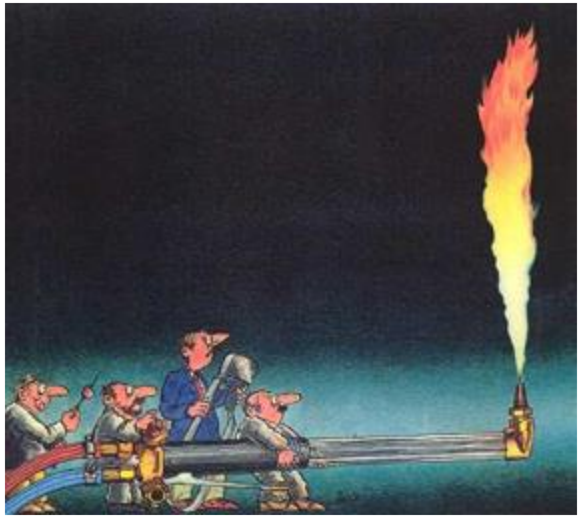
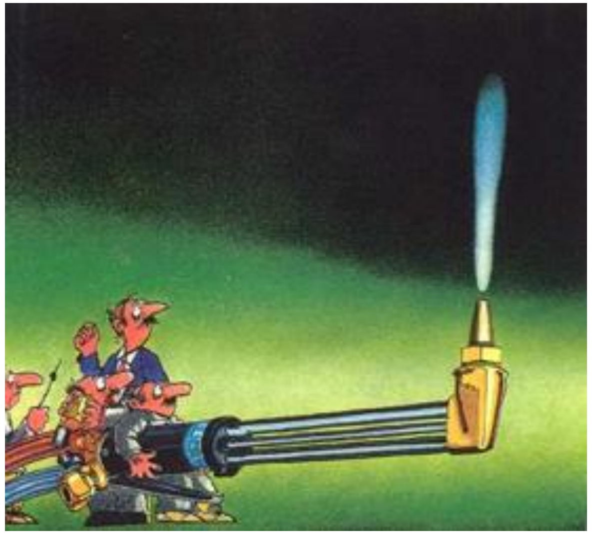
Sheet metal / plate cutting

Gas cutting



- Oxy-fuel cutting is a thermal cutting process that uses oxygen and fuel gas (such as acetylene, propane, MAPP, propylene and natural gas) to cut through materials.
- The oxyfuel process is the most widely applied industrial thermal cutting process because it can cut thicknesses from 0.5mm to 250mm, the equipment is low cost and can be used manually or mechanized.
- There are several fuel gas and nozzle design options that can significantly enhance performance in terms of cut quality and cutting speed.



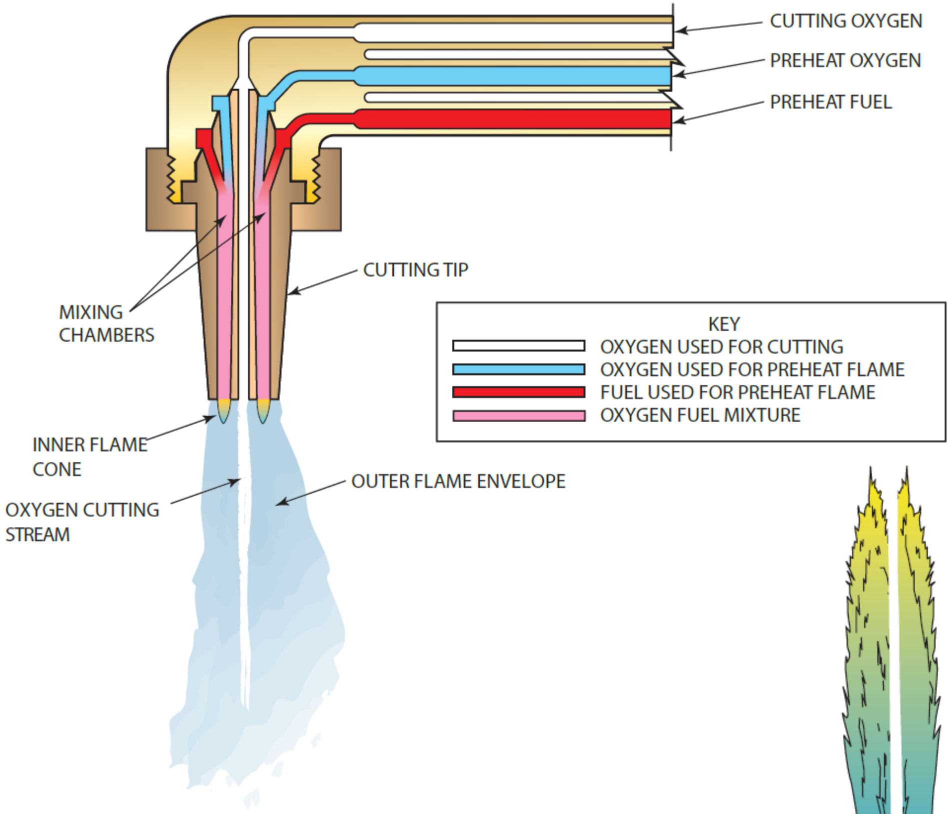
Oxy-fuel cutting

- Oxyfuel gas cutting (OFC) is a group of oxygen cutting processes that use heat from an oxyfuel gas flame to raise the temperature of the metal to its kindling temperature before a high-pressure stream of oxygen is directed onto the metal, causing it to be cut.
- Oxyfuel gas cutting is most commonly performed with oxyacetylene cutting (OFC-A).

