Plasma Cutting & Gouging

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Plasma cutting & gouging can be performed on all current carrying materials simply by utilizing the compressed air on-board the vessel. Flame cutting processes like Oxy- Acetylene and Oxy- Propane cutting and gouging can be performed on steel only.

Whether you are performing maintenance work on site or do manufacturing of parts in the engine workshop, plasma cutting and gouging offers unlimited possibilities for cutting all types of steel, aluminium, copper alloys, stainless steel, nickel alloys and titanium. In this article we clarify the most important questions and important facts about plasma cutters and how to practically perform plasma cutting and gouging safely onboard.

Background

Why is it that we only can use the flame cutting processes on steel?
In order for a metal to be cut by flame (oxy-acetylene/ oxy-propane) the following must apply:

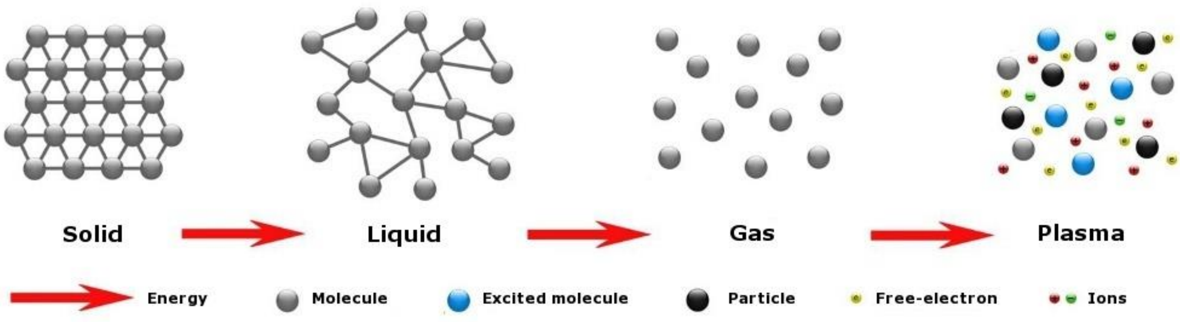
- The melting point of the metal must be above the ignition point of the metal. This is ok for steel that can be ignited at 900 °C (1652°F) and melt at 1550 °C (2822°F). This is not the case for Cast Iron that will melt before ignition point have been reached.
- The metals oxides (all metals form an oxide with oxygen in air that we refer to as rust) should melt before the metal itself. This is not the case for Aluminum that melts at 658 °C (1216 °F) but the aluminum oxides melt at 1926 °C (3500 °F).
- The heat produced by the combustion of the metal with oxygen must be sufficient to maintain the flame cutting operation. Aluminum and copper are good thermal conductors that fast transport the heat away from the cutting location.
- The thermal conductivity of the metal must be sufficiently low to bring the material to its ignition temperature. The same problem as above condition apply.
- The metals oxides formed during cutting must be sufficient fluid so as not interrupt the cutting operation. Cast iron have a thick sluggish silicate oxide that makes an oxy-acetylene cut difficult to maintain. Non-ferrous metals such as aluminum and copper also have refractory oxides (oxides that are chemically and physically stable at high temperatures) coverings, which prohibit normal flame cutting. Stainless steel cannot be flame cut with standard flame cutting equipment and technique because of the refractory chromium oxide.

Steel fulfil all the above conditions so it can be flame cut.

In Plasma cutting only one condition must apply in order to perform cutting:

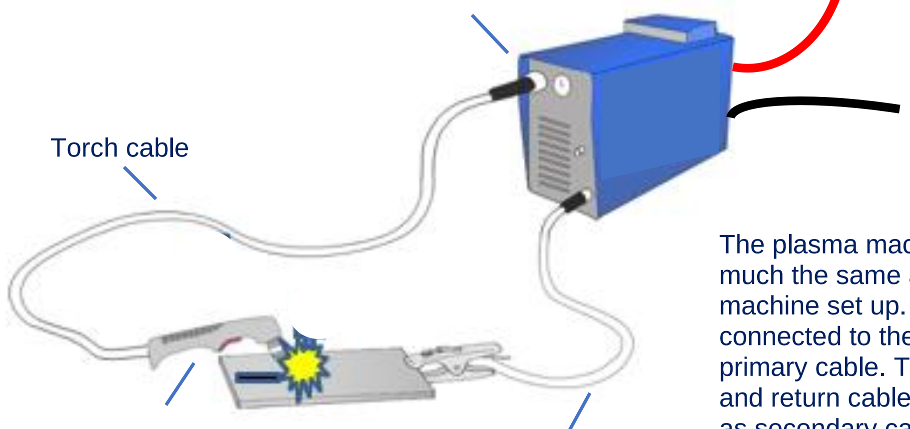
- The metal must be electric conductive.

