For our purpose: The arc welding processes most commonly used for weld repairs & surfacing in maintenance shops throughout the country.

- SMAW / stick
- GTAW / TIG
- GMAW / MIG
- FCAW / flux core
Maintenance Welding
the “unsexy” side of welding

Welding that is often performed in less-than-ideal conditions, including:
- Contaminated metals
- Out-of-position
- Dissimilar steels
- Field repairs (wind, rain, cold)
- Difficult to weld metals

Pre-Quiz

• What do you know about welding?
  – Collusion encouraged

  don’t be these guys
PRACTICAL METALLURGY 1
CARBON STEEL

An overview of basic metallurgical principles for welders, machinists, metalworkers & associated personnel

Discussion, Q & A – encouraged at all times

- **Terminology** used in the industry
  - Elements, mechanical properties & how tested
  - Allotropes of iron; crystal structures
  - Short videos, photos & samples throughout
- Brief discussion of **heat treatments**

Mechanical Properties of Steels

- **The ability of a material to become permanently deformed without failure**

<table>
<thead>
<tr>
<th>A. Toughness</th>
<th>B. Malleability</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Ductility</td>
<td>D. Elasticity</td>
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</tbody>
</table>
Mechanical Properties of Steels

✓ The ability of a material to return to original shape and dimensions after a deforming load has been removed

A. Tensile Strength  B. Yield Strength
C. Plasticity  D. Elasticity

Mechanical Properties of Steels

✓ The measured resistance of a metal to indentation, abrasion, deformation, or machining

A. Hardness  B. Britteness
C. Toughness  D. Elongation
Hardness Testing

- **Brinell hardness testing video (3:05)**
  - Hard spherical indenter
- **Rockwell hardness testing video (2:30)**
  - Rounded diamond indenter
- **Vickers hardness testing video (2:33)**
  - Pyramid diamond indenter

Note the grain structure of the magnified areas tested

Heat Treatments

✓ A heat treatment applied to ferrous products after hardening for the purpose of decreasing hardness & increasing toughness

<table>
<thead>
<tr>
<th>A. Annealing</th>
<th>B. Quenching</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Tempering</td>
<td>D. Stress Relieving</td>
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Metallurgy & Heat Treatment
The Pocket Book
by Atif A. Odeh

unique reference guide puts a wealth of useful metallurgical and heat treat information at your fingertips... packed with important information including tips, recipes, formulas, reference tables, photomicrographs, and more

5271 Zenith Parkway
Loves Park, IL 61111
The Arc Welding Circuit

- The electricity flows from the power source, through the electrode and across the arc, through the base material to the work lead and back to the power source.

Basic Electricity

- Voltage – The electrical potential or pressure that causes current to flow
  - Measured in Volts
- Current – The movement of charged particles in a specific direction
  - Measured in Amps
  - Direct or Alternating
- Polarity
  - DC- (Direct Current Electrode Negative)
  - DC+ (Direct Current Electrode Positive)
• Protect yourself and others from potential hazards including:
  – Fumes and Gases
  – Electric Shock
  – Arc Rays
  – Fire and Explosion Hazards
  – Noise
  – Hot objects

Electric Shock

• Electric shock can kill
• Do not touch live electrical parts
  – Primary Voltage – 230, 460 volt input power
  – Secondary Voltage – 6 to 100 volts for welding
• Insulate yourself from work and ground
• Follow all warnings on welding equipment
Fumes and Gases

- Fumes and gases can be hazardous to your health
- Keep your head out of the fumes
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area
- See product labeling and MSDS for ventilation and respirator requirements

Lincoln Safety Module 2: Fumes & Gases  < 8 min. total

Arc Rays

- Arc rays can injure eyes and burn skin
- The welding arc is brighter than the sun
- Precaution must be taken to protect your eyes and skin from UV radiation
- Wear correct eye and body protection

Lincoln Safety Module 4: PPE  9:17
Welders must wear protective clothing for
- Protection from sparks, spatter and UV radiation
- Insulation from electric shock

