ESPL Welding Training Course

Processes Allowed at ESPL:

- *TIG (Tungsten Inert Gas)*
- *MIG (Metal Inert Gas)*
- *Oxyacetylene annealing*
- *Soldering*

Topics Covered:

1. Theory
2. Operation and Best Practices
3. Welding Safety

- No “Stick” welding
- No welding of Stainless Steel
- No welding of Galvanized Steel

 slide 1

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To learn more thoroughly about welding, consider taking TSM 233, 3hrs

Welding

1. Theory

 slide 2

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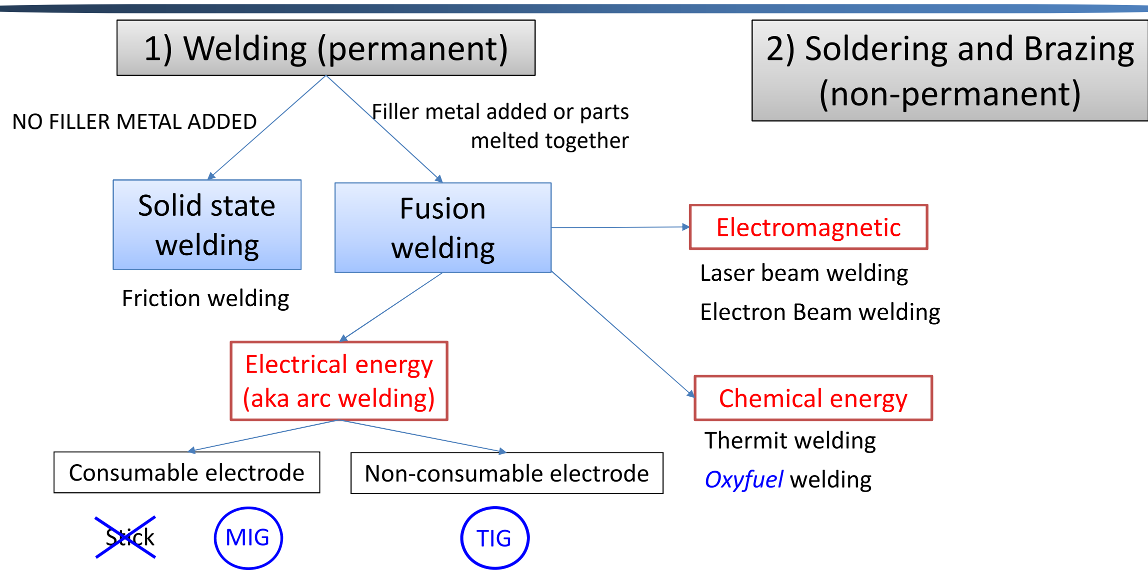
"Joining" classifications



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Soldering and brazing

- Alternative to welding that uses a filler metal between the parts.
- The entire joining area must be heated uniformly.
- Used when:
  - Metals have *poor weldability*
  - *Dissimilar metals* are to be joined
  - Intense heat of welding may *damage* components
  - Geometry of joint not suitable for welding
  - High strength is not required
- Brazing definition: filler metal T_m > 450°C (840°F)
- Solder definition: filler metal T_m < 450°C (840°F)

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Brazing and soldering fluxes

- They dissolve or inhibit formation of oxides on the metal surface.
- Displaced by filler metal and facilitates wetting of filler metal.
- Required by virtually all soldering/brazing methods
- Flux fumes are very dangerous, you must use snorkel ventilation, a fume hood, or fume capture.

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Soldering & brazing at ESPL

- Only lead-free solders are allowed – with vapor capture and/or ventilation of flux fumes.
- Brazing requires too high a temperature to safely teach at ESPL and is more difficult since it requires the entire joint to be very evenly heated. Find a professional to do this for you.

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Why no stick welding at ESPL?

- Stick welding, or SMAW, uses a *flux coated consumable electrode*, not a shielding gas to prevent oxides.
- According to OSHA, stick flux fumes are quite noxious:
  – MIG and TIG are less chemically dangerous because they can be done without using Flux.

ARC Welding in Decreasing Fume Production and Risk:

1. **Flux Core Arc Welding (FCAW)** filler metal electrode; flux shield
2. **Shielded Metal Arc (SMAW)** electrode provides both flux and filler material Stick
3. **Gas Metal Arc (GMAW or MIG)** widely used; consumable electrode for filler metal, external gas shield
4. **Tungsten Inert Gas (GTAW or TIG)** superior finish; non-consumable electrode; externally-supplied inert gas shield

https://www.osha.gov/Publications/OSHA_FS-3647_Welding.pdf

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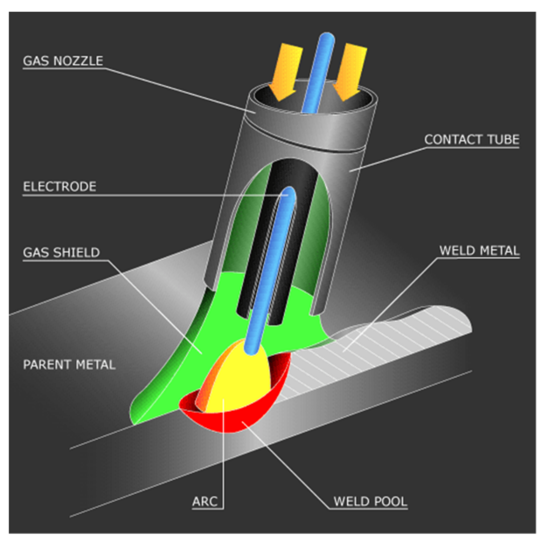
MIG (Metal Inert Gas) welding