Plasma is the fourth state of matter. We normally think of the three states of matter as Solid, Liquid and Gas. For the most commonly known element water, the three states are Ice, Water and Steam. The significant difference between these states relate to the energy level. If we add energy in the form of heat to ice, the ice melts and the result is water, a liquid. If we add more energy to water, it vaporizes to steam, a gas. If we add more energy to the gas, it becomes ionized gas, Plasma gas. The gas has become electric conductive. At a temperature of between 2000 °C (3600 °F) and 10000 °C (18000 °F) a process of ionization and dissociation of the gas molecules takes place.



The molecules are split in molecular and atomic ions and free electrons. When this happens, the gas, which has now become plasma, is electrically conductive because free electrons are available to carry current. A plasma torch uses an alloy copper nozzle to constrict the ionized gas stream to focus the energy to a small cross section. The gas flowing through the nozzle also serves as a medium to remove the molten metal heated by the ionized gas. Approximately 30% of gas is actually ionized (under optimum conditions) while the remaining 70% of the gas stream is used for material removal and cooling.

Plasma cutting/ gouging machine

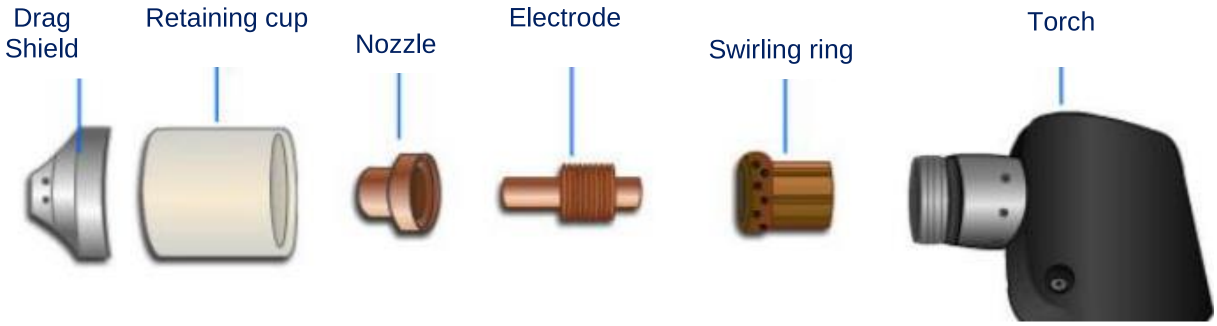


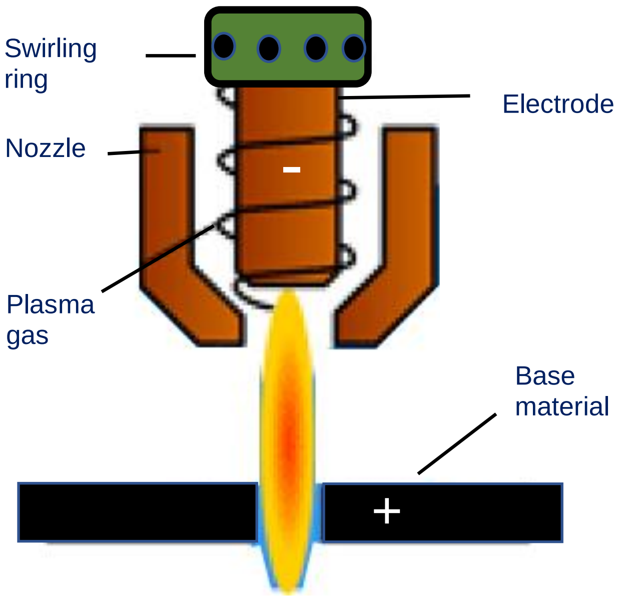
The plasma machine set up looks much the same as a welding machine set up. A power source connected to the mains by a primary cable. The torch cable and return cable are referred to as secondary cables. The additional item is the compressed air hose.

