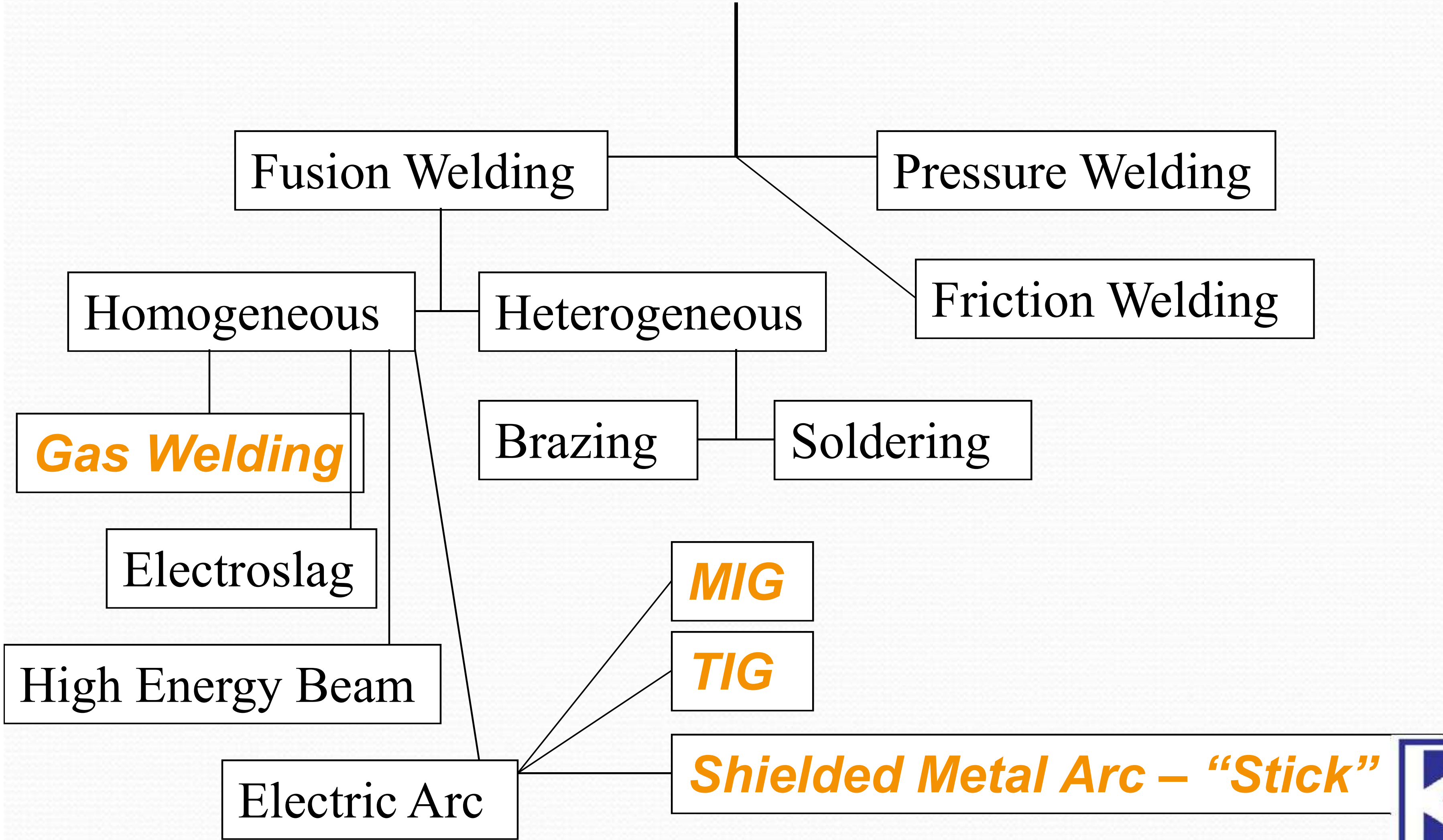
Welding Processes

- **EN358 – Ship Structures**

A Brief History of Welding

- Late 19th Century
  - Scientists/engineers apply advances in electricity to heat and/or join metals (Le Chatelier, Joule, etc.)
- Early 20th Century
  - Prior to WWI welding was not trusted as a method to join two metals due to crack issues
- 1930's and 40's
  - Industrial welding gains acceptance and is used extensively in the war effort to build tanks, aircraft, ships, etc.
- Modern Welding
  - the nuclear/space age helps bring welding from an art to a science

