IME 601 - FUNDAMENTALS OF MFG. ENG.

JOINING PROCESSES — BASIC CLASS NOTES

Reading Review and Class Preparation
This should be filled out prior to class.

Key Concepts to Be Discussed in Class:

Questions About Subject Matter for Class Session:

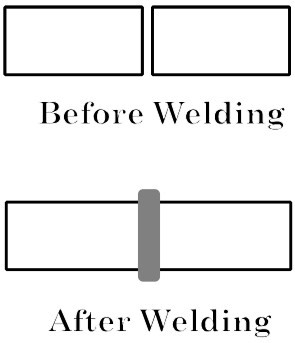
So What? Why? Who Cares?

- Quite often Making Something Requires Joining the Pieces Together
- Techniques other Than Mechanical Fastening are Often Used

- A Problem Correctly Stated is a Problem Half Solved
  - Charles Kettering

Outline

- Welding
  - Definition and Scientific Principles
  - Various Processes
- Brazing and Soldering
  - Focus on Comparison
- Adhesives
  - Mentioned Throughout

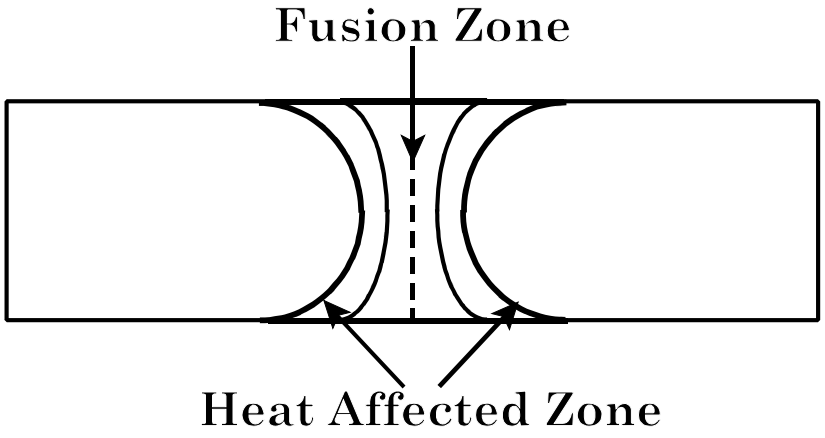


Definition of Welding

- Welding is a Fusion Joining Process
- In Metals
  - Both the Filler Metal and Base Metal Melt
- Weld Design Requires
  - Ensuring Melting
  - Ensuring Joining
  - Minimizing Effects

Parts/Zones of a Welded Joint

- Fusion Zone
  - Metal Quickly Solidifies
- Heat Affected Zone
  - Solid Metal "Annealed" Due to Heat Transfer



Concept Question

- Consider the Following Material Facts
  - Heating a Material Reduces Strength Both Before and After Cooling
  - Materials Which Solidify Quickly are Stronger
  - During Welding the Weld Pool Must Not Oxidize
- How Does This Effect Welding?

- What Must Be Done for a Good Weld?

- What is a Good Weld?

Melting

- Sufficient Energy Must Be Provided to Melt the Required Amount of Metal

Freshmen Experience

- Two Pieces of Steel
- Flame Welded (No Filler Metal)
- Dimensions
  Length = 1.5"
  Width = 0.5"
  Thickness = 0.0625"

Heat and Power Sources

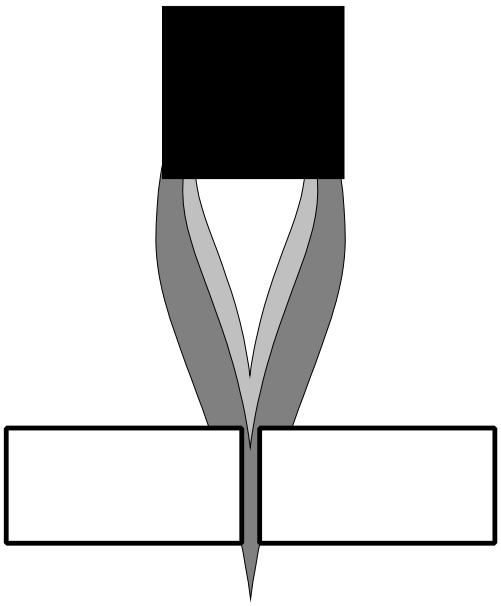
- Oxy-Acetylene
  - 48 kJ/L
  - Efficiency = 25%-50% or 50%-80%
- Shielded Metal Arc Welding
  - $5x10^6$ - $5x10^8$ W/m^2
  - Efficiency = 65%-85%