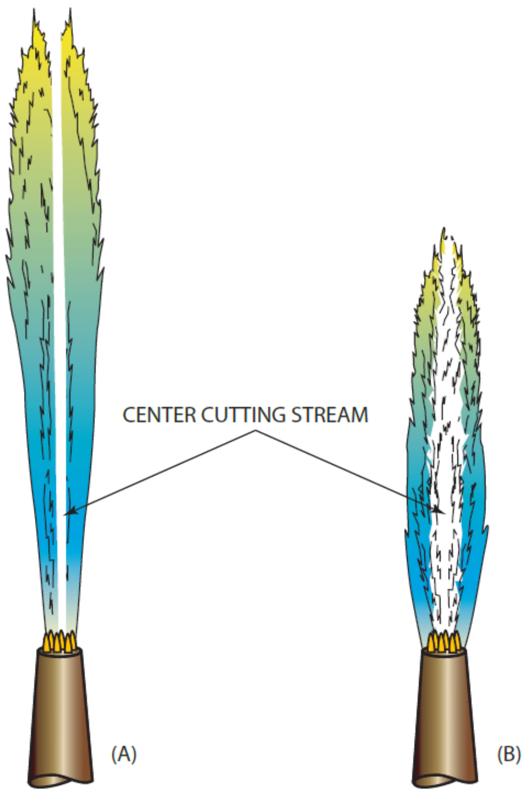
Fuel Gas	Flame (Fahrenheit)	Temperature* (Celsius)
Acetylene	5589°	3087°
MAPP®	5301°	2927°
Natural gas	4600°	2538°
Propane	4579°	2526°
Propylene	5193°	2867°
Hydrogen	4820°	2660°

The Chemistry of a Cut

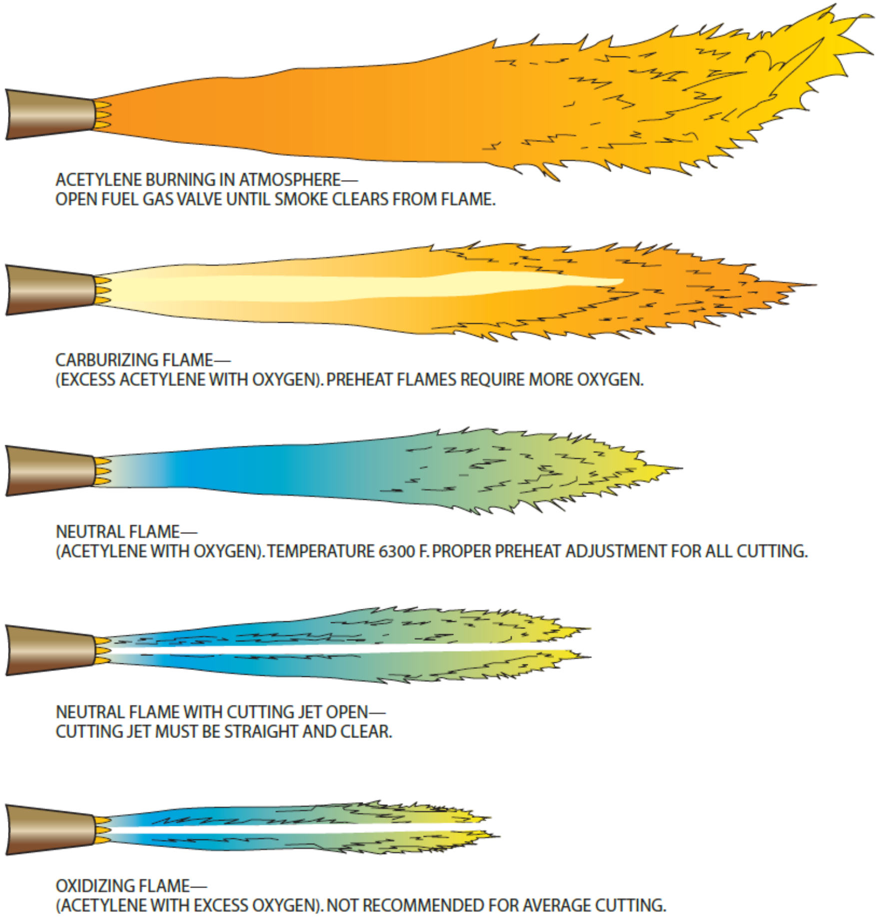
- The oxyfuel gas cutting torch works by first preheating the metal to its kindling temperature before a high-pressure stream of pure oxygen is turned on to rapidly oxidize or burn the metal away.
- Kindling point and kindling temperature are two terms that have the same meaning; they refer to the lowest temperature at which a material will combust or start burning.
- Combustion is a chemical reaction with heated iron (Fe) and high-pressure oxygen (O). The oxygen forms an iron oxide, primarily Fe3O4, that is light gray in color.
- As with any combustion process, heat is produced as the metal is burned. This heat helps carry the cut along.