Types of Welding



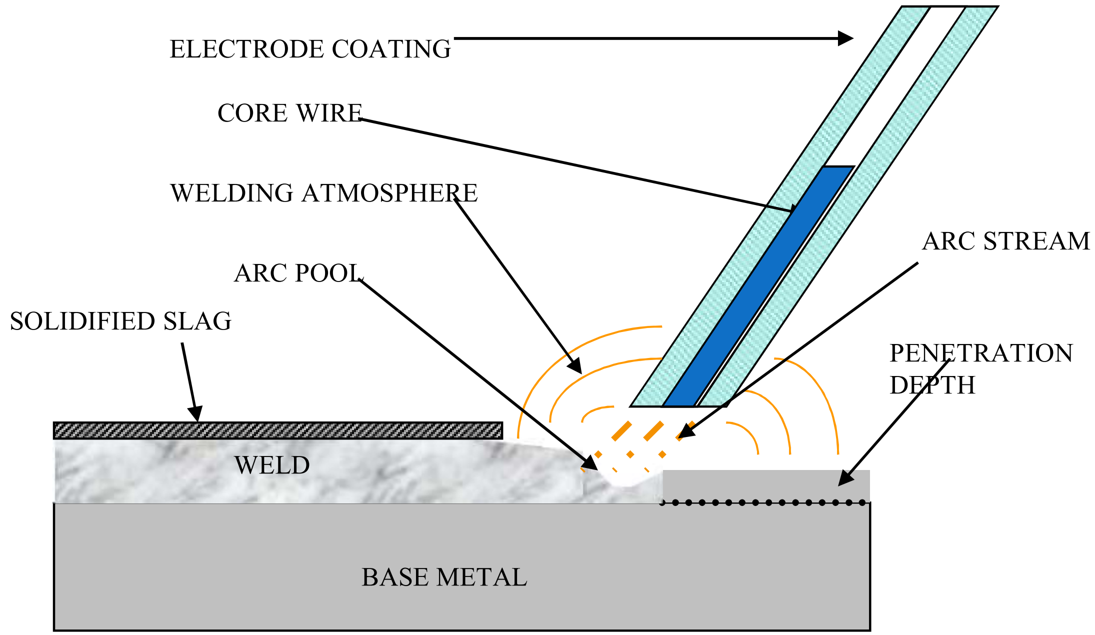
Weldability of a Metal

- Metallurgical Capacity
  - Parent metal will join with the weld metal without formation of deleterious constituents or alloys
- Mechanical Soundness
  - Joint will be free from discontinuities, gas porosity, shrinkage, slag, or cracks
- Serviceability
  - Weld is able to perform under varying conditions or service (e.g., extreme temperatures, corrosive environments, fatigue, high pressures, etc.)

Fusion Welding Principles

- Base metal is melted
- Filler metal may be added
- Heat is supplied by various means
  - Oxyacetylene gas
  - Electric Arc
  - Plasma Arc
  - Laser

Fusion Welding



Weld Metal Protection

- During fusion welding, the molten metal in the weld “puddle” is susceptible to oxidation
- Must protect weld puddle (arc pool) from the atmosphere
- Methods
  - Weld Fluxes
  - Inert Gases
  - Vacuum

Weld Fluxes

- Typical fluxes
  - SiO_2, TiO_2, FeO, MgO, Al_2O_3
  - Produces a gaseous shield to prevent contamination
  - Act as scavengers to reduce oxides
  - Add alloying elements to the weld
  - Influence shape of weld bead during solidification

Inert Gases

- Argon, helium, nitrogen, and carbon dioxide
- Form a protective envelope around the weld area
- Used in
  - MIG
  - TIG
  - Shield Metal Arc

Vacuum

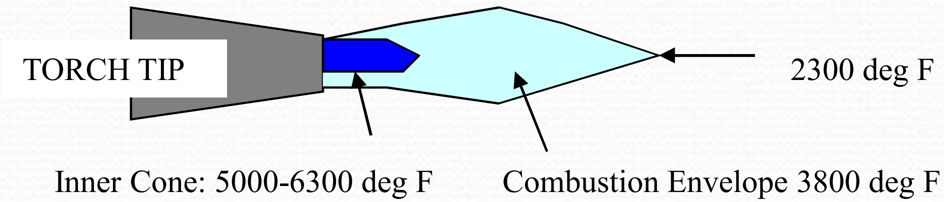
- Produce high-quality welds
- Used in electron beam welding
- Nuclear/special metal applications
  - Zr, Hf, Ti
- Reduces impurities by a factor of 20 versus other methods
- Expensive and time-consuming