- Accounts for about 50% of all welds
- Consumable wire electrode fed through a welding gun surrounded by an inert gas.
- Wire metal is the same metal as part;
- Argon gas with 25% CO_2 is required to do MIG welding at ESPL



http://www.arcabrasives.com/Fabrication/Welding.html

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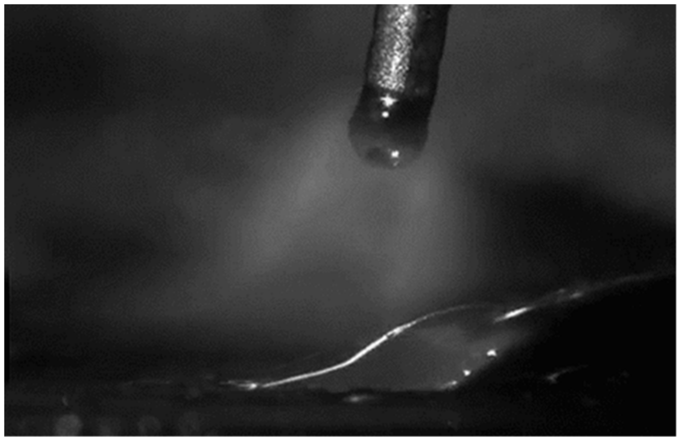
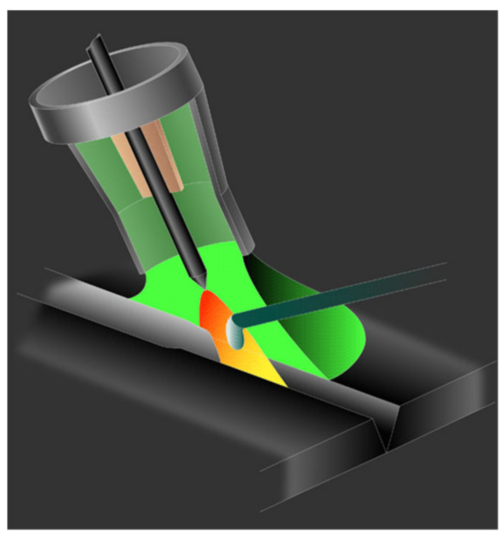
MIG gif



Current arcs between the filler rod and the part surface carrying charged molten metal droplets with it. Filler rod has inert gas flowing around it at all times.

TIG (Tungsten Inert Gas) welding

- Non consumable tungsten electrode.
- Welding can be done with or without filler metal.
- If filler metal is used, it is supplied typically as a stick.



http://www.arcabrasives.com/Fabrication/Welding.html

TIG gif

Tungsten electrode is on the left and stays out of the molten pool. Filler rod is on right and goes in and out of molten pool. Direction is to the right.

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Advantages and disadvantages

MIG

Pro:
- Faster welding
- Easier to learn

Con:
- Weld splatter
- Greater part distortion

TIG

Pro:
- Precision welding (smaller spot size)
- Can do thinner parts

Con:
- More dexterity required
- Slower process

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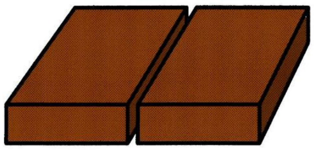
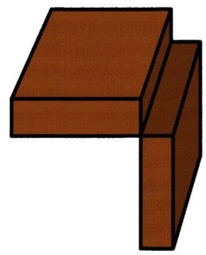
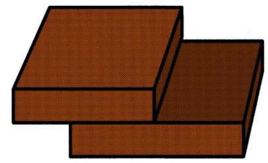
Types of weld joints:



Butt joint:
parts lie in same plane and are joined at their edges



Corner joint:
parts form a right angle and are joined at the corner



Lap joint:
consists of two overlapping parts

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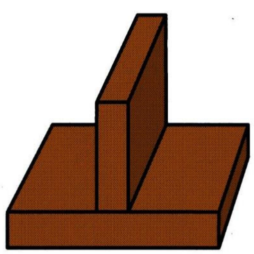
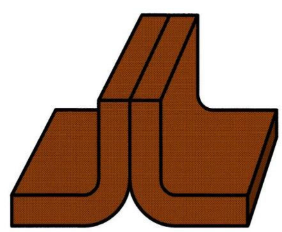
Types of weld joints:



Tee joint:
one part is perpendicular to the other. Weld on one or both sides.



Edge joint:
parts parallel with at least one edges in common. The weld is made along the common edge.

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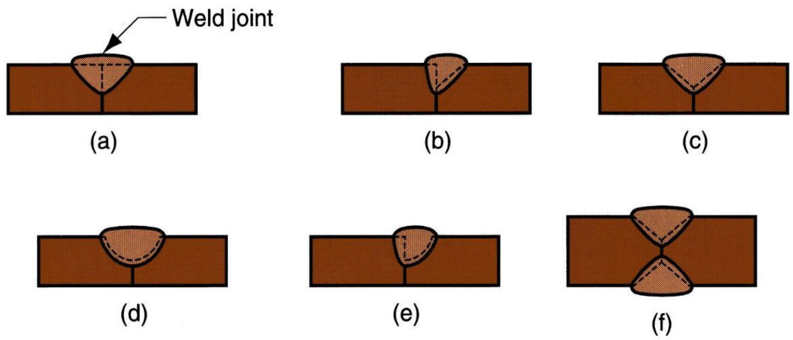
Typical “groove” welds on butt joints:

- One or more edges can be beveled to facilitate the weld penetration. Dashed lines show original part edges.