The power source function

– Converting AC input from the mains to constant current DC output. The open circuit voltage is typically in the range of 240 to 400 VDC. The output current (amperage) determines the speed and cut thickness capability of the system. The power supply is also to provide the correct energy to maintain the plasma arc after ionization.
– Safety Circuit to prevent accidental contact with the high open circuit voltage.
– Air flow Control. The power source is to provide the correct air pre-flow, pressure during cutting, and post-flow after cutting for cooling the torch, Water separator and filter is normally included to ensure clean, dry air.

The Plasma Torch





There are three major parts inside the torch body:

Electrode
Nozzle
Swirl ring (Baffle) that rotate the plasma gas)

These items are consumed over time during use and must be replaced. The electrode is connected to the negative side of a DC plasma power source. The nozzle is connected to the positive side for arc start, but is electrically isolated while cutting as the work piece is the positive side connected to the power source through the return cable.

The plasma cutter electrode:

The purpose of the electrode is to provide a starting point for the cutting arc. The electrode is made of copper with an insert of pure hafnium (Hf), the shiny button at the centre of the electrode. Hafnium is used because it releases electrons very easily and is resistant to oxygen from the air. Electrode consumption may be higher with compressed air than with pure nitrogen. When the hafnium insert is consumed, the electrode must be replaced. Replace the electrode if hafnium insert has a pit deeper than 2mm (1/16”).

The swirl ring (baffle) made of a high temperature plastic, assists cutting in many ways. To begin with, gas swirling helps cooling. Swirl gas improves cut quality. If plasma jet is not swirling, both kerf sides would be bevelled, sometimes to an extent that makes work-pieces useless. Some plasma cutting equipment swirls the gas in a clockwise direction, others in a counter clockwise direction. Check the manufacturer’s manual; the direction of flow will indicate which side of the cut will be bevelled.

The purpose of the nozzle is to constrict and focus the plasma arc. Constricting the arc increases the energy density and velocity. The tips are made of copper, with a specifically sized hole in the centre of the tip. Tips are sized according to the amperage rating of their respective torch. Replace nozzle if opening is deformed or 50% oversize. To ensure maximum cutting performance, replace the electrode and nozzles at the same time.

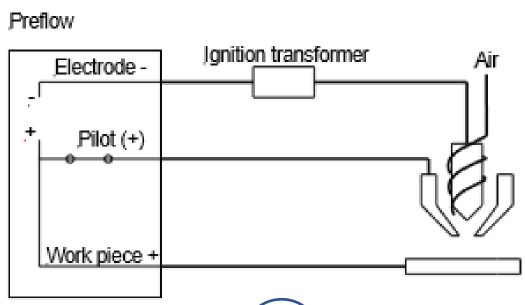
The retaining cup serves two functions. First, it holds the other consumable parts firmly in place. Second, it insulates and keeps the other consumable parts from making contact with the work piece.

The drag shield is constructed so that the required standoff is maintained inside the torch. Using drag cutting consumables allows the operator to drag the torch on the work piece while cutting at full output, which increases operator comfort and makes template cutting easier.

Arc Starting methods

Air is a good insulator, and plasma cutting requires that air is ionized in order to establish the current flow needed to form a plasma.

High frequency start. (1) In this method the arc starts without contact with the workpiece in a three-step process. (2) A high voltage spark briefly ionizes the air within the torch head. This makes the air conductive and allows the "pilot arc" to form. The pilot arc forms within the torch head, with current flowing from the electrode to the nozzle inside the torch head. The pilot arc burns up the nozzle, a consumable part, while in this phase. (3) The air then blows the plasma out the nozzle towards the work, providing a current path from the electrode to the work. (4) When the control system senses current flowing from the electrode to the work, it cuts the electrical connection to the nozzle. Current then flows from the electrode to the work, and the arc forms outside the nozzle. Cutting can then proceed, without burning up the nozzle. Nozzle life is limited by the number of arc starts, not cutting time. This method makes starting easy, but there is a penalty: high frequency can interfere with computers and other equipment. If the environment onboard involves sensitive PLC or PC controlled equipment, it’s important to choose alternate starting methods that eliminate that potential problem.