Types of Fusion Welding

- Oxyacetylene Cutting/Welding
- Shielded Metal Arc ("Stick")
- Metal Inert Gas (MIG)
- Tungsten Inert Gas (TIG)

Oxyacetylene Welding

- Flame formed by burning a mix of acetylene (C_2H_2) and oxygen



- Fusion of metal is achieved by passing the inner cone of the flame over the metal
- Oxyacetylene can also be used for cutting metals

Shielded Metal Arc (Stick)

- An electric arc is generated between a coated electrode and the parent metal
- The coated electrode carries the electric current to form the arc, produces a gas to control the atmosphere and provides filler metal for the weld bead
- Electric current may be AC or DC. If the current is DC, the polarity will affect the weld size and application

Shielded Metal Arc (con’t)

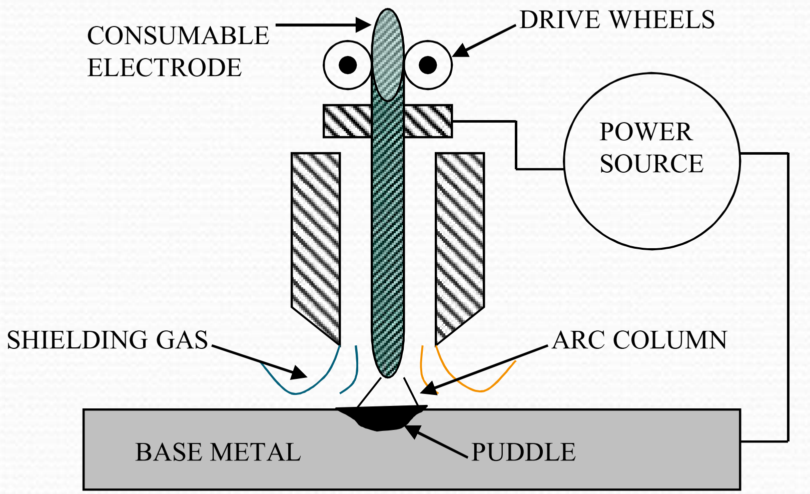
- Process:
  - Intense heat at the arc melts the tip of the electrode
  - Tiny drops of metal enter the arc stream and are deposited on the parent metal
  - As molten metal is deposited, a slag forms over the bead which serves as an insulation against air contaminants during cooling
  - After a weld ‘pass’ is allowed the cool, the oxide layer is removed by a chipping hammer and then cleaned with a wirebrush before the next pass.

Inert Gas Welding

- For materials such as Al or Ti which quickly form oxide layers, a method to place an inert atmosphere around the weld puddle had to be developed

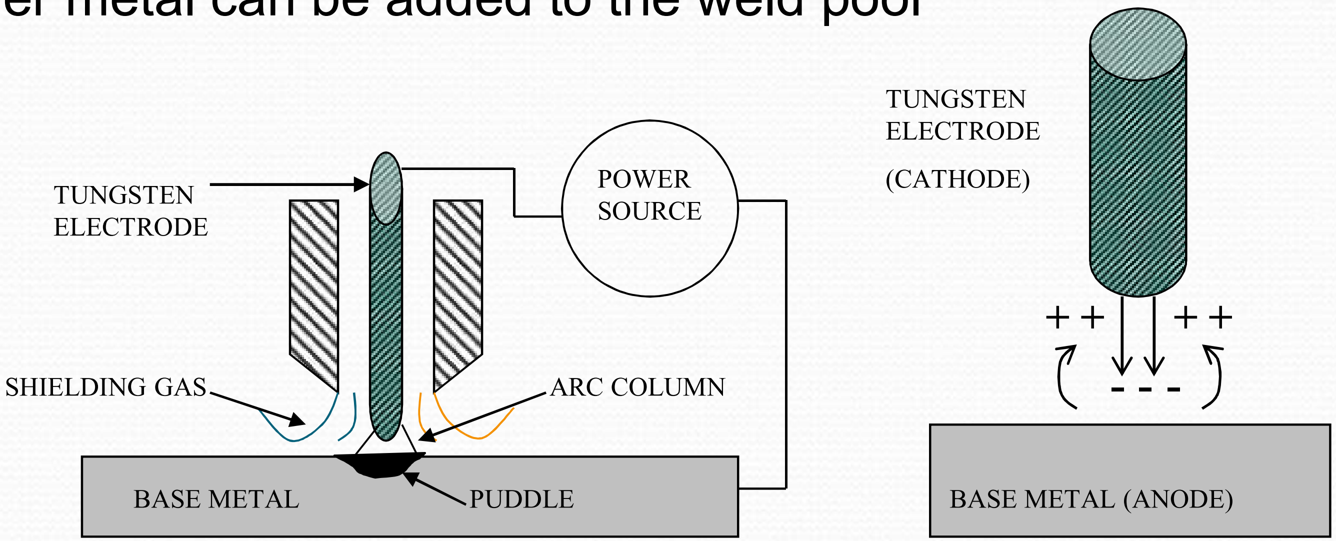
Metal Inert Gas (MIG)