CUTTING OXYGEN
PREHEAT OXYGEN
PREHEAT FUEL
CUTTING TIP
MIXING CHAMBERS
INNER FLAME CONE
OXYGEN CUTTING STREAM
OUTER FLAME ENVELOPE
KEY
OXYGEN USED FOR CUTTING
OXYGEN USED FOR PREHEAT FLAME
FUEL USED FOR PREHEAT FLAME
OXYGEN FUEL MIXTURE



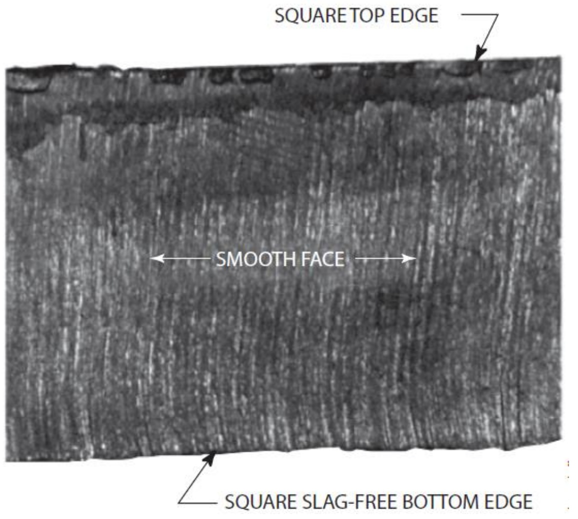
CENTER CUTTING STREAM
(A)
(B)

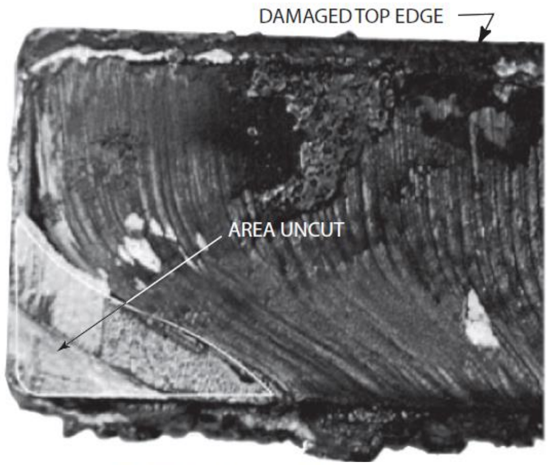


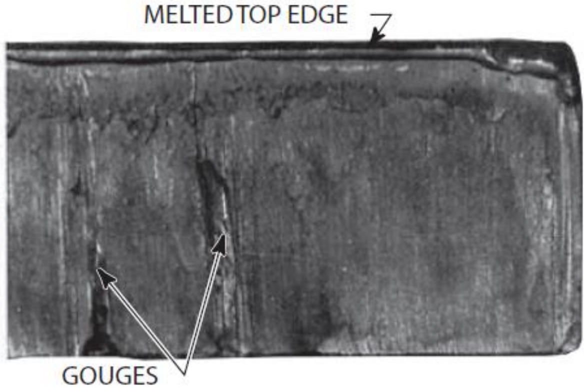
ACETYLENE BURNING IN ATMOSPHERE—
OPEN FUEL GAS VALVE UNTIL SMOKE CLEARS FROM FLAME.
CARBURIZING FLAME—
(EXCESS ACETYLENE WITH OXYGEN). PREHEAT FLAMES REQUIRE MORE OXYGEN.
NEUTRAL FLAME—
(ACETYLENE WITH OXYGEN). TEMPERATURE 6300 F. PROPER PREHEAT ADJUSTMENT FOR ALL CUTTING.
NEUTRAL FLAME WITH CUTTING JET OPEN—
CUTTING JET MUST BE STRAIGHT AND CLEAR.
OXIDIZING FLAME—
(ACETYLENE WITH EXCESS OXYGEN). NOT RECOMMENDED FOR AVERAGE CUTTING.