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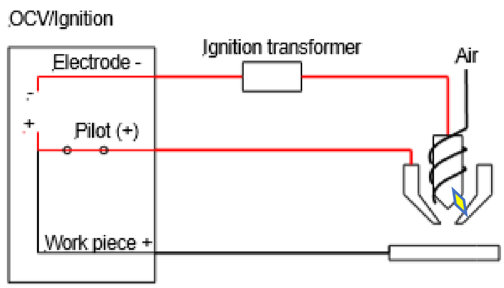

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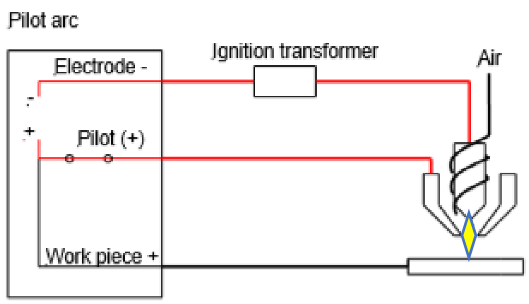

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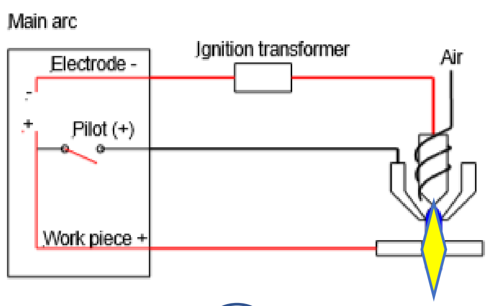

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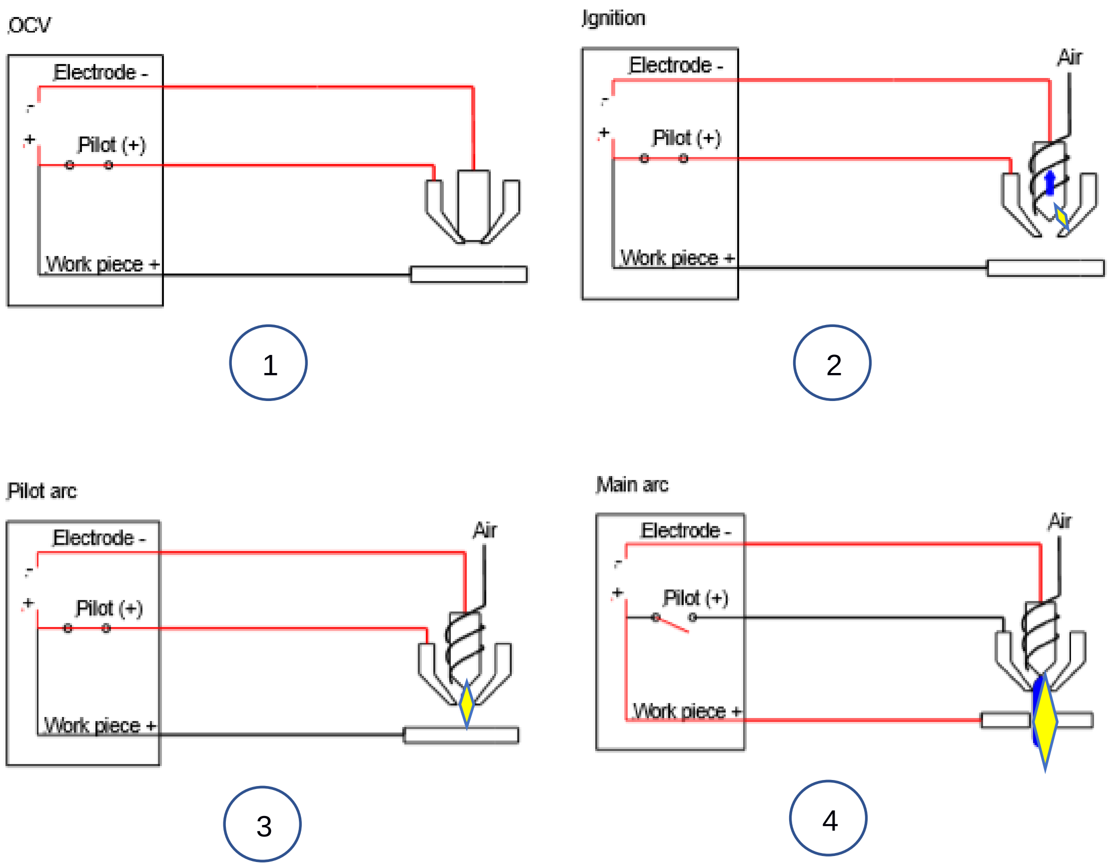
Lift arc method (blowback start). This method uses a DC positive nozzle with a DC negative electrode inside. (1) Initially, the nozzle and the electrode physically touch. When the trigger is pulled, current flows between the electrode and the nozzle. (2) The plasma gas (compressed air) builds up pressure and the electrode and nozzle are forced apart, which causes an electrical spark that converts the air into a plasma jet. (3) As the electrode pulls away from the nozzle, a pilot arc is established. (4) The transfer from pilot to cutting arc occurs when the pilot arc is brought close to the work piece. This transfer is caused by the electric potential from nozzle to work.