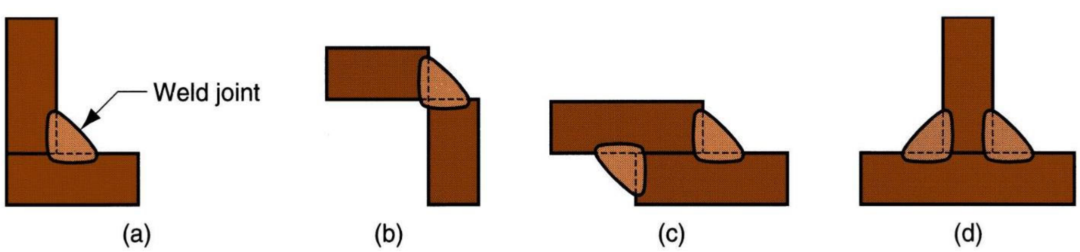


(a) no bevel; (b) one-sided bevel; (c) both parts beveled; (d) U-groove bevel;

(e) single-sided U-bevel; (f) double sided bevels for thicker parts.

Typical “fillet” welds

- Filler metal used to form weld creates a right-triangle cross section. Minimal edge preparation needed.



(a) inside fillet corner joint; (b) outside fillet corner joint; (c) double fillet lap joint; and

(d) double fillet tee joint.

Weld quality problems:

1. Residual stresses and distortion
   – Due to rapid heating and cooling of small regions
2. Welding defects
   – Cracks, slag inclusions, cavities and incomplete penetration.

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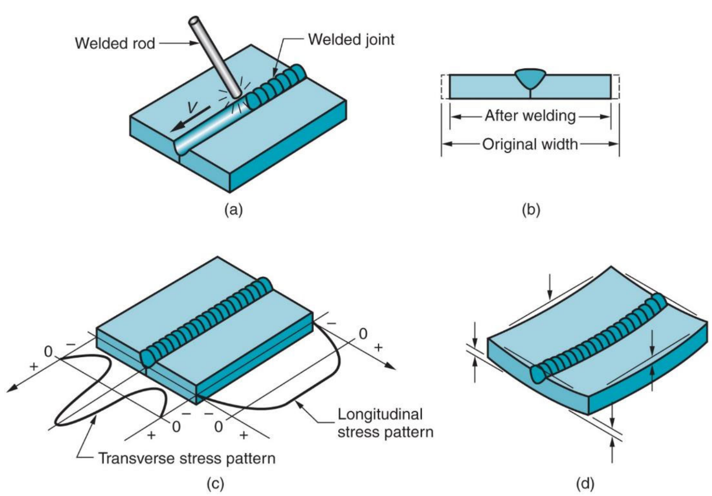
Weld distortion

- Part material will be consumed and weld area contracts:



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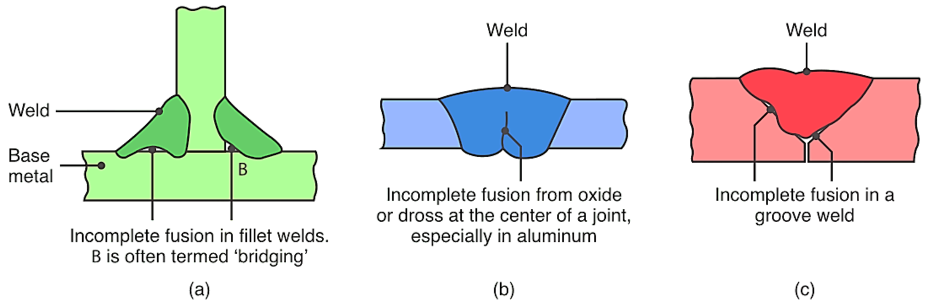
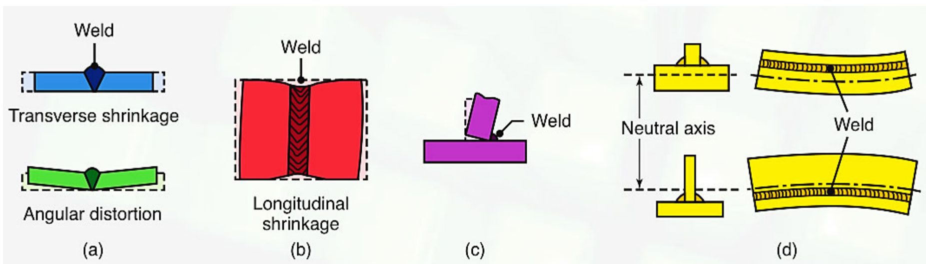
Welding defects: incomplete fusion & distortion





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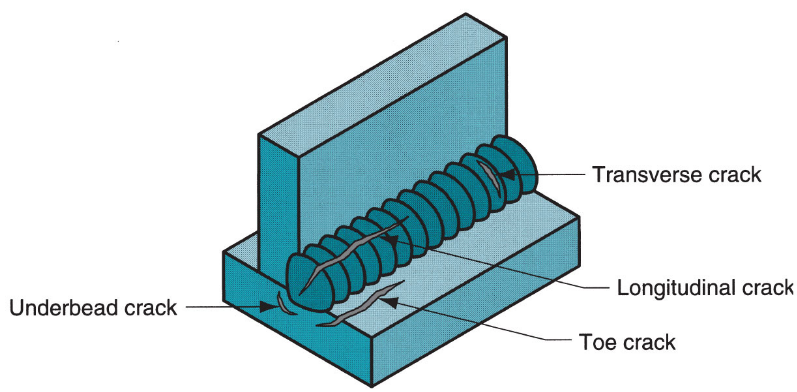
Welding defects: cracks

- Visible after shrinkage during solidification.