- Uses a consumable electrode (filler wire made of the base metal)
- Inert gas is typically Argon

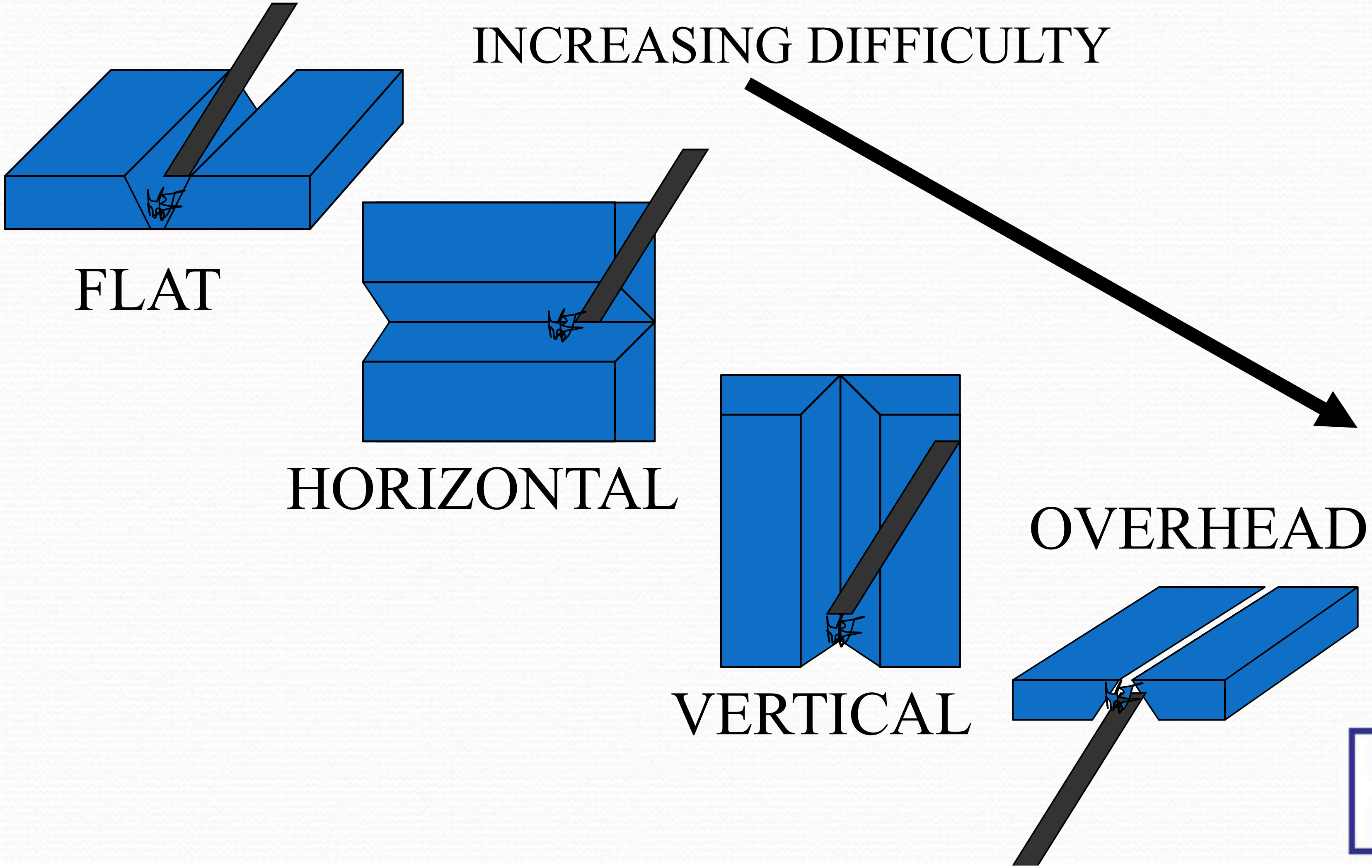


Tungsten Inert Gas (MIG)