Pilot Arc Control Methods

On some power sources the pilot arc remains on even after the cutting arc is established. The advantage is that when cutting over a piece of expanded metal, the cutting arc is maintained as the arc moves from one piece of metal to the other. A disadvantage of leaving the pilot arc on at all times during the cutting process is that it can lead to faster consumable wear. Some power sources have ways of controlling the pilot arc so that it is on when needed and can be shut off when not needed. The operator can select the expanded metal position for a continuous pilot arc or the tip saver position where the pilot arc shuts off after the cutting arc is established.

Plasma gas

Plasma arc cutting gases must have high ionization potential (energy), high thermal conductivity to deliver high heat energy to the work piece, and high atomic weight to produce the energy to blow or push out metal from the cut. Compressed air (approximately 80% nitrogen) with its high ionization potential and density is commonly used to minimize gas costs. Compressed air requires installation of filters or line dryers to remove oil vapours and moisture. The best compressed air onboard will be the control air. All plasma manufacturers include minimum air flow and pressure requirements in the owner's manual. If you do a lot of cutting, or plan to cut thick plate, we recommend using a compressor that is 1.5 to 2 times the plasma system requirement. The gas pressure and flow rates must be properly set to the equipment manufacturer's recommendation. For general guidance:

Smaller plasma units 10mm (3/8″) steel cutting commonly have air requirements at about 113-142 l/min (4-5 SCFM*) at 6- 8bar (90-120 Psi**).

Medium-sized plasma units 16 -19mm (5/8″-3/4″) steel cutting take about 170 l/min (6 SCFM) at 6-8bar (90-120 Psi).

Heavy-duty plasma units 19-24mm (3/4″-1″) steel cutting will need about 198-227 l/min (7-8 SCFM) at 6- 8bar (90-120 Psi).

*SCFM =Standard cubic feet per minute.
**PSI=Pounds per square inch.

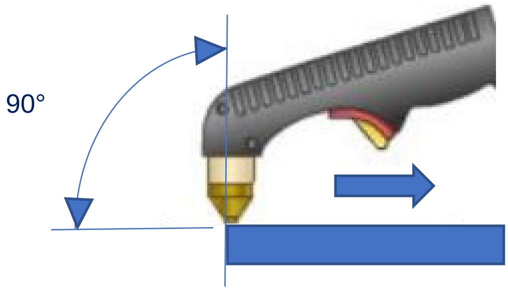
The gas supply piping and hoses to the cutting unit must be of sufficient size to carry the pressure and gas volume required. Use a minimum 10mm (3/8") ID (inside diameter) piping or hoses to provide the necessary pressure and volume of gas to the power source. If the piping or hose is more than 12m (40 feet) in length, use a minimum 12mm (1/2") ID.

Many plasma cutters have built-in regulators with air filters, but good practices call for additional filters and separators on the gas supply to remove water or other contaminants. Remember that water is highly conductive, and if water enters the torch, it can cause internal arcing that can damage the torch.