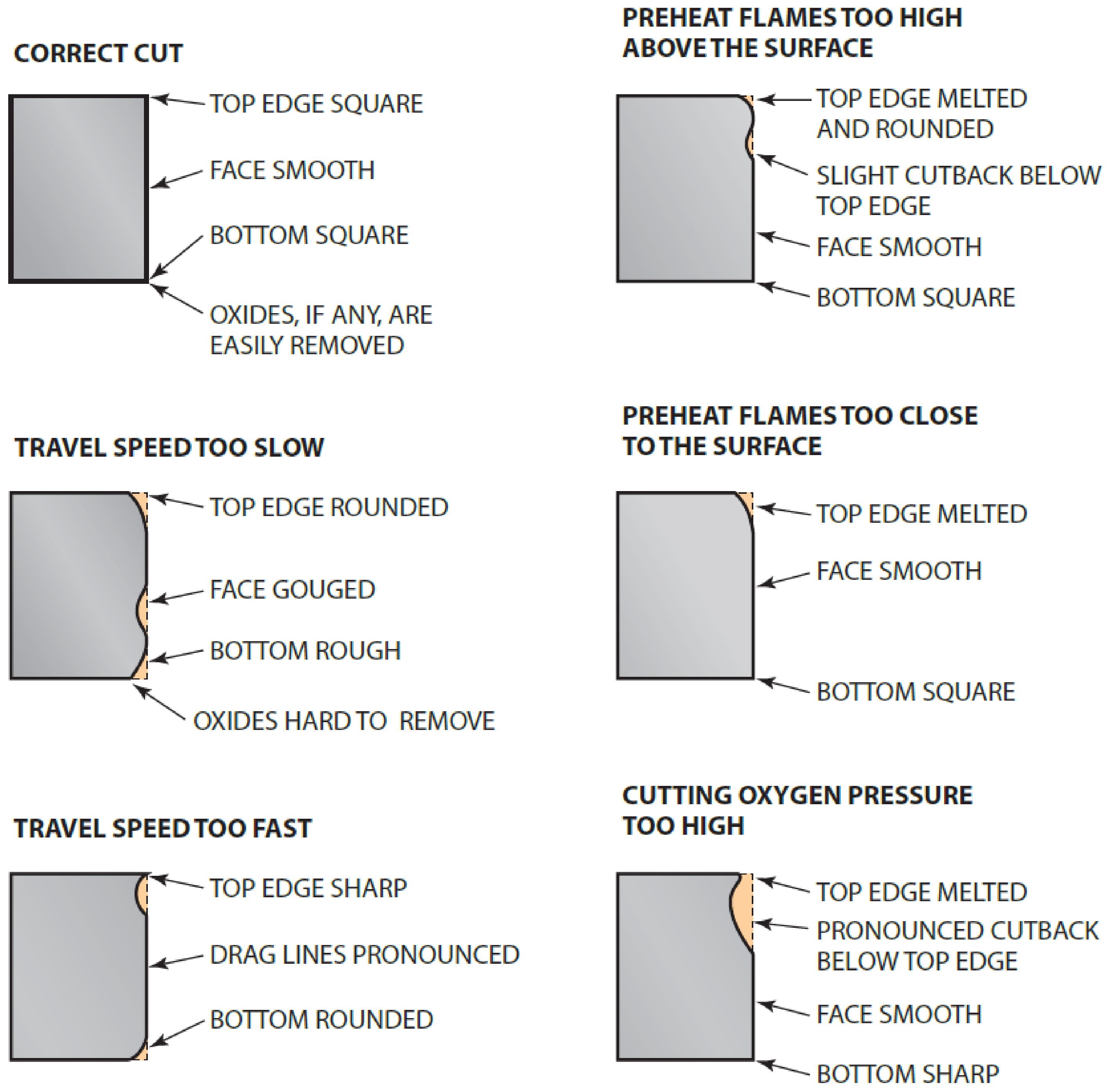
Physics of a Cut

- Preheat:
  - The size and number of preheat holes in a tip have an effect on both the top and bottom edges of the metal.
  - An excessive amount of preheat flame results in the top edge of the plate being melted or rounded off.
- Speed:
  - The cutting speed should be fast enough so that the drag lines have a slight slant backward.
  - If the cutting speed is too fast, the oxygen stream may not have time to go completely through the metal, resulting in an incomplete cut.
  - Too slow a cutting speed results in the cutting stream wandering, thus causing gouges in the side of the cut.
- Pressure:
  - A correct pressure setting results in the sides of the cut being flat and smooth.
  - A pressure setting that is too high causes the cutting stream to expand as it leaves the tip, resulting in the sides of the kerf being slightly dished.
  - When the pressure setting is too low, the cut may not go completely through the metal.

