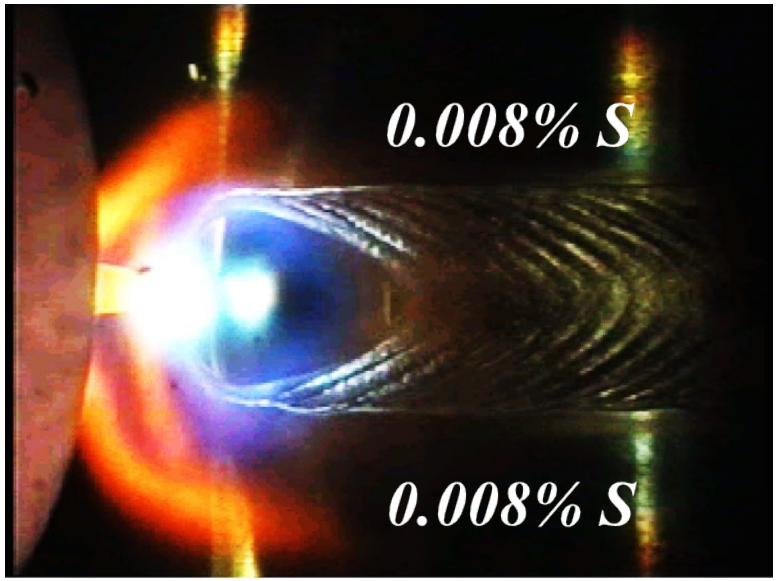


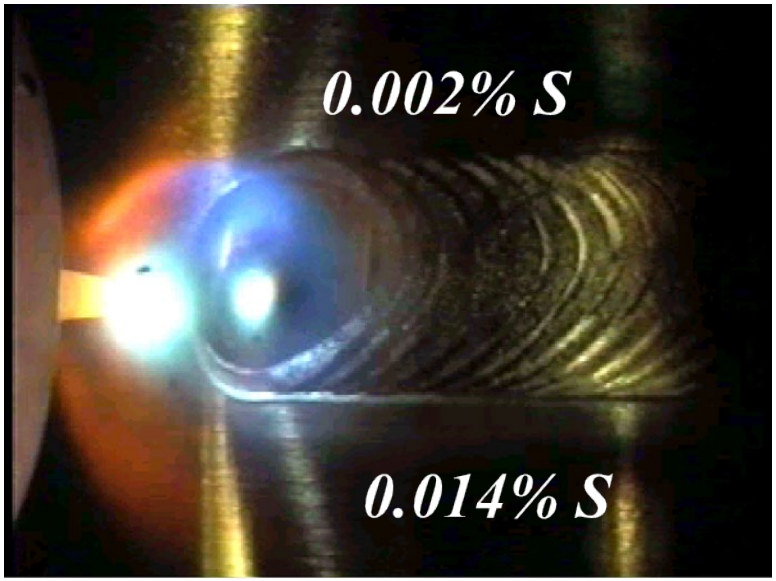
- Penetration is subject minor chemical element variations (S)

S ≥ 0.005%  S= 0.003-0.008%  S ≤ 0.003%

- In tube seam welds, requires post-weld cold work + solution anneal heat treat

# Commonly Used Welding Methods




Similar S content

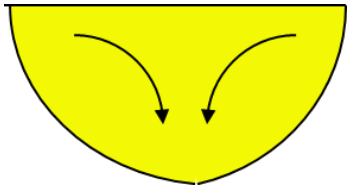
Puddle centered on Joint

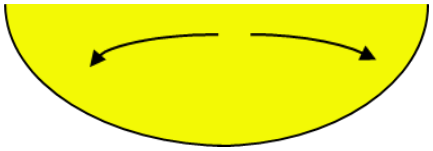
Full Penetration

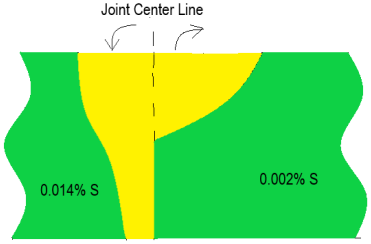
Mis-matched S content

Weld pool shifted to low S side

Penetration ???