• Protective clothing includes …
  - Fire-proof clothing without rolled sleeves, cuffs or frays
  - Work boots
  - Welding gloves, jackets, bibs, and fire-proof pants
  - Welding cap, helmet and safety glasses
  - Ear protection – ear plugs and muffs

• Loud noises can damage your hearing
• Keep loud noises at a safe level by using proper hearing protection such as:
  - Ear plugs
  - Ear muffs
Fire and Explosion Hazards

- Welding sparks can cause fires and explosions
- Sparks and spatter from the welding arc can spray up to 35 feet from your work
- Flammable materials should be removed from the welding area or shielded from sparks and spatter
- Have a fire extinguisher ready
- Inspect area for fires 30 minutes after welding

Lincoln Safety Module 3: Fire & Explosions 7+ min.

SMAW

Shielded Metal Arc Welding

a.k.a.:

- “stick” (2 reasons)
- manual arc welding (MAW) also, manual metal arc welding (MMAW)

Note: Most of the following slides are part of the Lincoln Electric educational training materials available on their website.
During this overview, we will discuss the following topics:

- Safety
- SMAW Basics
- Equipment Set-Up
- Welding Variables
- Process Advantages and Limitations

The SMAW process is great for maintenance and repair work!

The American Welding Society defines SMAW as **Shielded Metal Arc Welding**

**SMAW:**

- Is commonly known as ‘Stick’ welding or manual arc welding
- Is the most widely used arc welding process in the world
- Can be used to weld most common metals and alloys
Let’s take a little closer look at the SMAW process...

1- The Electrode

- Is a consumable - it gets melted during the welding process
- Is composed of two parts
  - Core Rod (Metal Filler)
    - Carries welding current
    - Becomes part of the weld
  - Flux Coating
    - Produces a shielding gas
    - Can provide additional filler
    - Forms a slag
2- The Arc

- An arc occurs when the electrode comes in contact with the workpiece and completes the circuit … like turning on a light!
- The electric arc is established in the space between the end of the electrode and the work
- The arc reaches temperatures of 10,000°F which melts the electrode and base material

Can you identify the weld joint and position being used?

3- Weld Puddle

- As the core rod, flux coating, and work pieces heat up and melt, they form a pool of molten material called a weld puddle
- The weld puddle is what a welder watches and manipulates while welding

1/8" E6013 at 125 Amps AC
4- Shielding Gas

- A shielding gas is formed when the flux coating melts.
- This protects the weld puddle from the atmosphere preventing contamination during the molten state.

The shielding gas protects the molten puddle from the atmosphere while stabilizing the arc.

5- Solidified Weld Metal

- As the molten weld puddle solidifies, it forms a joint or connection between two pieces of base material.
- When done properly on steel, it results in a weld stronger than the surrounding base metal.
6- Slag

- Slag is a combination of the flux coating and impurities from the base metal that float to the surface of the weld.
- Slag quickly solidifies to form a solid coating.
- The slag also slows the cooling rate of the weld.
- The slag can be chipped away and cleaned with a wire brush when hard.

Application Activity

Let’s review the SMAW process ...

- 1 = __________
- 2 = __________
- 3 = __________
- 4 = __________
- 5 = __________
- 6 = __________
SMAW Equipment Set Up

1. Turn power supply on
2. Connect work clamp
3. Select electrode
   a. Type
   b. Diameter
4. Adjust output
   a. Polarity
   b. Amperage
5. Insert electrode into electrode holder

SMAW Process Variables

- Settings on the machine
  - Polarity: DC+, DC-
  - Amperage Output
- Operator Controlled Variables
  - Work Angle
  - Travel Angle
  - Arc Length
  - Travel Speed

An AC-only machine will not have a polarity switch like this AC/DC machine.
To begin the SMAW Process, you must first strike an arc. This can be done using one of the following techniques:

- **Scratch start** – scratch the electrode on the base metal like a match
- **Tap Start** – tap the rod against the base metal

**Work Angle**

- The work angle is the angle between the electrode and the work as depicted on the left.
- Work angles can vary depending on the position the weld is being made in.
Travel Angle

- Also commonly called Lead Angle
- The travel (lead) angle is the angle between the electrode and the plane perpendicular to the weld axis.