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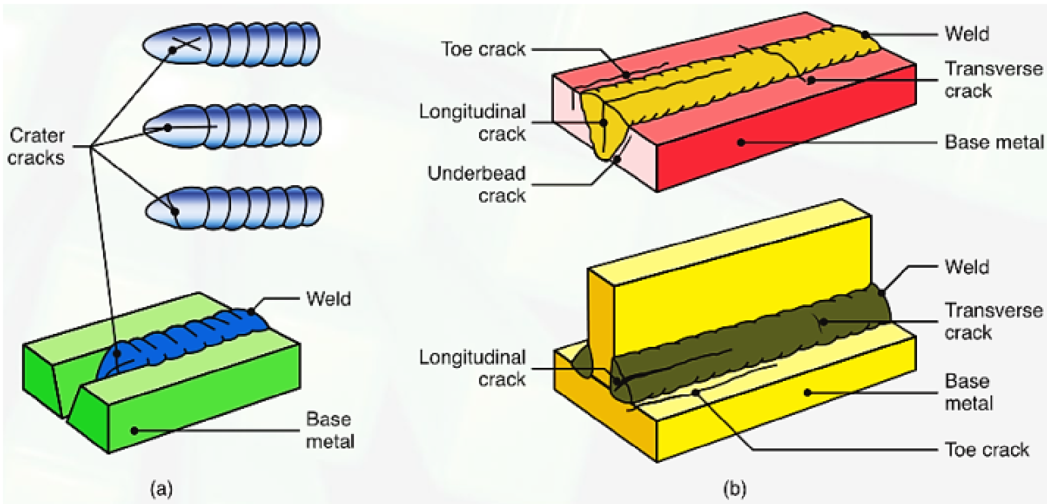
Welding defects: cracks



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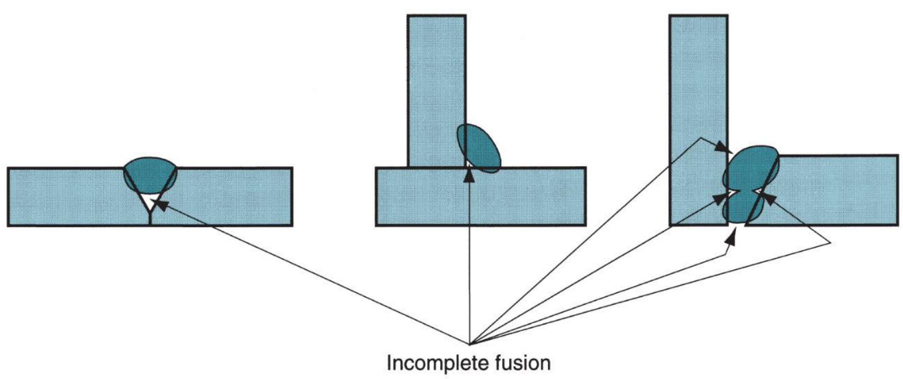
Welding defects: cavities

- Caused by incomplete fusion of parts:



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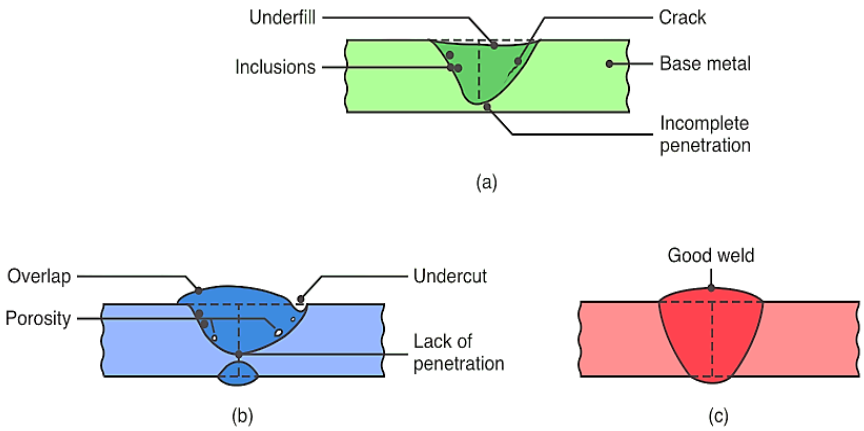
Welding defects: penetration



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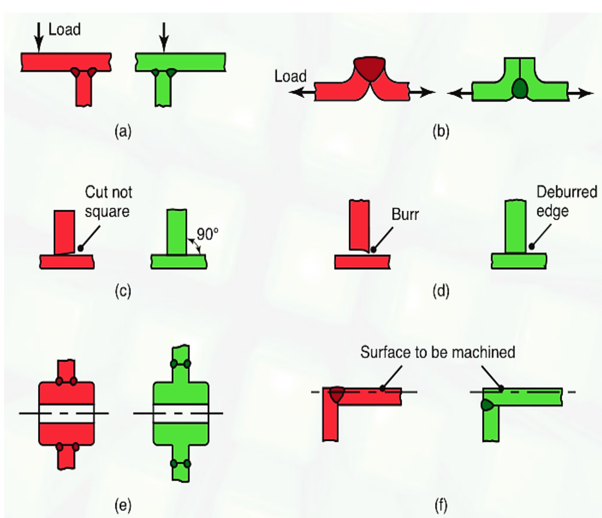
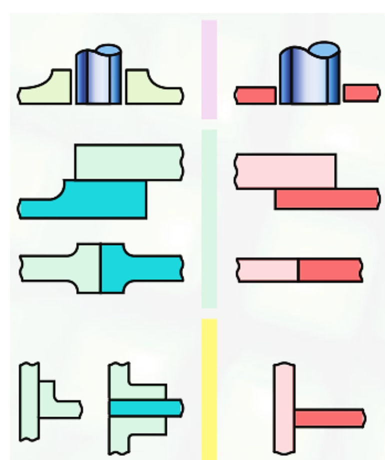
Design advisor (i.e. green/blue are better, red is not)