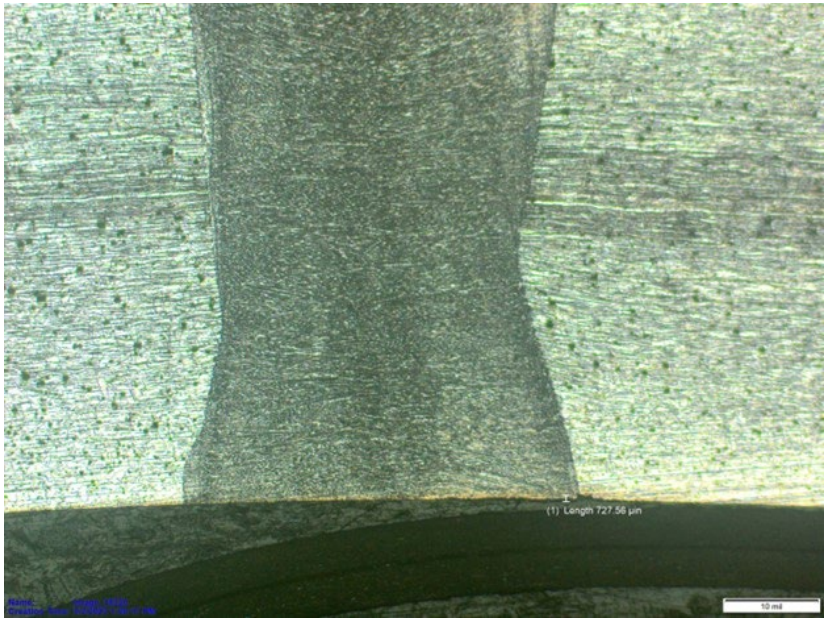



UNITED INDUSTRIES

**LBW v GTAW**

*Photos of automatic orbital TIG welds by Arc Machines, Inc.*

# Weld Penetration Profiles

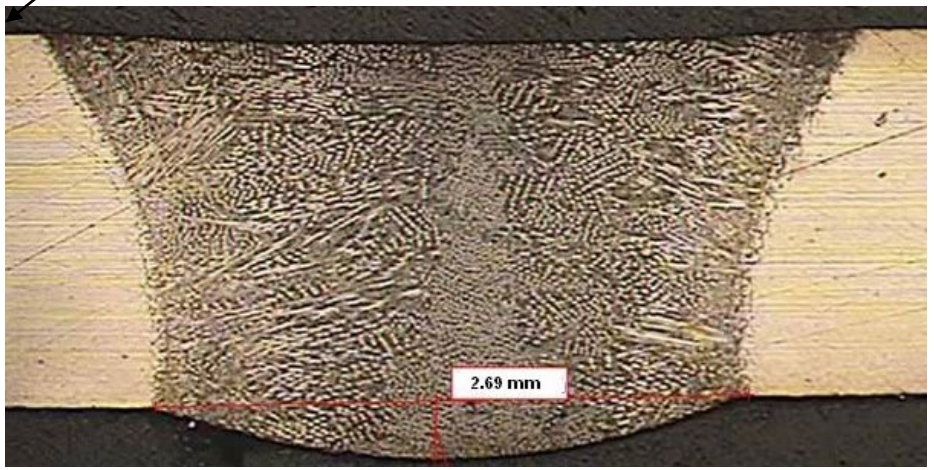


LBW

Weld root ≈ 0.040” (1 mm)