Notice
The time required to form the joint through flame welding is 10x that of arc welding

Ref: Messler R.W.: Principles of Welding;Wiley (1999)

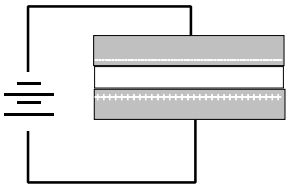
Oxy-Fuel Welding

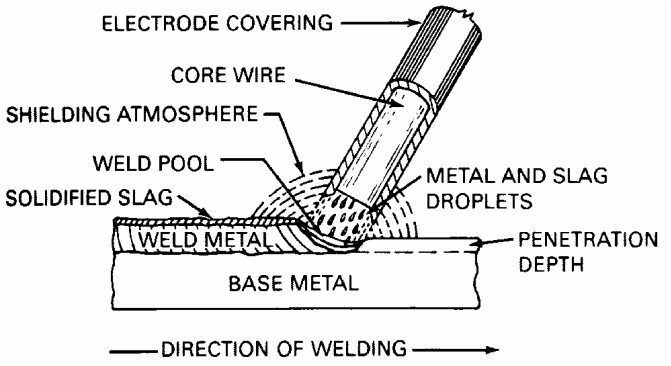
- Heat Supplied by Combustion of Acetylene (C_2H_2)
- Control of Flame
  - Oxidizing
  - Neutral
  - Reducing



Shielded Metal Arc Welding

- Power Source
  - Electric Arc (Lightning)

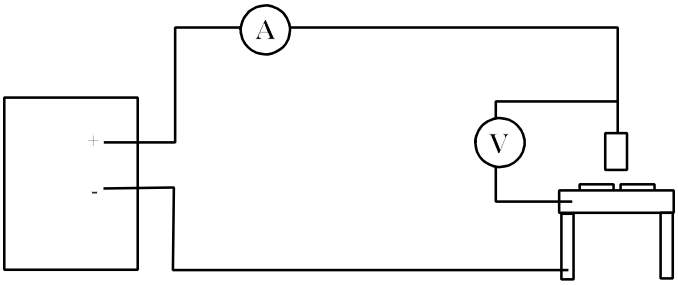




Ref: D.Dickinson: Course Notes and NEMJet

Typical Set Up

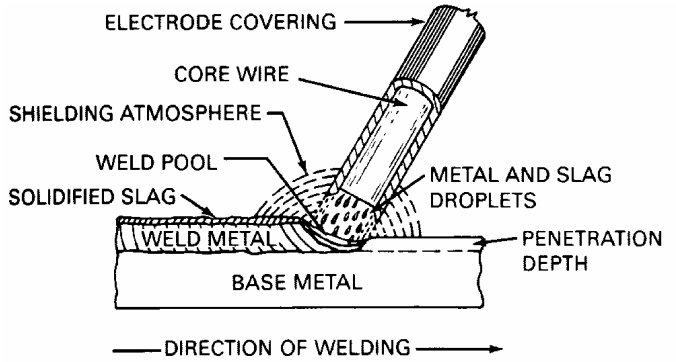
- Huge Voltage
- Safety



Ref: Messler R.W.: Principles of Welding;Wiley (1999)

SMAW More Details

- A Flux Coats the Electrode
  - During Welding Heat is Generated
  - Flux Evaporates
  - Removes $O_2(g)$



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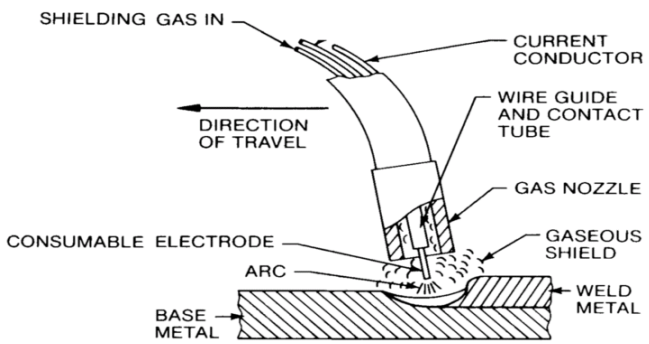
SMAW Advantages

- Easily Implemented
- Inexpensive
- Flexible
- Compared to Flame Sources
  - Cost ?
  - Easier Protection of Weld Pool
  - Faster

GMAW or MIG

- Power Source
  - Electric Arc
  - Like SMAW
- Protection
  - Inert Gas From Feed