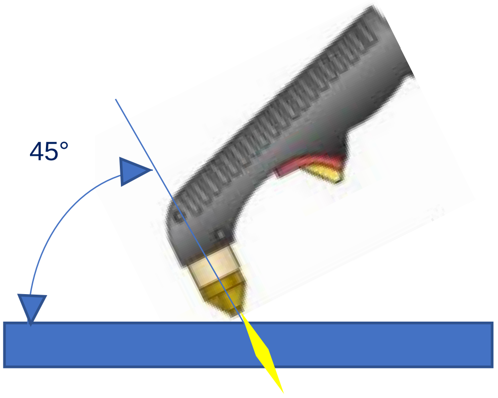
Cutting technique

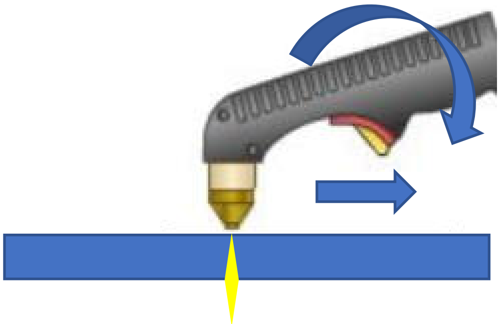
With a hand-held torch there are two methods for starting the cut: edge starts and pierce starts.

To use an edge start, place the torch directly over the edge of the work piece. With the tip centred on the edge of the metal, start the arc and begin moving the torch along the cut line. Keep the torch at approximate 90-degree to the work surface.



Assist yourself by using a straight bar or angle iron to rest the torch towards when doing straight cuts. Instead of drag-shield, you can also use a roller guide to maintain a consistent standoff. It makes cutting straight line with a handheld plasma cutter easy.





Pierce cuts are a little more difficult. The torch will need to be angled slightly over the starting point. This will prevent the molten metal from the beginning of the cut from being blown back into the tip and electrode.

Once the cutting arc has pierced through the metal, move the torch to a vertical position and continue along the cut line. The thicker the metal, the longer it will take the cutting arc to pierce through the metal.

The process of piercing a hole in the metal will cause a blow hole that is wider than the normal kerf, so the initial pierce should be done in the scrap portion of the part not on the cut line. Whenever possible, directly centre the nozzle orifice over the edge of the workpiece and do the edge start.

Gouging technique

There will normally be a need to change some of the consumables in the torch when going from cutting to gouging. The technique for plasma arc gouging requires the torch be angled 30° to 40° from the base metal surface. This torch angle and the speed of travel will determine the gouging depth. It is important that not too much material is removed in a single pass. It is better to remove by gouging to the required depth and width by using multiple passes. To remove old or imperfect welds, use a gouging tip. The hole on a gouging tip is three to four times wider than a regular tip. Its cone shape pushes out the plasma arc, which can remove more material than the constricted orifice of a regular tip. Gouging may be used for edge preparation (U-groove), removal of welds, or discontinuities in welds, and it may be used in all positions. The current, travel speed, standoff distance, lead angle, and tip size will determine the amount of material removed and the profile of the gouge.

You can use the shield cup body with either the gouging shield cap or the shield deflector. Also, you can use the single piece shield cup.

Limitations to plasma cutting.

Oxy- acetylene may still be the preferred process for steel applications. Oxy- acetylene torch cutting operates independent of electrical power or compressed air and can also cut thicker sections of steel > 25mm (1 inch) more quickly than plasma cutting.

What type of plasma machine to choose?

Specify the thickness of the metal most frequently cut.

Most plasma cutting power sources are rated on their cutting ability and amperage. If you most often cut metal less than 6mm (¼") thick, you should consider a lower amperage plasma cutter. If you most frequently cut metal that is above 6mm (½") in thickness, look for a higher amperage unit.

Plasma cutters operating at the limit of their current capacity may make poor quality cuts. Instead, you may get a severe cut which barely makes it through the plate and leaves behind dross or slag. Every unit has an optimal range of thickness. Make sure it matches up with what you need. In general, a 6mm (¼") machine has approximately 25 amps of output, a 12mm (1/2") machine has a 50-60-amp output while a 19- 24mm (¾" - 1") machine has 80- or 100-amps output. If you want to use the plasma cutter also for gouging you will need an 80- or 100-amp machine.