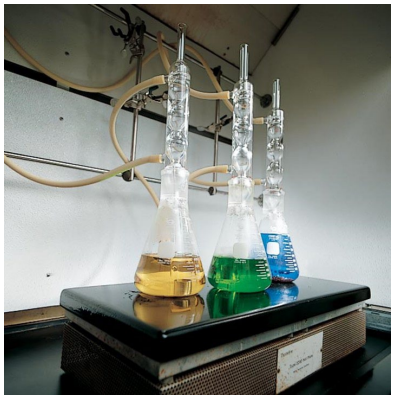
Scale bar = 0.010”

TIG

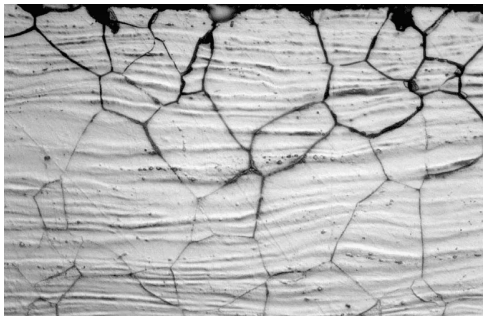



Weld root ≈ 0.108” (2.7 mm)

# Corrosion Tests

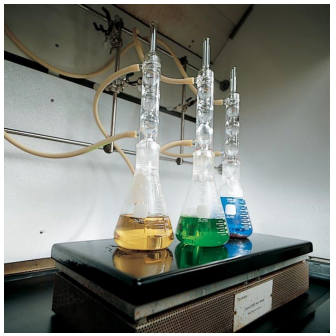


- *ASTM A249/S7 Weld Decay Test*
  - *Attacks retained delta ferrite*
  - *CR = ΔW / ΔB*
    - *Ideal = 1.0, Acceptance 1.25 Max*
  - *GTAW Results 1.05 -1.5 (Weld attacked more than base metal)*
  - *LBW Results 0.85 – 1.0 (Base metal attacked more than weld)*



- *ASTM A262-E Intergranular Corrosion*
  - *Evaluates ductility*
- *ASTM A380 Passivation Tests*
  - *Free Iron Test - Identifies iron contamination at surface*
  - *Water Break Test – Identifies hydrophobic contaminants*

# Corrosion Tests



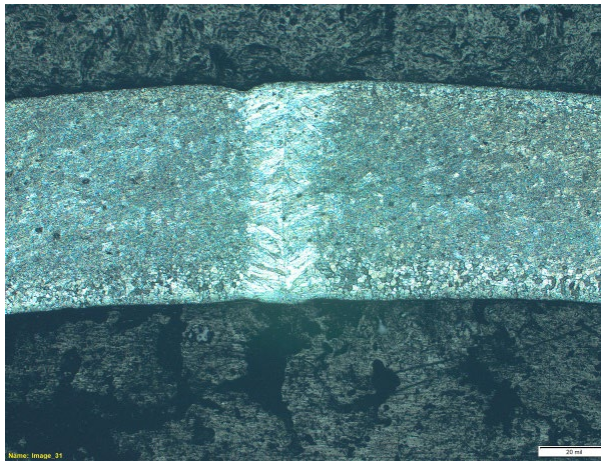
- *ASTM G28A & G28B Intergranular Corrosion*
  - *For Nickel alloys*
  - *GTAW – requires extensive secondary heat treat or filler metal*
  - *LBW Results - in-line anneal at weld mill passes*

- *ASTM G48 Pitting Resistance*
  - *For Superaustenitic Stainless (317L, 904L, 6XN)*
  - *GTAW – requires extensive secondary heat treat or filler metal*
  - *LBW Results - in-line anneal at weld mill passes*