- Tungsten electrode acts as a cathode
- A plasma is produced between the tungsten cathode and the base metal which heats the base metal to its melting point
- Filler metal can be added to the weld pool



Welding Positions



Weld Defects

- Undercuts/Overlaps

- Grain Growth
  - A wide ΔT will exist between base metal and HAZ. Preheating and cooling methods will affect the brittleness of the metal in this region
- Blowholes
  - Are cavities caused by gas entrapment during the solidification of the weld puddle. Prevented by proper weld technique (even temperature and speed)

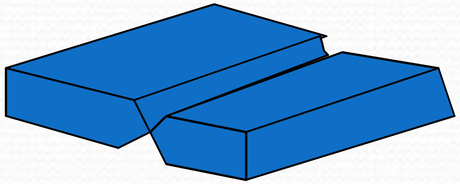
Weld Defects

- Inclusions
  - Impurities or foreign substances which are forced into the weld puddle during the welding process. Has the same effect as a crack. Prevented by proper technique/cleanliness.
- Segregation
  - Condition where some regions of the metal are enriched with an alloy ingredient and others aren't. Can be prevented by proper heat treatment and cooling.
- Porosity
  - The formation of tiny pinholes generated by atmospheric contamination. Prevented by keeping a protective shield over the molten weld puddle.

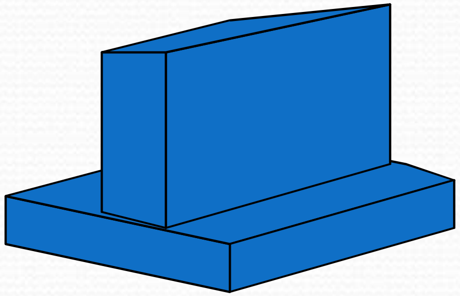
Residual Stresses

- Rapid heating and cooling results in thermal stresses detrimental to joint strength.
- Prevention
  - Edge Preparation/Alignment – beveled edges and space between components to allow movement
  - Control of heat input – skip or intermittent weld technique
  - Preheating – reduces expansion/contraction forces (alloys) and removes moisture from the surface
  - Peening – help metal stretch as it cools by hitting with a hammer. Use with care since it may work harden the metal
  - Heat Treatment – "soak" the metal at a high temperature to relieve stresses
  - Jigs and Fixtures – prevent distortion by holding metal fixed
  - Number of Passes – the fewer the better.