Welding



Soldering



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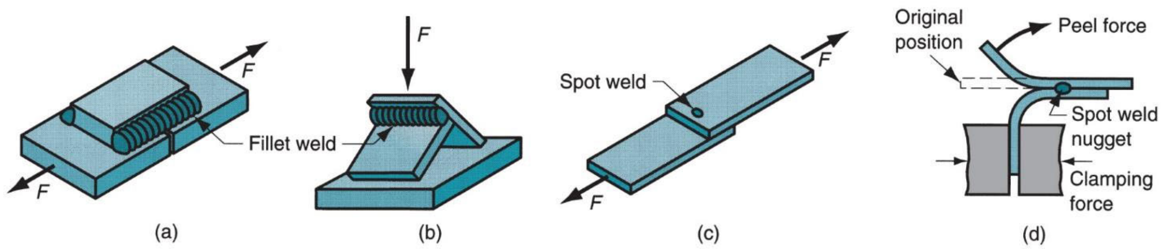
Weld inspection and testing

- Inspection methods – generally non-destructive
  - Visual inspection of surface for cracks and inclusions.
  - Ultrasound or x-rays to look for cracks and voids below the surface.
- Testing – generally destructive
  - Common tensile and shear tests:



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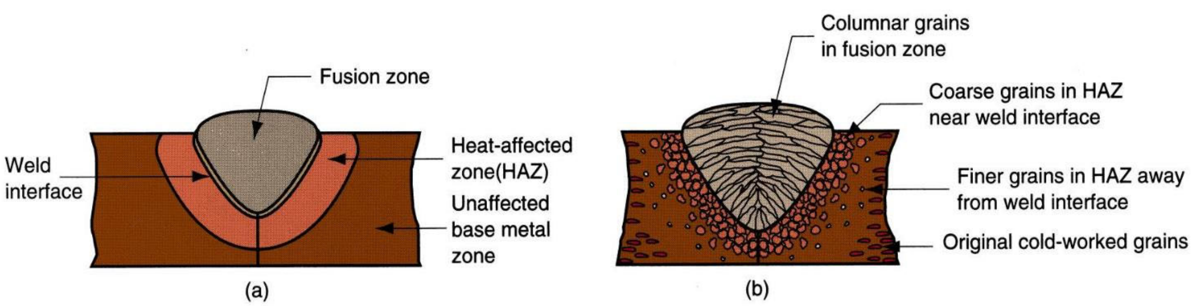
Thermal changes and weld defects

Cross section of a typical fusion welded joint: (a) principal zones in the joint, and (b) typical grain structure.



Mechanical properties are generally weaker in the HAZ (Heat Affected Zone), and this is *typically were failures occur*.

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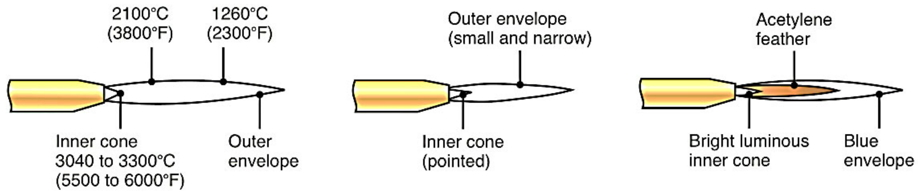
OxyFuel (e.g. oxyacetylene) flame temperature

Flame formed by acetylene (C_2H_2) and oxygen produces the highest flame temperature.



(a) Neutral flame — **1:1 ratio of gases**

(b) Oxidizing flame — **Oxygen rich**

(c) Carburizing (reducing) flame — **Acetylene rich**

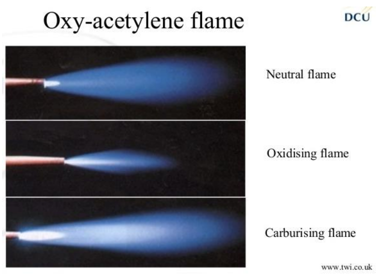


Table O-1
Oxyacetylene Flame Temperatures

Ratio of Oxygen to Acetylene	Type of Flame	Temperature °C	Temperature °F
0.8 to 1.0	Carburizing	3065	5550
0.9 to 1.0	Carburizing	3150	5700
1.0 to 1.0	Neutral	3100	5600
1.5 to 1.0	Oxidizing	3427	6200
1.8 to 1.0	Oxidizing	3482	6300
2.0 to 1.0	Oxidizing	3370	6100
2.5 to 1.0	Oxidizing	3315	6000

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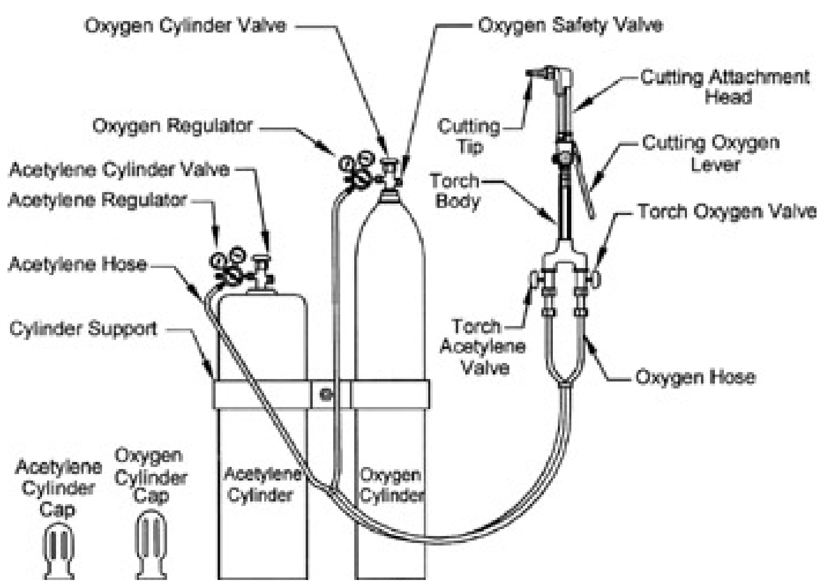
OxyFuel (e.g. oxyacetylene) part identification