Like welding equipment, the duty cycle is important for continuous cutting. Duty cycle is simply the time you can continuously cut before the machine or torch will overheat and require cooling. Duty cycle is rated as a % of a 10-minute period. For example, a 60% duty cycle at 50 amps means you can cut with 50 amps output power continuously for 6 minutes out of a 10-minute period. The higher the duty cycle, the longer you can cut without downtime.

Look for a machine that provides a quick, positive transfer from pilot to cutting at a large transfer distance. These machines will be more forgiving to the operator and will better support gouging, essential for proper fit-up in heavy plate gouging.

Many users operate their plasma cutter for a variety of cutting applications and need to move the machine around onboard from site to site. Having a lightweight, portable unit and a means of transportation for that unit - such as an undercarriage or shoulder strap can make all the difference. Additionally, if deck space in a work area is limited, having a machine with a small footprint is valuable. If portability is essential, consider units which offer storage for the work cable, torch and consumables.

Protected controls are a must for many hard-use environments. Some machines offer a protective cage around the air filter and other integral parts of the machine. Filters are important because they ensure oil is removed from the compressed air. Oil can cause arcing and reducing cutting performance.

Look for a plasma cutter that has a big, easy-to-read control panel that is user-friendly. A well-designed panel allows a user with limited experience to pick up a plasma torch and be productive quickly. A machine with settings and procedures clearly printed on the unit will help with set-up and troubleshooting. Ergonomics are important for hand-held units. How does the torch feel in the hand? Comfort reduces operator fatigue and promotes cleaner, faster cuts.

Make sure the plasma machine can work towards the voltage and frequency onboard. When selecting a plasma cutting machine, it is important that one take into consideration the number of phases (1 phase or 3 phase), voltage (115, 230, 380, 440V) and frequency (50 or 60 Hz) on the receptacle the plasma machine is to be connected to. Some modern plasma cutters are dual phase, voltage and frequency and will automatically adapt.

The machine manufacturer/supplier should be able to provide a world vide service and the ability to provide necessary spares.

Hidden cost: consumable cost /consumable life

Plasma cutting torches have a variety of consumable items that require routine replacement. For hand-held torches, the retaining cap, shield, nozzle, electrode and swirl ring are easily replaced and should be swapped out as cutting performance deteriorates, rather than at the point of failure. It's a hidden cost. Look for a manufacturer that offers a machine with the fewest number of consumable parts. A smaller number of consumables mean less to replace and more cost savings. Look in the manufacturer's specifications for how long a consumable will last - but be sure when comparing one machine against another that you are comparing the same data.

Plasma cutters with built-in air compressor

The smaller range plasma cutters are by some manufacturers supplied with a built-in compressor. This can be a convenient feature if compressed air is not available or if the compressed air does not have sufficient quality. NB. The compressor will add weight to the plasma cutter. On to that comes that most ships have easy access to compressed air making this feature not so interesting after all. Consider if compressed air is available and of sufficient quality (low water content and/or oil) before deciding.

Safety

As it is with any cutting or welding process, safety is the prime consideration. The equipment owner's manuals will provide safety recommendations that must be followed. The plasma arc emits intense visible and invisible radiation (ultraviolet and infrared). Operators need to be fully clothed with dark leather or woolen clothing. Ultraviolet radiation can cause rapid disintegration of cotton-based clothing. Dark clothing reduces reflection, particularly underneath the welding helmet where reflected ultraviolet burns can occur to the face and neck. To provide adequate protection for the eyes, use filter lenses conforming to ANSI Z49.1

The table suggested filter glass shades for plasma cutting and gouging.

Arc Current in Amps	Lowest Shade Number	Recommended Shade Number
Under 40	5	5
40-60	6	6
60-80	8	8
80-300	8	9
300-400	9	12

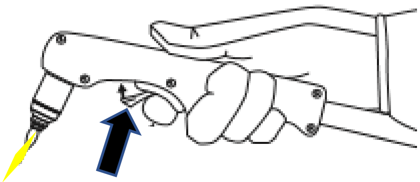
When cutting thicker materials, it may be necessary to wear ear protection.