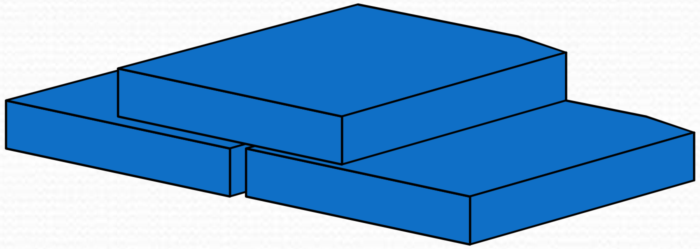
Joint Design



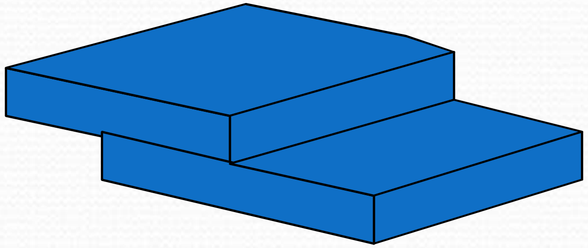
BUTT JOINT



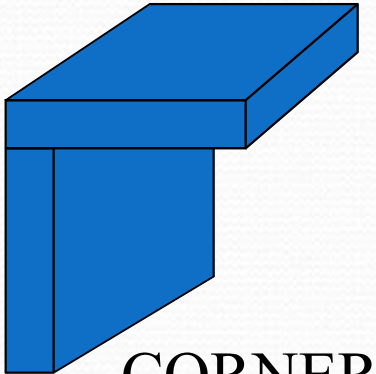
FILLET JOINT



STRAP JOINT

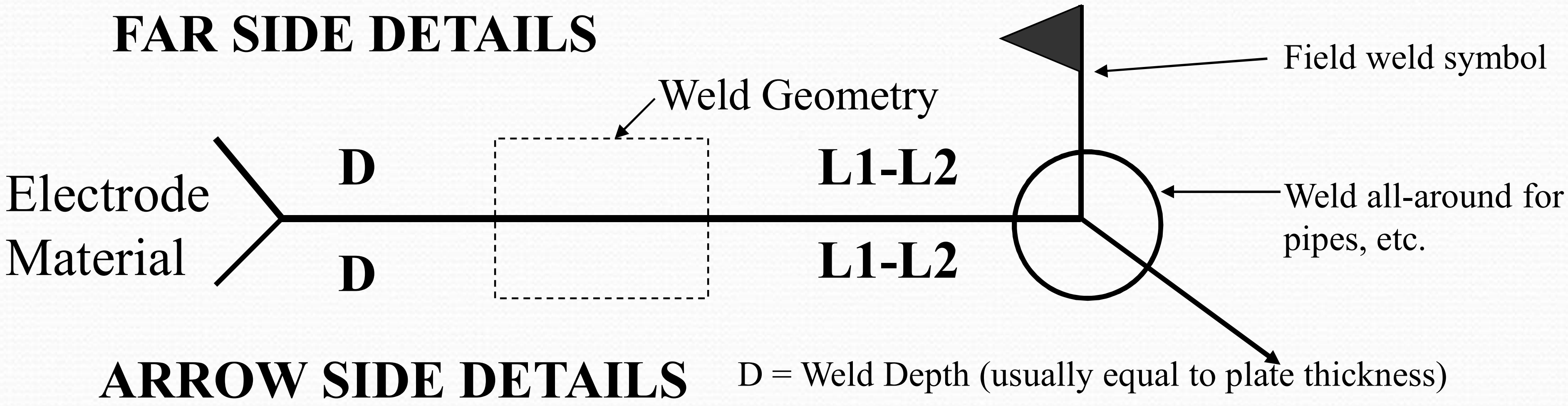


LAP JOINT



CORNER

Generalized Welding Symbol



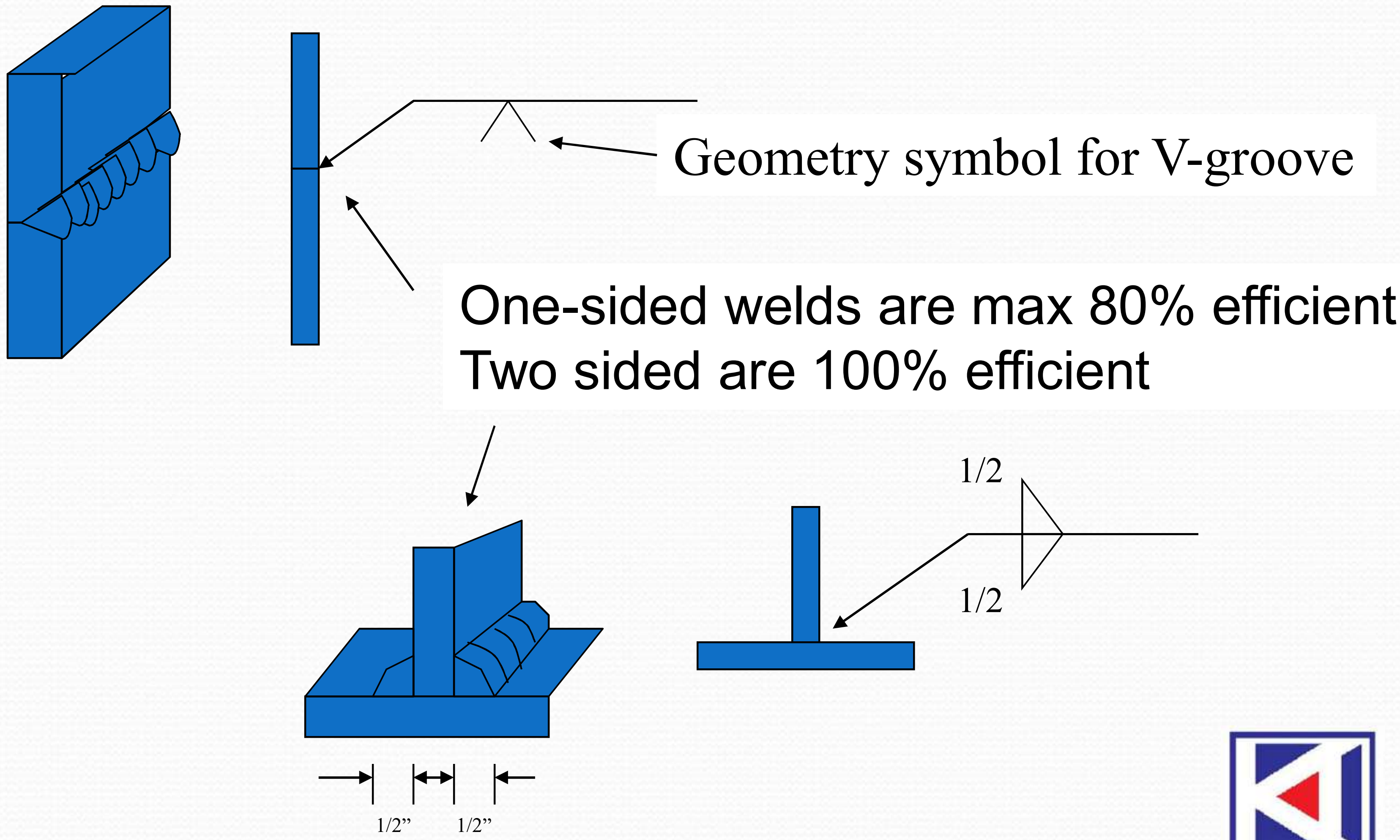
D = Weld Depth (usually equal to plate thickness)