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Oxyacetylene: lighting and setting the torch

1. Make sure your environment is free of flammable material
2. Open both gas cylinders, check for sufficient pressure.
3. Open “Oxy” valve on the torch, and set the output pressure of the oxygen gas to ~10 psi.
4. Clock-wise turning, increases regulator output pressure.
5. Close “Oxy” valve on the torch, open the “fuel” valve and set the output pressure to ~5 psi.
6. With the fuel flowing use the striker to light a flame.
7. Open “Oxy” valve and adjust to achieve a sharply defined inner cone with no outer feather.
8. When shutting down, first close the oxygen valve.

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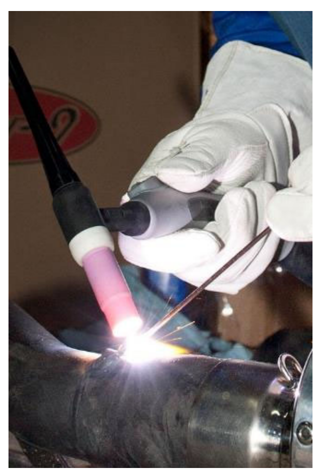
Welding

2. Operation & best practices



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Ways to minimize weld warpage

- Use welding *fixtures* to physically restrain parts
- Use *heat sinks* to rapidly remove heat
- *Tack weld* at multiple points before seam welding
- *Preheat* base parts, primarily aluminum
- Stress relief by annealing after welding
- Weld material in small increments

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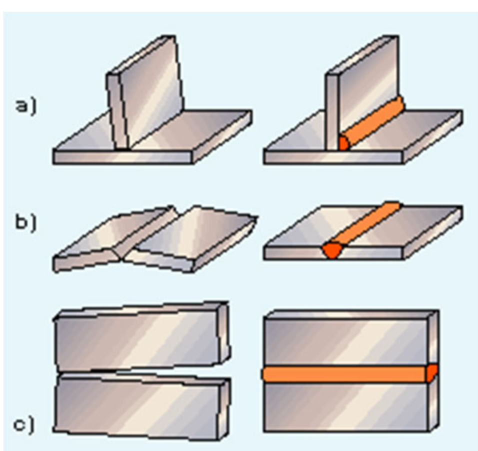
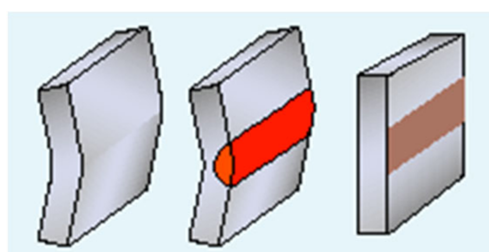
Pre-setting parts to prevent distortion





http://www.twi-global.com

Parts are pre-set by a pre-determined amount (often determined by experience) so that after welding parts are aligned correctly.

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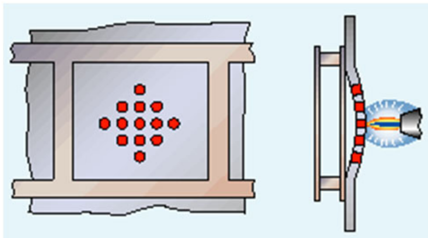
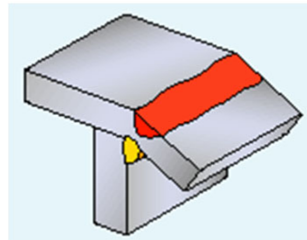
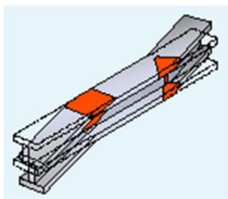
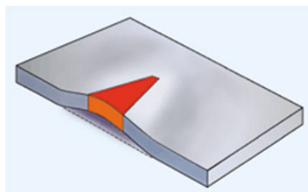
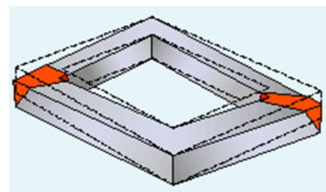
Melting and heating to remove distortion











Localized heating or melting can remove buckling in thin parts, or on the backside of a fillet welds can straighten angular distortions.