Adequate ventilation is required during the plasma arc cutting process due to the brightness of the plasma arc, which causes air to break down into ozone. These fumes must be removed from the work area or eliminated at the source by an appropriate exhaust system. Take the proper precautions to avoid being burned by hot molten material; sparks can travel in excess of 11m (35 feet) during the cutting process. Do not wear any clothing with cuffs or uncovered pockets, and always wear the proper insulated gloves.

Note that plasma cutters work with Low Amperage and High Voltage and therefore need special safety features. The torch connection to the front of the plasma cutter should be according to EN 60974 standard that states that a torch connection should be made so that there is no risk for electrical shock and no possibility to remove the torch without a tool. The torch connection, which is the negative voltage, will if exposed be very dangerous given that the open circuit voltage often exceeds 300VDC and the cutting voltage is approx. 100VDC. The risk to the operator or other personnel is extremely high. The torch must also have the necessary safety features for CE marking like safety circuit to prevent accidental activation of arc when removing the torch consumables. In most plasma cutters the circuit will be broken if the operator unscrews the head to change the consumables.

Note safety pins that break the circuit in the moment the shield cup is removed.

Preferably use a plasma torch with a safety catch over the trigger to avoid accidental firing the torch.



Keep longest possible distance between plasma cutters machines front and location where plasma cutting takes place. The machine need cooling and dust from the cutting can be drawn into machines interior if it is placed too close to cutting location.

Avoid using extension cords for the primary cable whenever possible.

The air entering the plasma cutter must be absolutely dry from moisture/ water and free from oil. Plasma cutting systems require clean, dry gas to operate properly. Moisture in the gas line is the cause of many system problems. It can cause shortened consumable life and premature torch failure. To check for moisture in the gas line, set the system to the air set position and hold a piece of paper under the tip. If any moisture appears on the paper, inspect the system for the source of the moisture or install an air dryer in the system.

Use edge starts whenever possible instead of pierce starts. Edge starts improve consumable life since there is less chance for molten metal to be blown back into the tip.

Make sure that location where return clamp is fastened to base material are grinded to secure good electric conductivity.

Try to place the return clamp as close to the cut line as possible. If possible, place the clamp on the workpiece itself. Inspect the cables for loose connections, worn spots, or anything else that might resist the electrical flow. Only secure the return clamp to clean metal for getting the best cutting performance. Grind off the paint or rust before clamping as these may inhibit the flow of electricity.

Every ½ year make sure to remove the plasma machines cover plate and blow through with dry compressed air. This is in order to remove dust and dirt from electric components.

Symbols and marks

S mark
The S mark indicates that the power supply and torch are suitable for operations carried out in environments with increased hazard of electrical shock according to IEC 60974-1.

CSA mark
Products with a CSA mark meet the United States and Canadian regulations for product safety. The products were evaluated, tested, and certified by CSA-International. Alternatively, the product may have a mark by one of the other Nationally Recognized Testing Laboratories (NRTL) accredited in both the United States and Canada, such as UL or TÜV.

CE mark
The CE marking signifies the manufacturer's declaration of conformity to applicable European directives and standards. Only those versions of products with a CE marking located on or near the data plate comply with European Directives. Applicable directives may include the European Low Voltage Directive, the European Electromagnetic Compatibility (EMC) Directive, the Radio Equipment Directive (RED), and the Restriction of Hazardous Substances (RoHS) Directive. See the European CE Declaration of Conformity for details.

Eurasian Customs Union (CU) mark
CE versions of products that include an EAC mark of conformity meet the product safety and EMC requirements for export to Russia, Belarus, and Kazakhstan.

GOST-TR mark
CE versions of products that include a GOST-TR mark of conformity meet the product safety and EMC requirements for export to the Russian Federation.

RCM mark
CE versions of products with a RCM mark comply with the EMC and safety regulations required for sale in Australia and New Zealand.

CCC mark
The China Compulsory Certification (CCC) mark indicates that the product has been tested and found compliant with product safety regulations required for sale in China.

UkrSEPRO mark
The CE versions of products that include a UkrSEPRO mark of conformity meet the product safety and EMC requirements for export to the Ukraine.

Serbian AAA mark
CE versions of products that include a AAA Serbian mark meet the product safety and EMC requirements for export to Serbia.

RoHS mark
The RoHS mark indicates that the product meets the requirements of the European Restriction of Hazardous Substances (RoHS) Directive.