L1 = Weld Length

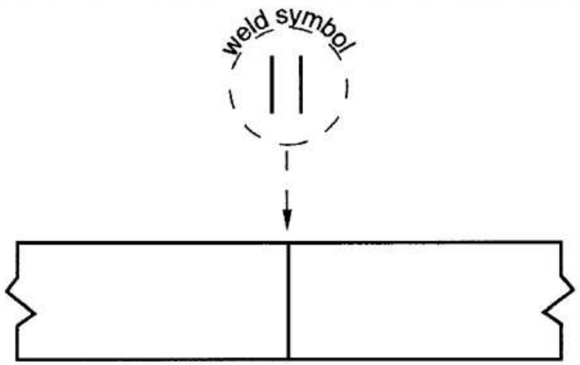
L2 = Distance between centers for stitched welds

The Field Weld Symbol is a guide for installation. Shipyards normally do not use it, except in modular construction.

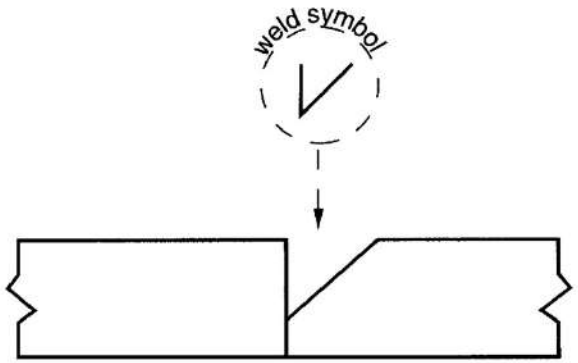
Example Welding Symbol



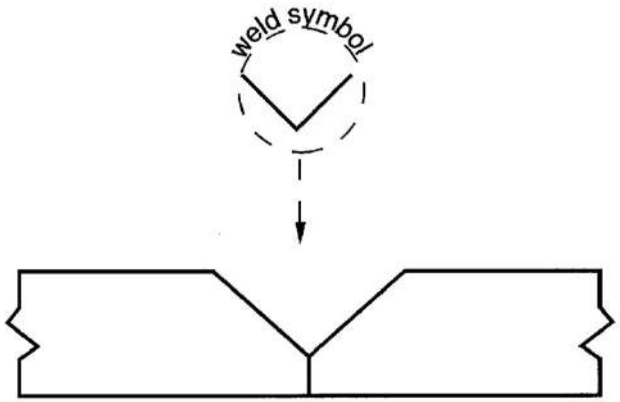
Weld Symbols (Butt Joints)