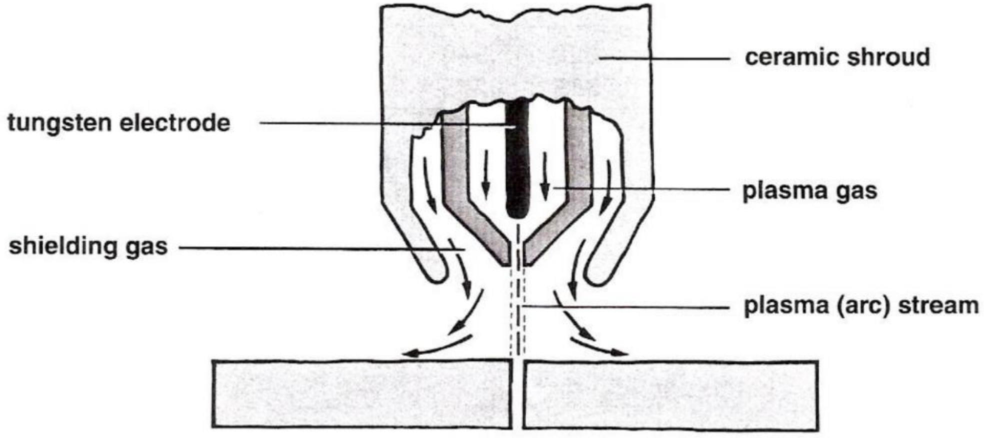






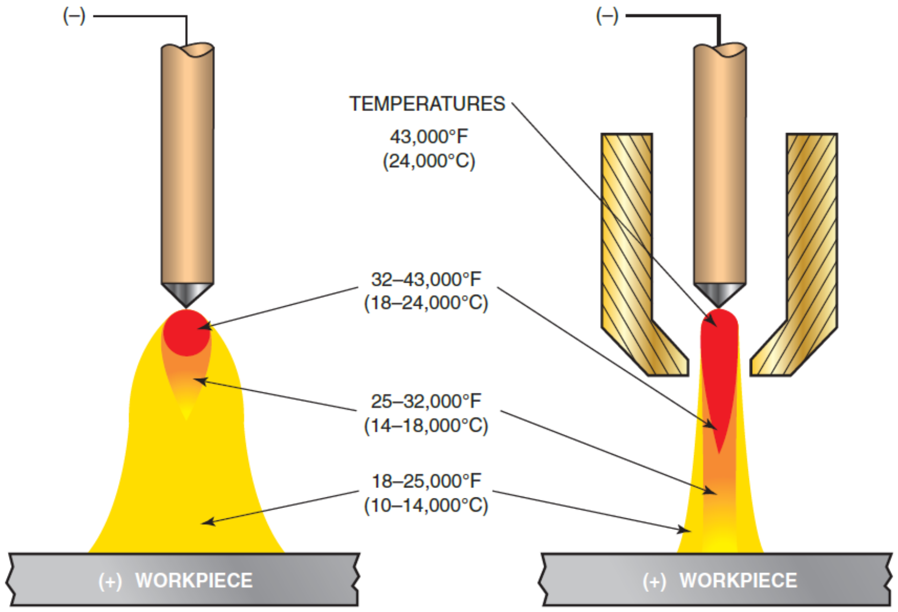

CORRECT CUT
TOP EDGE SQUARE
FACE SMOOTH
BOTTOM SQUARE
OXIDES, IF ANY, ARE EASILY REMOVED
PREHEAT FLAMES TOO HIGH ABOVE THE SURFACE
TOP EDGE MELTED AND ROUNDED
SLIGHT CUTBACK BELOW TOP EDGE
FACE SMOOTH
BOTTOM SQUARE
TRAVEL SPEED TOO SLOW
TOP EDGE ROUNDED
FACE GOUGED
BOTTOM ROUGH
OXIDES HARD TO REMOVE
PREHEAT FLAMES TOO CLOSE TO THE SURFACE
TOP EDGE MELTED
FACE SMOOTH
BOTTOM SQUARE
TRAVEL SPEED TOO FAST
TOP EDGE SHARP
DRAG LINES PRONOUNCED
BOTTOM ROUNDED
CUTTING OXYGEN PRESSURE TOO HIGH
TOP EDGE MELTED
PRONOUNCED CUTBACK BELOW TOP EDGE
FACE SMOOTH
BOTTOM SHARP

Plasma arc cutting



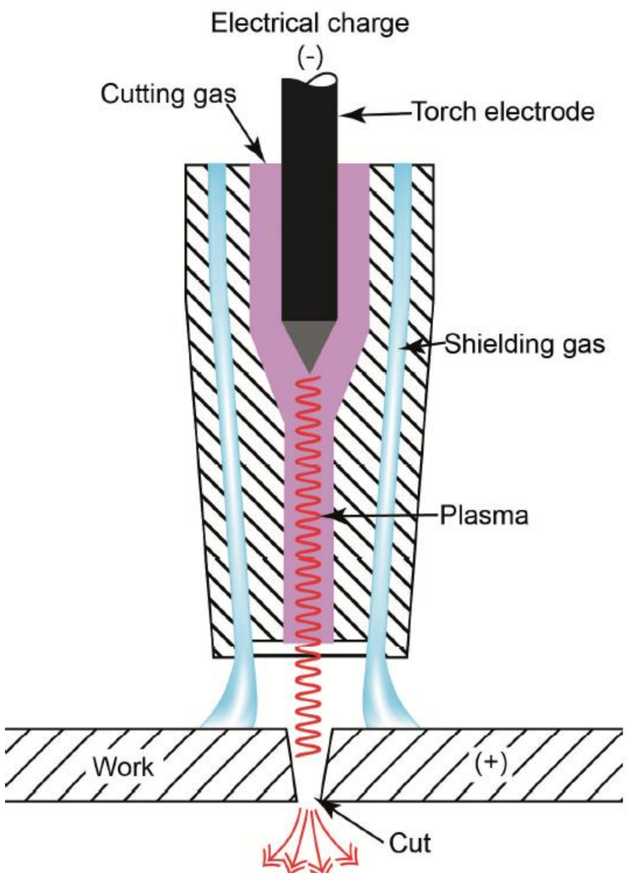
- Plasma is an electrically conductive gas.
- The ionisation of gases causes the creation of free electrons and positive ions among the gas atoms.
- Plasma cutters have the unique ability to cut metals without making them very hot.
- This means that there is less distortion and heat damage than would be caused with an oxyacetylene cutting torch.
- Very intricate shapes can be cut out without warping.
- The cuts are made by a high temperature, high velocity gas jet generated by constricting an arc between a tungsten electrode and the component.
- Stainless steel and non-ferrous metals such as aluminium.

- The plasma created by an arc is an ionized gas that has both electrons and positive ions whose charges are nearly equal to each other.
- The term arc plasma is defined as gas that has been heated to at least a partially ionized condition, enabling it to conduct an electric current.
- Plasma welding torches produce a low-velocity plasma and cutting torches produce a high-velocity plasma stream.
- Plasmas produce both high temperature and intense light.
- The amount of heat and light depends on the amount of energy in watts (volts and amps).



Plasma (Cutting) Gas Selection

- Selecting the proper gas for the material you are cutting is critical to get a quality cut.
- Plasma gas is also called the cutting gas.
- This is the gas that is ionised in the plasma process and exits through the nozzle orifice.
- Examples of plasma gas are:
  - Air
  - Oxygen
  - Nitrogen
  - Argon-Hydrogen



There are a number of variations of the conventional plasma cutting process such as:

- Duel gas plasma cutting
  - This process uses two different gasses, one for the plasma and one as an external shielding gas.
  - Shielding gas to protect the cut surface, it will be much cleaner and free from oxides and nitrides.
- Water injected plasma cutting
  - This process uses a concentrated column of water surrounding the plasma column.
  - The water column concentrates the plasma stream by increasing its swirl, resulting in a higher density and increased temperature for faster mechanized cutting.
- Water shielding plasma cutting
  - The large quantity of water in this process is used to cool the torch and reduce the sound and reflected light.
  - This mechanized cutting process uses a much higher water flow than does the water injection process.
- Precision plasma cutting
  - This mechanized process is used on thinner materials at slower cutting speeds so that very accurate cuts can be made.

Cutting speed

- Manufacturers have developed charts that list various types of materials, thicknesses of materials, and the recommended cutting speed.
- The charts may also include information regarding the maximum cutting speed for each material and thickness.
- The higher speeds do not produce the same high-quality cuts as the recommended cutting speeds.
- For a given electric power and gas mixture, there is an optimum speed range for each type and thickness of material.
- Excess speed causes a decreased kerf width with an increased bevel but current intensity is the main factor determining kerf width.