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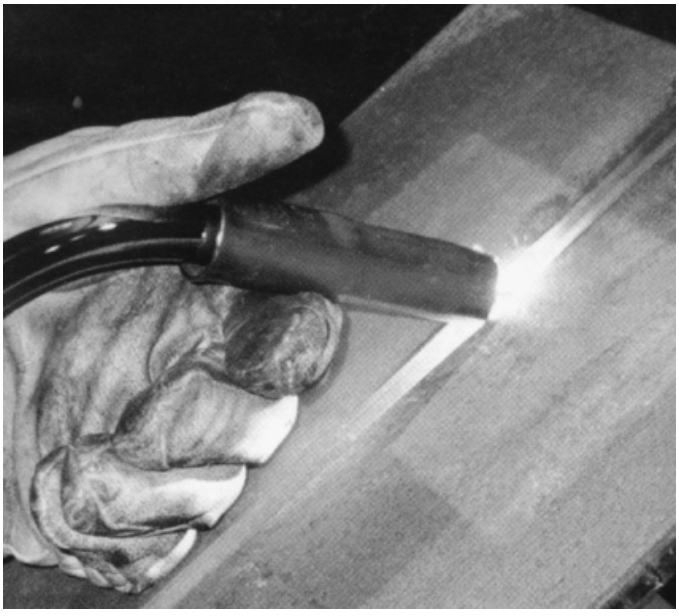
MIG Gun

- Bulkier than SMAW Stick Holder
- Requires
  - Gas Souce
  - Metal Wire Feed
  -



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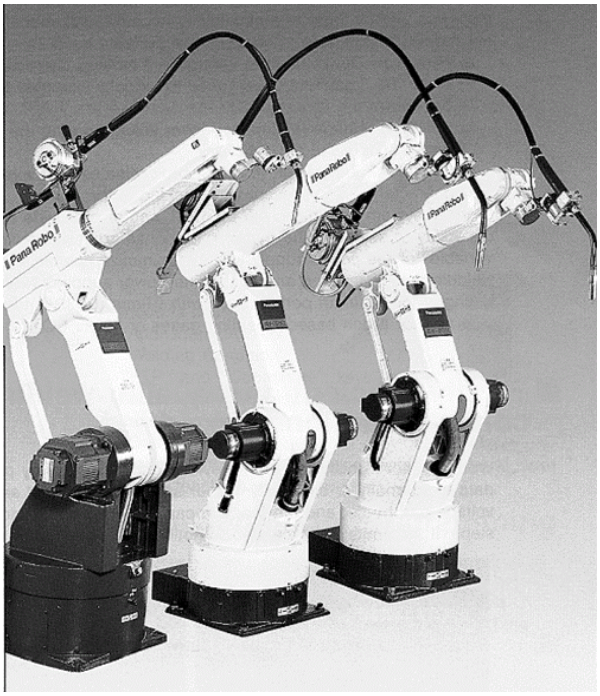
Robots and Automation

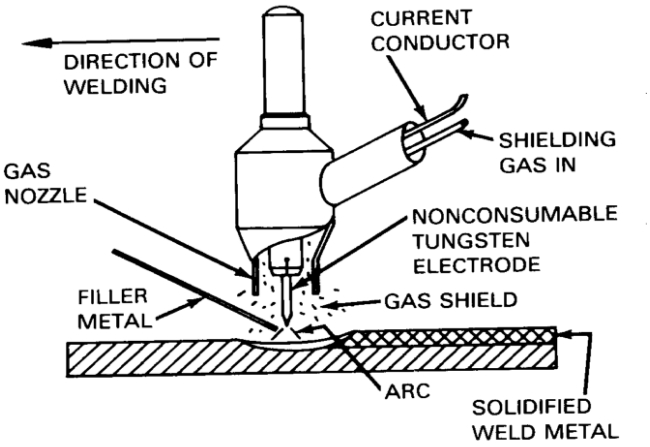
- MIG Welding is Automatabile
  - Wire Feed
  - Gas Flow Rate
  - Position
- Difficult Manual Operation



Ref: D.Dickinson: Course Notes and NEMJet

GTAW

- Heat Source
  - Arc From Tungsten (W) Electrode
- Protection
  - Inert Gas from Feed
- Alloying
  - Filler Rod can Be Used