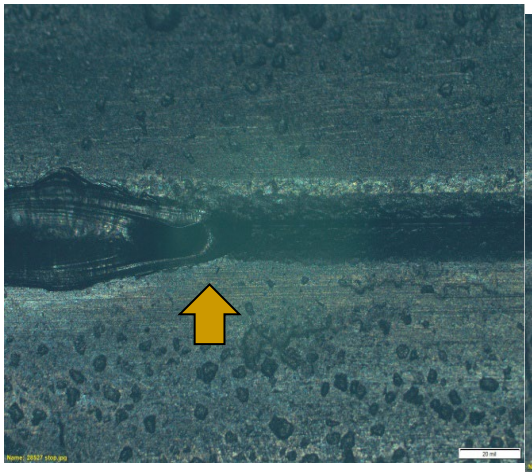
# Quality Tests

## *Tests Done Only in the United Lab*

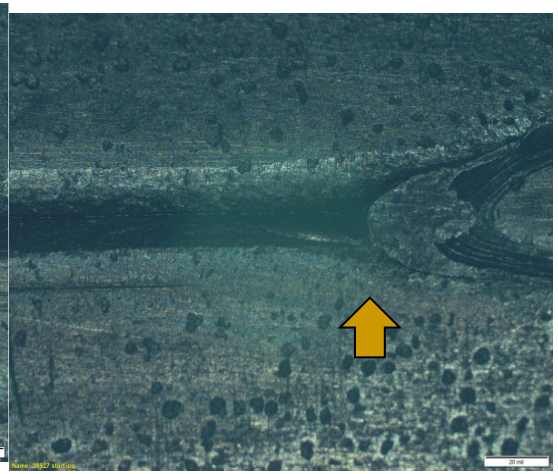
- *Photo-micrographs*
  - *Weld Stop-Start Micros*
    - *Done every shift*
    - *Check register of strip for proper alignment at point of welding*