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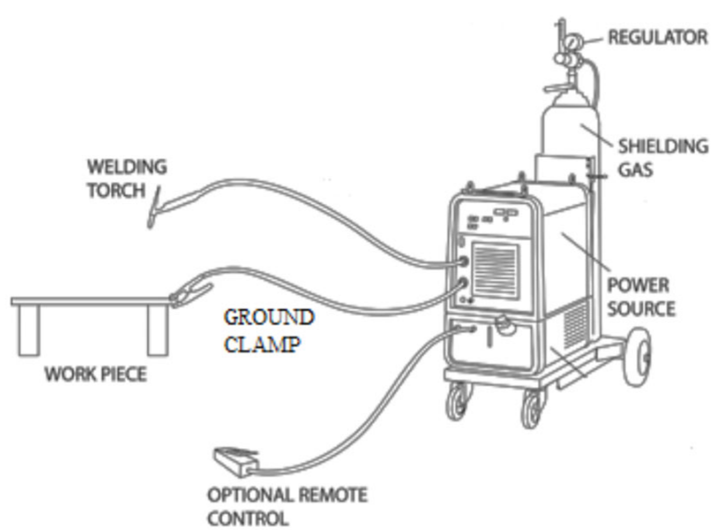
TIG welding part identification



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TIG welding electrical settings

Typically use 1 amp for each 0.001” of metal thickness

Use DC for welding steel or AC for welding Aluminum

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TIG and MIG ground clamp

- Completes the circuit, allows electrode to arc and allows electricity to flow through the part.
- Should be clamped as close to work piece as possible

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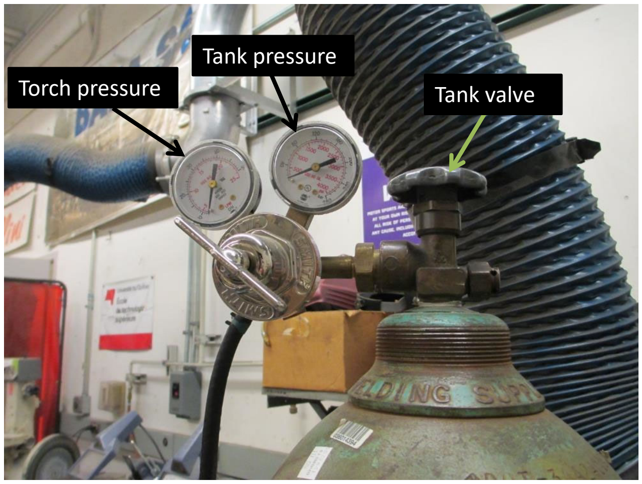
TIG welding gas tank part identification



Typically gas pressure to the torch is 15-20 cubic feet per hour (cfh).

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Incorrect gas glow causes inclusions & porosity

- Pressure should be adjusted to achieve between 15-25 cubic feet per hour (cfh).
- Don't assume a higher rate is better. High flow rates can create turbulence that pulls in contaminants and also cause arc wondering.

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Gas cylinder safety

- Cylinder caps MUST be on the tank BEFORE you remove the restraining chain or move a tank without a cart.
- Never drag a cylinder - roll it back and forth to move it.
- Cylinder must always be in the upright position.
- Chains should secure tank between midpoint and top shoulder.
- Do not leave tanks in egress routes.
- Never paint a cylinder.
- Separate full tanks from empty tanks.

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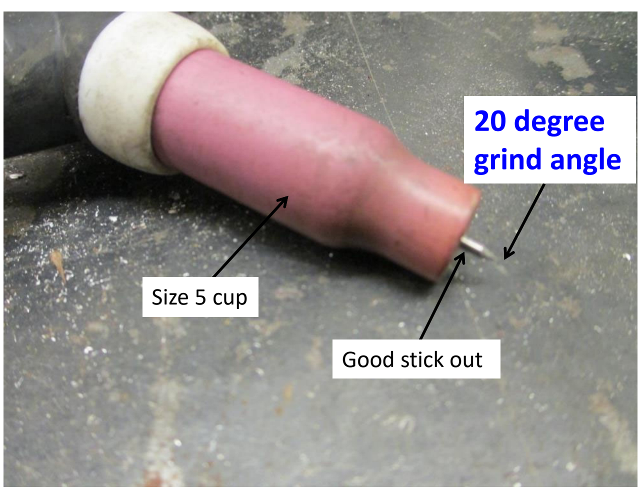
TIG welding torch end



Tip sticks out $^{3}/_{16}$" to $^{1}/_{4}$"

Keep tip about the same distance above the surface.

Steel has sharp tip, aluminum needs a rounded tip

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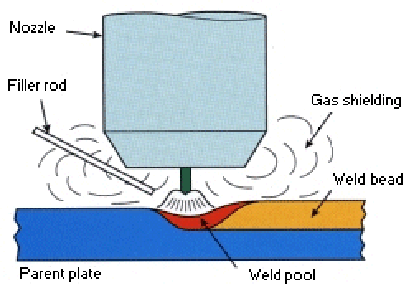
Weld puddle / pool

- Will appear as a bright circle when welding and is the section of the weld that is currently liquid.
- Controlling the puddle is key to making a good weld.



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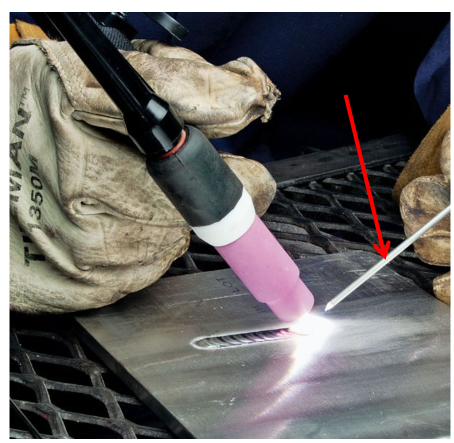
Filler rod

- Filler rod is coated in a protective layer but is made up of the same metal as the base part.
- Filler rod is added to the weld manually.
- Should be dipped into the puddle and quickly removed



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Welder setup videos

- How to set up a TIG welding torch
  www.youtube.com/watch?v=u8a999EIXfc
- Holding a torch and grinding tungsten
  www.youtube.com/watch?v=QSfeWtmWynI&t=1m22s
- Torch angle and tip preparation
  www.youtube.com/watch?v=tNYmo2_DI6c&t=39s
- Safety and setting up gas cylinder
  www.youtube.com/watch?v=bWIKtsiR68w&t=52s