Mild Steel

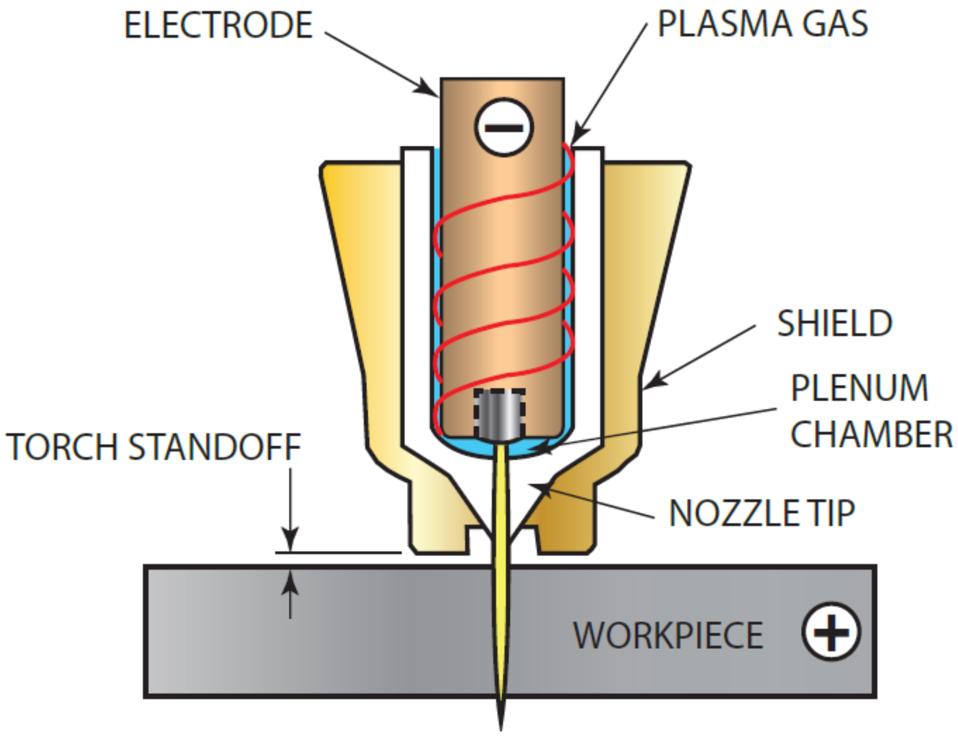
Arc Current	Arc Voltage	Pierce Delay	Material Thickness		Recommended Cut Speed		Maximum Cut Speed	
			in	mm	ipm	mm/min	ipm	mm/min
100	153	0.5	1/4	6.4	135	3429	208	5283
	155	0.5	3/8	9.5	77	1955	119	3022
	159	1.0	1/2	12.7	57	1447	88	2235
	160	1.0	5/8	15.9	40	1016	61	1549
	161	1.5	3/4	19.0	26	660	47	1193
	163	NA	1	25.4	18	457	28	711
	167	NA	1 1/4	31.8	12	305	19	482

Metals

- Any material that is electrically conductive can be cut using the PAC process.
- In a few applications nonconductive materials can be coated with conductive material so that they can be cut also.
- However, it is possible to make cuts in metal as thick as 7 in. (180 mm) or more.
- The most popular materials cut are carbon steel up to 1 in. (25 mm), stainless steel up to 7 in. (180 mm), and aluminum up to 6 in. (150 mm).
- Other metals commonly cut using PAC are copper, nickel alloys, high-strength, low-alloy steels, and clad materials.

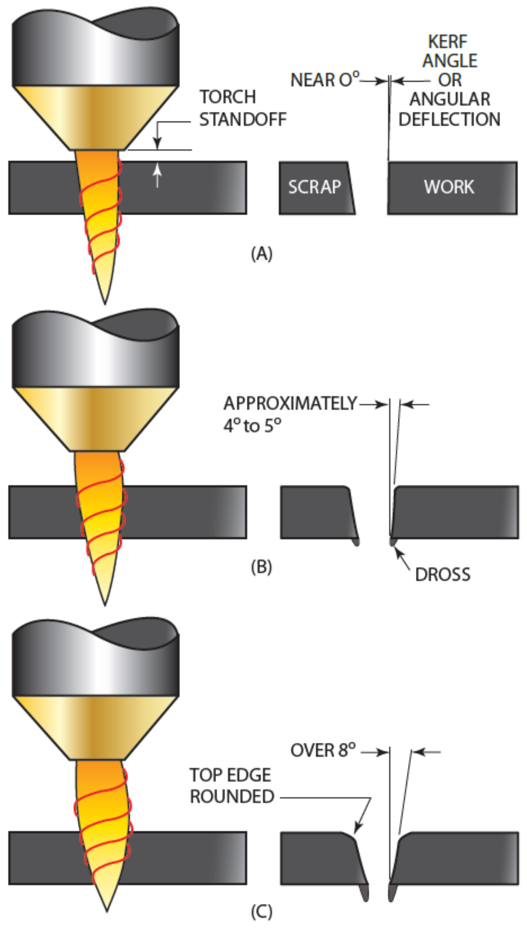
Torch Standoff Distance

- The torch standoff distance is the distance from the nozzle tip to the work.
- This distance is very critical to producing quality plasma arc cuts.
- As the torch is raised, increasing the standoff distance, the arc force is diminished.
- The plasma stream loses some of its stiffness and is constricted by the metal's resistance to being cut. This causes the kerf angle or angular deflection to increase.



SoD and Kerf

- The terms *kerf angle* and *angular deflection* refer to the squareness of the cut.
- At the correct standoff distance the work side of the cut is nearly square.
- As the distance increases and the plasma stream begins to be deformed, the kerf angle increases and dross begins to form on the bottom edge as the top edge starts to be rounded.
- As the torch is raised further above the metal surface, the kerf angle begins to rapidly increase.