Ref: D.Dickinson: Course Notes and NEMJet

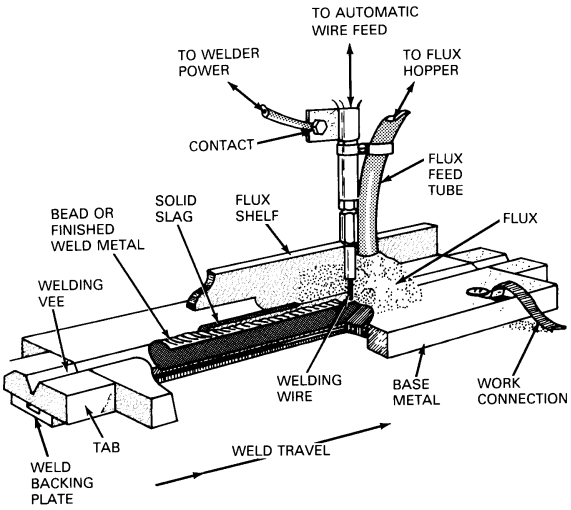
TIG Gun

- TIG Gun
  - Complicated
- Filler Metal
  - On the Side
- Requires
  - Gas Source
  - Wire Feed
  - Tip Maintenance

Ref: D.Dickinson: Course Notes and NEMJet

Spot Welding

- The Arc is Submerged in Powder

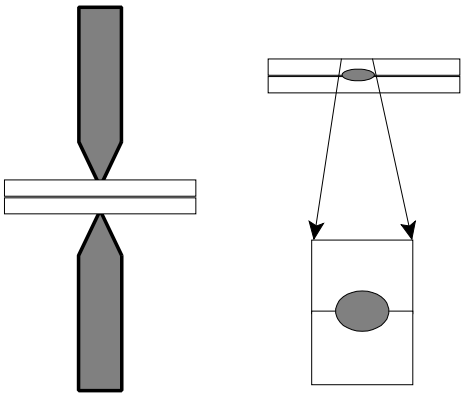


Ref: D.Dickinson: Course Notes and NEMJet

Spot Welding

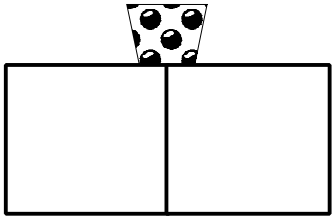
- Electric Resistance Welding
  - Electrical Contact Under Pressure
  - Localized

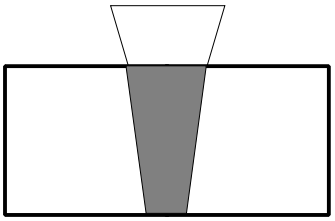
$$E = I^2 Rt$$



Thermit Welding

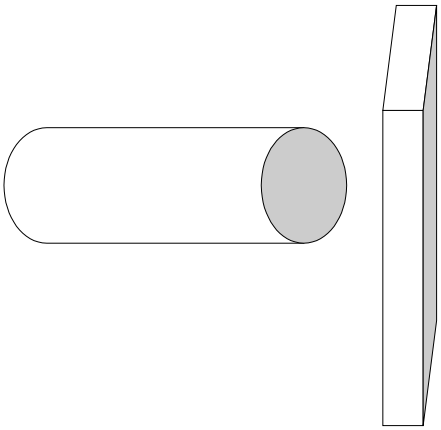
- Use of Chemical Reaction
  - $Al(s) + Fe_2O_3(s) \rightarrow Fe(l) + Al_2O_3(s)$





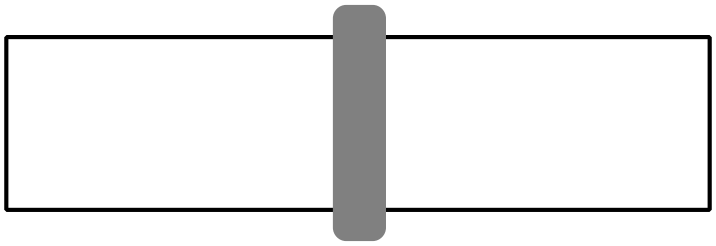
Friction Welding

- Use Friction to Generate Heat
  - High Speed Part
  - Causes Joint to Form



Definition of Brazing

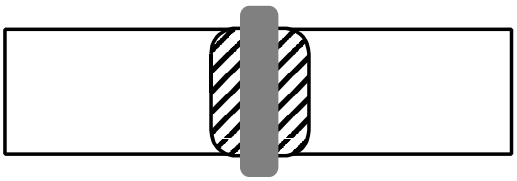
- Joint forms Without Melting Base Materials
- Filler Metal Must Have a T_L of 450°C
- Filler Metal Must Wet the Base Metal Surfaces and Be Drawn into Joint by Capillary Action



Ref: Brazing Handbook;AWS (1991)

Definition of Soldering

- Similar to AWS Definition of Brazing
  - Non-Fusion Metallurgical Joining Process
  - Temperature Less than 450°C
  - Capillary Action Necessary
- Reasons for Definitions
  - Historical
  - Practical
  - Scientific
- Key is the Lower Temperature