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Welding technique videos

- Basic TIG & MIG welding techniques

  www.youtube.com/watch?v=VEEpikDY058&t=30s
- TIG welding troubleshooting – too hot or cold, too far or close

  www.youtube.com/watch?v=CVAByfuZXIY&t=113s
- TIG welding troubleshooting – tungsten tip and gas flow

  www.youtube.com/watch?v=RTH49rGzspM

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Rules of welding

- If something seems wrong STOP, remove foot from peddle, move torch away from work part and check your setup.
- Do not let the electrode touch the work part or the weld puddle.
- Remove paint and any coating at least 1” from weld area.
- Always clamp parts tight, heat from welding causes large warpage in work part.
- To get good at welding takes a lot of practice.

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What to do before welding

1. You MUST have a buddy to weld
2. Remove flammable material from your work area.
3. Check for proper PPE
4. Open argon tank gas valve
5. Securely connect ground clip to the work part
6. Check tungsten electrode length and tip cleanliness
7. Turn on welder
8. Adjust torch argon pressure

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What to do during welding

1. Flip mask down.
2. Hold torch near part (~2 mm away)
3. Slowly step on peddle until arc starts.
4. Adjust current with foot.
5. Weld (explained on next slide)
6. When done welding, stop pressing peddle.
7. Post-flow of argon prevents contamination: HOLD TORCH OVER WELD FOR ~7 sec.

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Welding technique best practices

1. Create weld pool and ensure proper size.
2. Slightly zig zag torch along weld path.
3. Dip filler rod into weld pool to add material as needed.
4. Take care not to melt a complete hole in work part.

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What to do after welding

1. Close argon tank gas valve
2. Empty gas line pressure to the torch
3. Turn off welder
4. Remove ground clip from work part
5. Wait for torch and work part to cool before moving them
6. Disassemble torch and clean up

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Welding

3. Safety

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Dangers when welding

1. Very High Heat
2. High Electric Current
3. Very Bright Light
4. UV Radiation
5. Dangerous Fumes

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Biggest concern is the very high temperature

- Problem:
  - Burns
- PPE Needed:
  - Welding gloves
  - Face shield – welding helmet
  - Long sleeves
  - Pants
- Precautions:
  - Don't touch recently welded parts
  - Pay attention where your filler rod is when it is hot

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High temperature safety

- Problem:
  - Starting a nearby fire
- Precautions:
  - Do not weld within 10 feet of flammable cabinets.
  - Don't have any flammables within 10 feet of the welding area, including trash cans!
  - "Buddy" is on "fire watch" during welding.

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9853

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High electric current safety

- Problem:
  - Shocking yourself or potential electrocution.
- Precautions:
  - Always have the grounding clip on the work part.
  - Always work with a buddy, within line of sight.

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Very bright light safety

- Problem:
  - Eye damage
- PPE needed:
  - Welding helmet
- Precautions:
  - Don't look straight at someone else welding without a welding helmet

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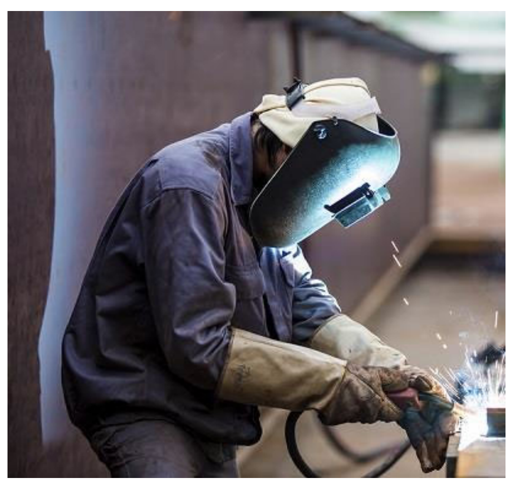
UV radiation safety

- Problems:
  - Sunburn
  - Eye damage
- PPE Needed:
  - Welding helmet
  - Long sleeves
  - Pants



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Dangerous fumes safety

- Problems:
  - Lung damage
  - Cancer
  - Kidney damage
- Precautions:
  - Do only in a well ventilated area (e.g. place snorkel intake as close as reasonably possible to the welding.)

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What is in welding fumes?

- Metals:
  - Aluminum, Antimony, Arsenic, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Molybdenum, Nickel, Silver, Tin, Titanium, Vanadium, Zinc.
- Gases:
  - Shield gas: Argon, Helium, Nitrogen, Carbon Dioxide.
  - By products: Nitric Oxide, Nitrogen Dioxide, Carbon Monoxide, Ozone, Phosgene, Hydrogen Fluoride, Carbon Dioxide.
- Chromium is in stainless steel, and can be converted to its hexavalent state which is highly toxic.
  No student welding of stainless steel or galvanized at ESPL!

https://www.osha.gov/Publications/OSHA_FS-3647_Welding.pdf

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Ventilation safety

- Acute exposure to welding fumes and gases can result in *eye*, *nose* and *throat irritation*, *dizziness* and *nausea*.
- If you experience symptoms, *shut down* equipment and leave area immediately; *seek fresh air and medical attention*.

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Welding safety summary

- Welding takes a lot of practice to master.
- Proper setup can improve welds and make learning easier.
- Welding has a number of very serious dangers:
  - Heat burns
  - Blinding light
  - Electric shock
  - Fires
  - Gas cylinders under pressure
- There is a lot to keep track of – let your buddy help to keep everyone safe!

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