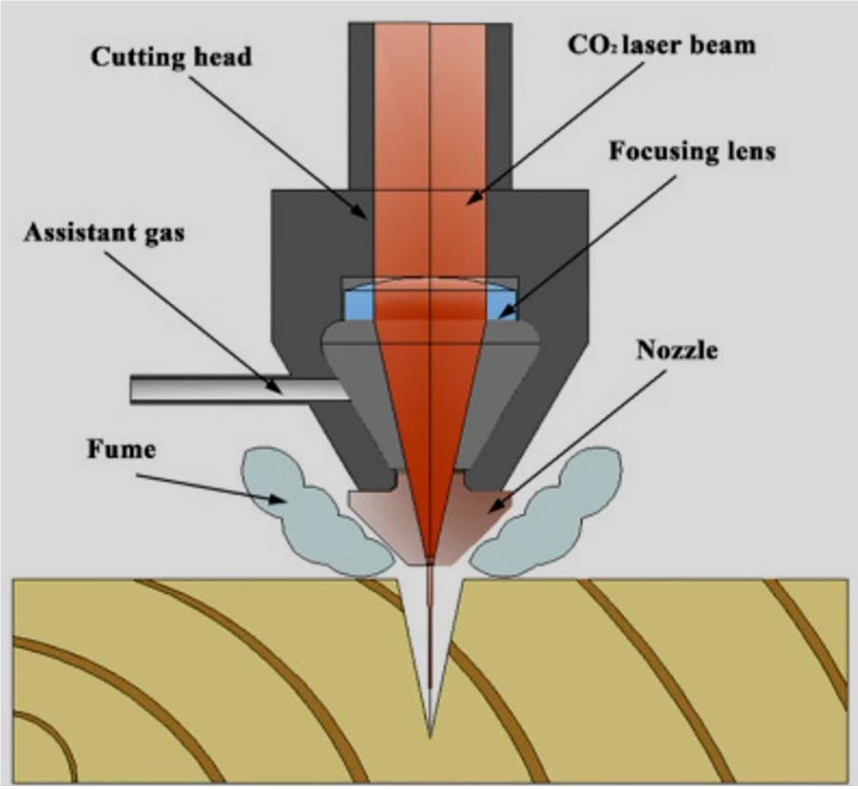


Kerf

- The kerf is the space left in the workpiece as the metal is removed during a cut.
- The width of a PAC kerf is often wider than that of an oxyfuel cut.
- Several factors will affect the width of the kerf.
  - *Standoff distance*
    - The closer the torch nozzle tip is to the work, the narrower the kerf will be.
  - *Orifice diameter*
    - Keeping the diameter of the nozzle orifice as small as possible will keep the kerf smaller.
  - *Power setting*
    - Too high or too low of a power setting will cause an increase in the kerf width.
  - *Travel speed*
    - As the travel speed is increased, the kerf width will decrease; however, the bevel on the sides and the dross formation will increase if the speeds are excessive.

Laser cutting

- Laser cutting
  - Pyrolytic
  - Photolytic
- Pyrolytic
  - Material removal is due to heating of the substrate material.
  - Melting and evaporation.
  - Pulsed laser producing light in the infrared or visible part of the spectrum (Nd:YAG and CO2) are used.



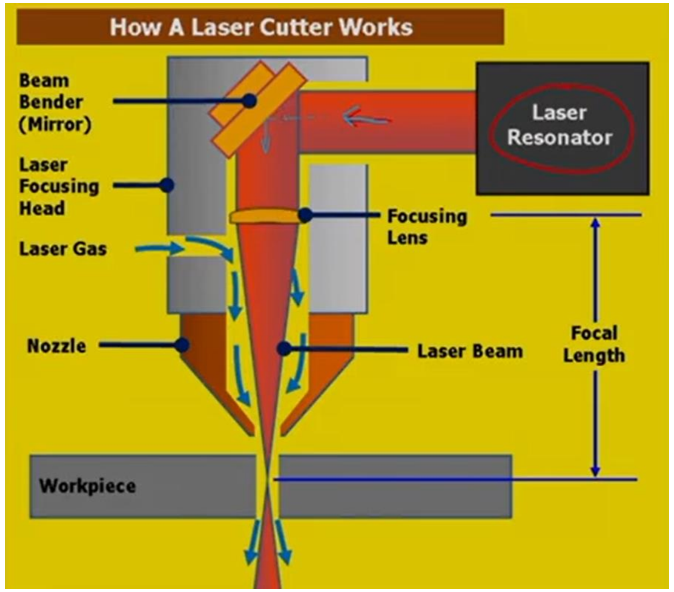
- The power density in the laser spot should be the order of 106 W/cm2 or higher.
- Material melts and some of it evaporates at the bottom of the hole created.
- Rapid expansion of the vapour > a steep pressure gradient arises with the surrounding atmosphere > causes the molten material and vapour to be rapidly ejected from the hole (‘molten ejection’).
- Generate recast layer on the inside wall of the hole.
- Sometimes builds up the dross at the entrance or exit of the hole.
- At higher power densities (over 108 W/cm2) material removal by evaporation is controlled > less cast build up and better hole quality.

- The laser penetrates to the substrate depending on the wavelength of the laser and refractive index.
- The high electric field generated due to laser light removes the electrons from the substrate.
- The generated free electrons collides with the atoms of the substrate > transfer energy > heating the surface > vaporization.
- The pressure between the seed plasma and the atmosphere lead to a rapids expansion and cooling of the plasma.
- The process takes place in vaccum or gaseous environment.