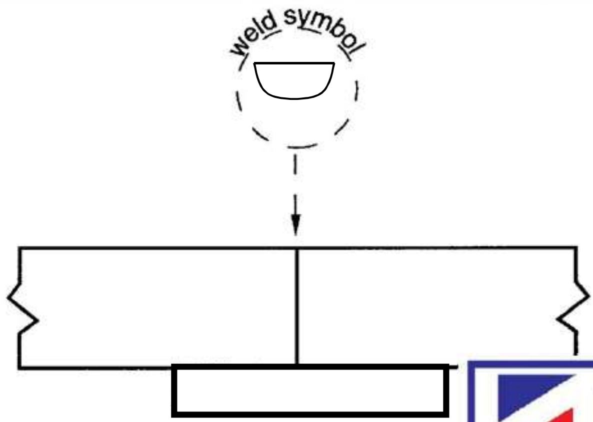
Square-Groove



Bevel-Groove

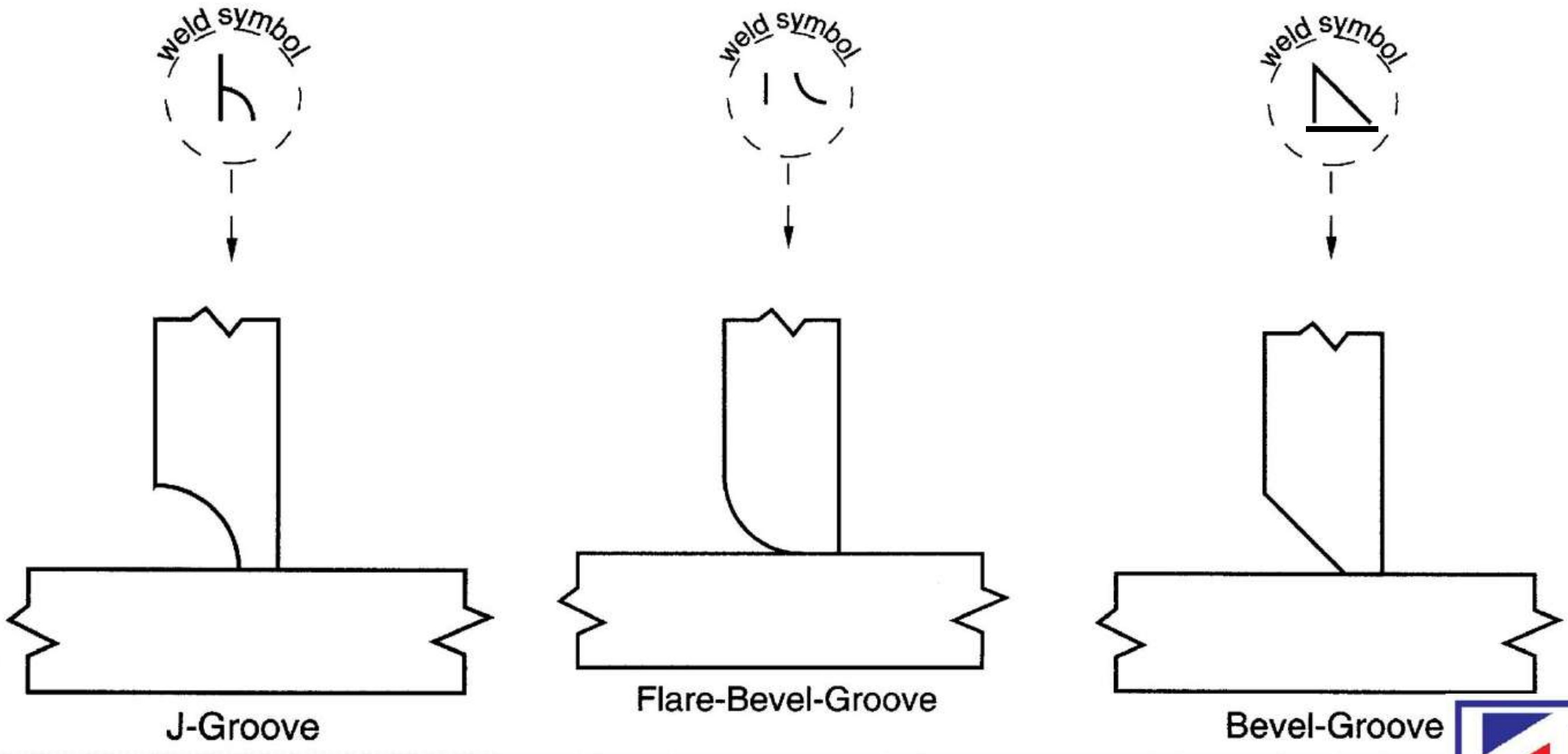


V-Groove



Backing

Weld Symbol (Fillet Joints)



Weld Symbol (Corner Joints)