Arc Length

- After striking the arc, maintain a 1/8” distance between the electrode and the workpiece
  - If the arc length becomes too short, the electrode will get stuck to the workpiece or ‘short out’
  - If the arc length becomes too long; spatter, undercut, and porosity can occur
**Travel Speed**

- The travel speed is the speed at which the electrode moves along the base material while welding.
  - Too fast of a travel speed results in a ropey or convex weld.
  - Too slow of a travel speed results in a wide weld with an excessive metal deposit.

**Filling the Crater**

- At the end of the weld, the operator breaks the arc which creates a ‘crater’.
- Use a short pause or slight back step at the end of the weld to fill the crater.
- Large craters can cause weld cracking.

Back stepping is a short move in the opposite direction of weld travel.
Here is the proper technique for restarting a weld:

1. Strike Arc Here
2. Move Electrode to Crown of Crater
3. Resume Forward Travel

Oxy-Fuel Cutting & Heating

- Fuel gasses used
- Cylinder safety practices
- Equipment
- Safety gear
- Alternative Fuels
- Victor Technologies Safety Checklists
This was an accident that occurred in Russia. Russians have dash cams in order to provide additional evidence in court, to guard against police corruption and insurance fraud.

**Cylinder Safety**

**Oxygen**

- Separated from other gases in air.
- Cylinders are made from seamless drawn steel.
- Cylinders are hydrostatically tested to around 3300 psi.
- Cylinders are equipped with a high-pressure (back-seating) valve.
- Protector cap screws onto neck ring.
Acetylene

- Gas with distinctive, nauseating odor; highly combustible when mixed with oxygen; highly unstable at pressures above 15 psi. Explosive at 29 psi.
- Calcium carbide and water.
- Cylinder packed with porous material (agamassan).
- Equipped with fusible plugs.

Acetylene Cylinder

Cut-away view of inside of the cylinder showing type of valve, felt pad in neck & agamassan material that is saturated with acetone.
Acetylene

- Opened with valve handle, or on older style cylinders…a special square wrench (key) is used.
- For considerable amounts of welding, a manifold system may be used.
- Flash arrestors prevent an explosion or backfire from reaching the regulator or cylinder.

Cylinder Safety

- To move a cylinder, rotate it on its bottom edge while walking behind cylinder (Never walk to the side of cylinder).
- Never lift a cylinder by the protector cap.
- Always keep cylinders in a vertical position.
- Do not allow grease or oil to contact cylinder valves.
Cylinder Safety

- Avoid exposing cylinders to furnace heat, radiators, open fire, or sparks from a torch.
- Shut off cylinder valves completely before moving cylinders.
- Do not tamper with or attempt to repair cylinder valves.
- Never wrap electrical wires or welding cables around cylinders, or gauges.

Acetylene fire surveillance video
(2 min.)

Cylinder Safety

- Keep valves closed on empty cylinders.
- Cylinders should be chained during use and when stored.

Guy runs away, knocks himself out – stupid video (0:36)
Equipment

- Oxy-Fuel Torch
  - Welding tips
  - Cutting tips
  - Specialty tips
  - Heating tips (“rosebud”)
- Valves & Regulators
- Flashback Arrestors or Check valves
- Hoses

Equipment

- Sparklighter
- Goggles or glasses & face shield
- Apron, shop coat, or coveralls
- Leather coats, sleeves, or capes
- Leather gloves
Other Gases Used in Oxy-Fuel Systems

• MAPP gas
  (Methylacetylene propadiene stabilized)
• Hydrogen
• Propane
• Natural gas
• Propylene

Backfire & Flashback

Backfire – A quick recession of the flame into the welding/cutting tip, typically followed by extinction of the flame.

Flashback – A recession of the flame into the mixing chamber of the torch. (Usually accompanied by a loud “pop”).
A big thank you to Victor Technologies for the well-produced Oxy-Fuel Safety video training program included here.

Victor Oxy-Fuel Safety video

Thanks for attending Maintenance Welding & Safety