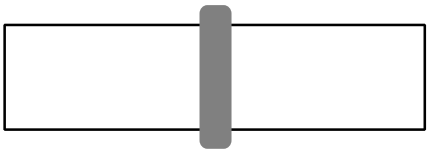


Temperature 450°C

- Historical
  - Brazes Based on Cu-Zn Alloys of Brasses
  - Solders Based on Sn Based Alloys
- Practical
  - Lowest T Braze Al-4Cu-10Si (T_M = 524°C)
  - Highest T Solder Au-3Si (T_M = 363°C)
- Scientific
  - Brazes Form Solid Solutions at Interface
  - Solders Form Intermetallics at Interface

Fluxes in Brazing

- Filler Metal Must Wet the Base Metal Surfaces and Be Drawn into Joint by Capillary Action



Ref: Brazing Handbook: AWS (1991)

- Oxide Formation Must Be Prevented

- You Will Need to Add Flux When Brazing

Brazing or Welding?

- Two Pieces of 1040 Steel
  - Joined With Copper Filler Metal

- Two Pieces of Copper
  - Joined With Copper Filler Metal

- Two Pieces of Copper
  - Joined With 70-30 Brass Filler Metal

- A Piece of Copper and a Piece of 1040 Steel
  - Joined With Copper Filler Metal

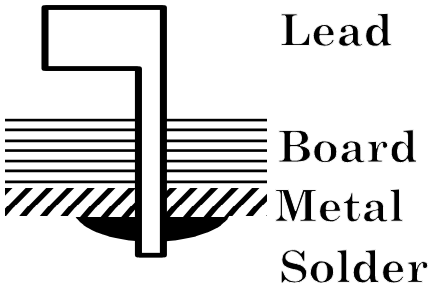
Sample Solder Alloys

- Mostly Tin (Sn) Based
- Historical Workhorse Lead(Pb)-Tin(Sn)

Solder	Tm (C)	Shear Strength (MPa)	Ductility %
Sn-Pb	183	28	1.3
Sn-Ag	221	30	0.69
Sn-Bi	138	24	1.3
95-5	280	30	18.3

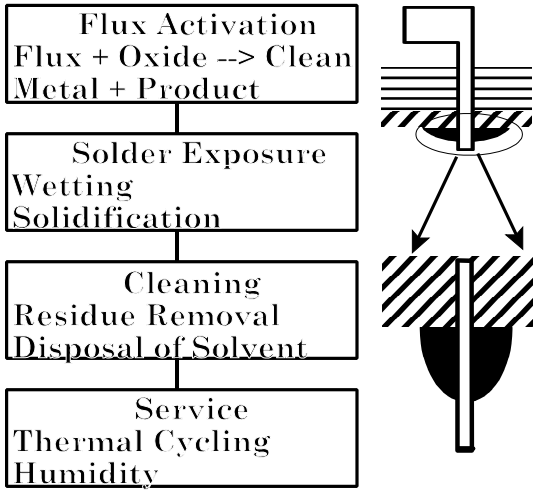
Importance of Solder Joints

- Provides Electrical Contact
  - Requires Metallurgical Bond
  - Strength / Fatigue Resistance Required
- Critical for Electronic Performance
  - Unglorified Part of Semiconductor Revolution
  - "For Want of a Nail ... A Kingdom was Lost"



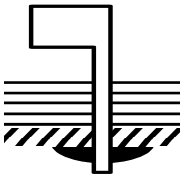
Production of Solder Joints

- Form Contact Between Lead and Metal
  - Remove any Oxide or Impurity
  - Cause Molten Solder to Wet Metal
  - Solidify Solder
  - Remove any Residue

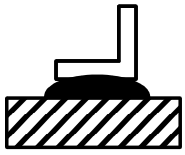


Miniaturization of Joints

- Increasing Amount of SMT
- Paste
  - Combination of Alloy Powder and Flux
  - Identified Based On Through-Hole Experience



Through-Hole Assembly



Surface Mount Assembly

Low Temperature Problems

- Cleaning Required
  - Prior to Soldering

- More Aggressive Fluxes are Needed

- Very High Thermal Stress
  - Solder is in Tension

Summary

- Welding
  - Base Metal and Filler Metal Melt
  - Strength Considerations
  - Fuel Sources
  - Oxide Prevention

- Brazing / Soldering
  - Only Filler Metal Melts
  - Same Considerations as In Welding
  - Problem With Metal Combinations

- Adhesive Bonding
  - Focus on Similarities