*LBW Bead Shape*

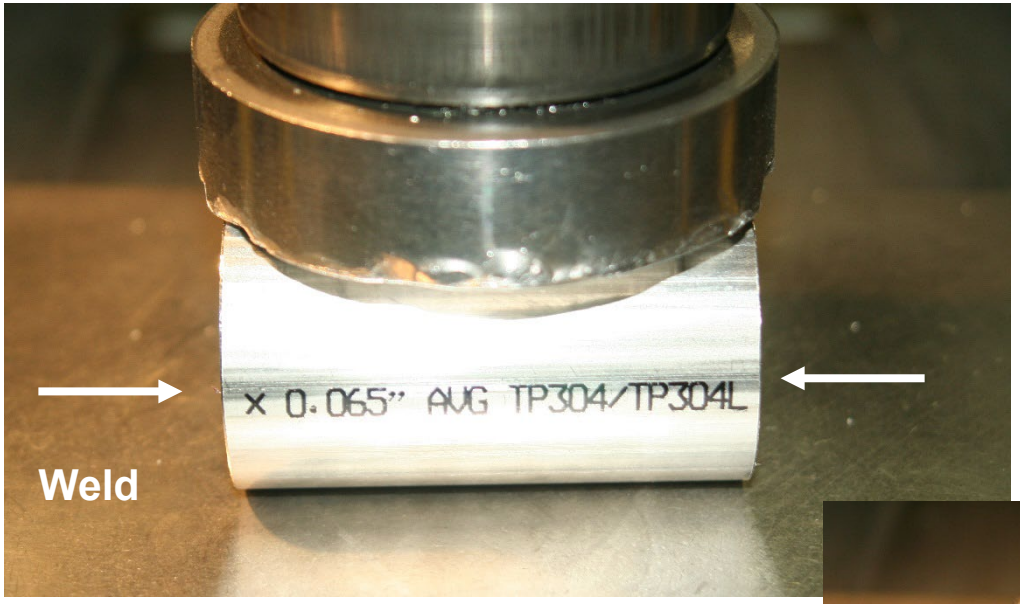


*Stop*



*Start*

# ASTM Required Mechanical Tests

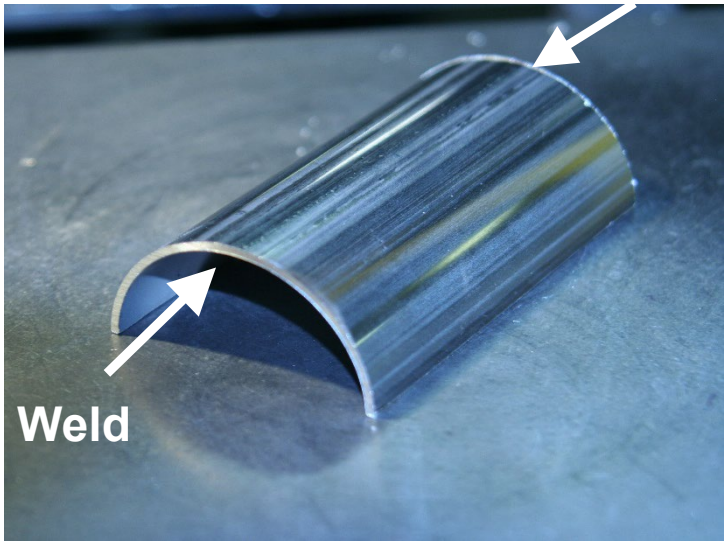


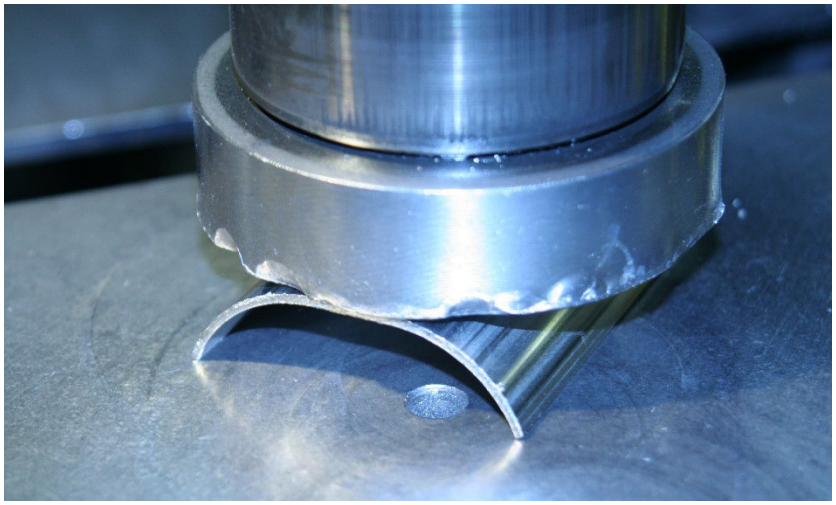
Flattening

(Face Bend)