- **Photolytic process**
  - Material removal from the breaking of chemical bonds.
  - To break molecular bonds, the energy level of each single photon must be higher than the bond energy, of the order of few electron volts.
  - Excimer lasers emit light of very short wavelength (i.e. in the UV spectrum)
  - The photon energy is then in the range of 4 to 8 eV, powerful enough to break many of the molecular bonds of natural and synthesized materials.

Arrangements of laser cutting

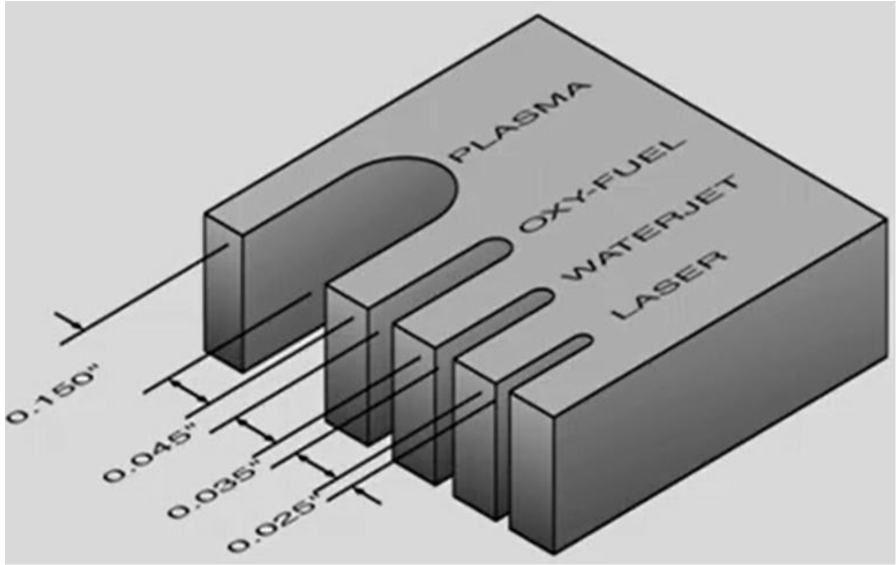
- Laser cutting-
  - Thermal process
  - Focused laser beam is used to melt material in localized area.
  - A co-axial gas jet is used to eject the molten metal and create a kerf.
- A continues cut is generated by stirring the laser beam on workpiece under CNC control.
- There are three major categories of laser cutting
  - Fusion cutting
  - Flame cutting
  - Remote cutting

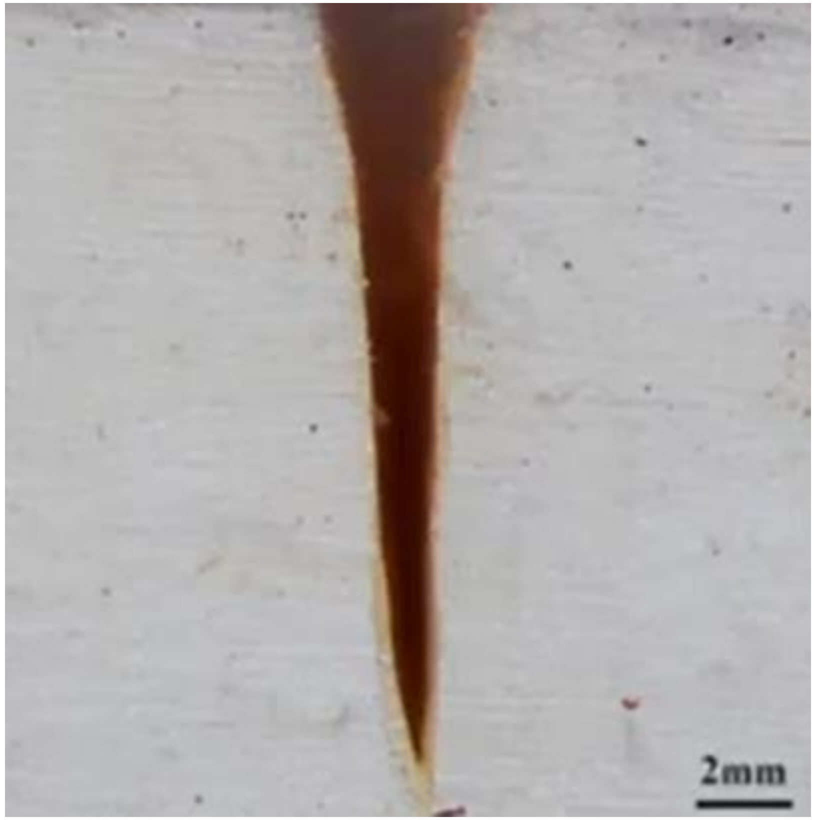


- *Fusion cutting*
  - An inert gas (typically nitrogen) is used to expel the molten material out of kerf.
  - Nitrogen gas does not exothermically react with the molten material > does not contribute to the energy input.
- *Flame cutting*
  - Oxygen is used as the assistant gas.
  - Exerts mechanical forces on the molten material + creates an exothermic reaction > increases the energy input to the process.
- *Remote cutting*
  - The material is partially evaporated (ablated) by a high intensity laser beam allowing thin sheets to be cut with no assist gas.

Kerf in laser cutting

- The laser burns away a portion of material when it cuts through.
- Kerf is width of material that is removed by a cutting process.
- Kerf shape
  - V-shaped
  - A taper wall where the upper part is wider, the kerf gradually narrows down until the width of the lower part becomes zero.





- Striations are formed at the top of the surface during laser cutting according to cutting speed.
- Striation, i.e. periodic lines appearing on the cut surface, is one of the most important quality factors in laser cutting.
- It affects the surface roughness, appearance and geometry precision of laser cut products.