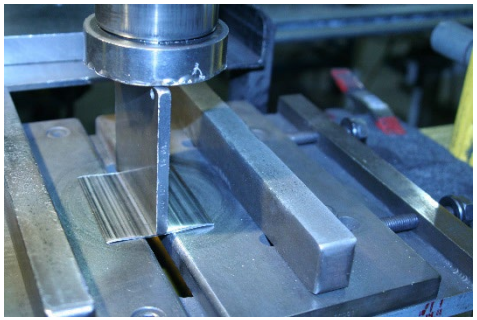
# ASTM Required Mechanical Tests

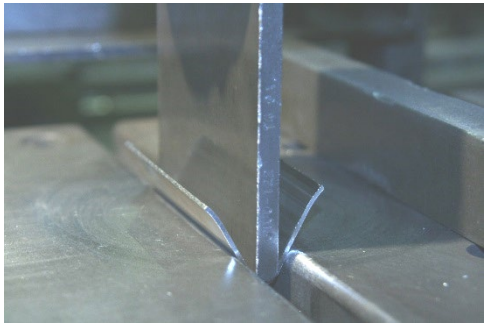
Reverse Flattening

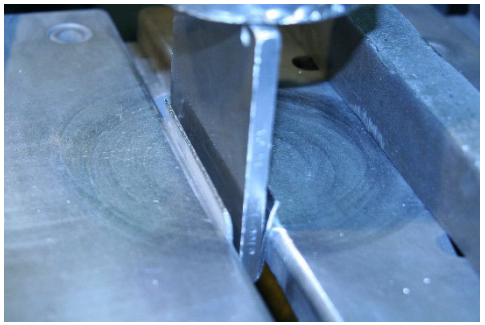


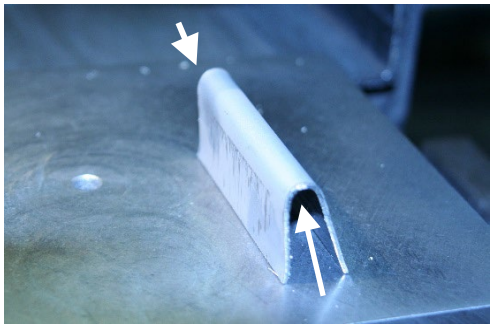



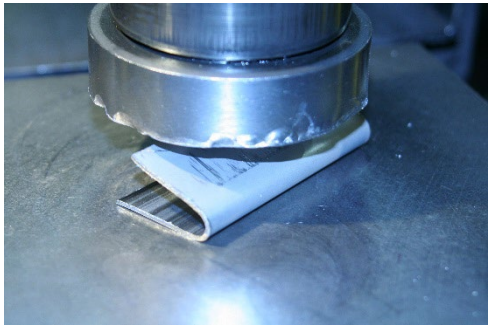
# ASTM Required Mechanical Tests











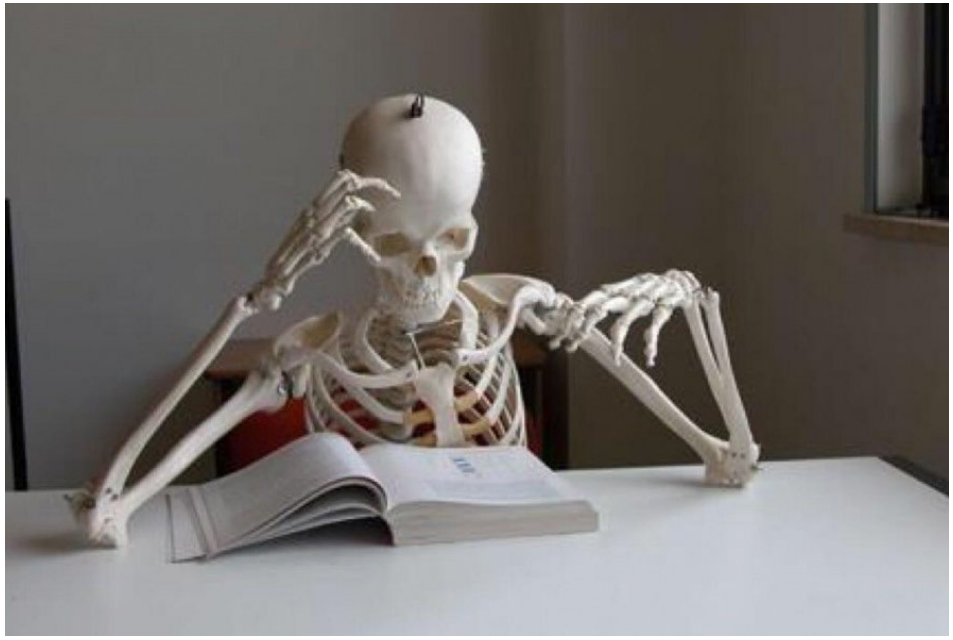
**Weld**

Reverse Bend Flattening (root bend)

# Tube Quality Control!

That's How United Makes Sure That You Are Getting The Finest Stainless Steel Tubes Available!

# Why buy GTAW tubes when you can get United's quality LBW tubes?



Still looking for the answer!

# Tube Quality Control ?

Contact Our Sales Dept if U have

?

Unitedindustries.com

608.365.8891