SanRex

Plasma Welding

Handbook

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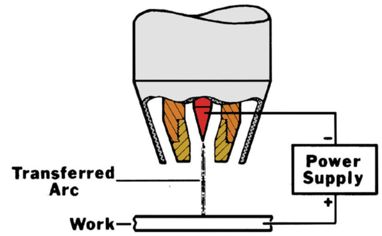
Form No.:081520PWH

PLASMA ARC WELDING

Plasma Arc Welding (PAW) is an arc welding process that employs a high temperature, constricted plasma gas column to obtain the melting and coalescence of most metals. This column of plasma is constricted by an orifice placed downstream of the electrode.



The term Plasma, refers to a gas that has been sufficiently ionized to conduct an electrical current. As we see matter in the world around us, we are usually conscious of it existence in three states ... solid, liquid and gas. We are all aware of the difference between solids, liquids, and gases, and the fact that increasing the temperature changes a material from one state to another. When enough energy is applied to a gas, this will cause an ionization of the gases atomic structure. This process is visible to us in the form of fluorescent lighting in our homes and offices, lightening in the night sky, or even our very sun. Most of the visible universe is a type of plasma.

When energy (heat) is added to a material in a gaseous state, the temperature of the gas keeps increasing. if enough energy is added, the temperature becomes high enough that the gas no longer exists as individual molecules. The molecules come apart and the material made up of individual atoms, if the temperature is further increased, the atoms will then lose electrons and become ions. This material then consists of a combination of ions (with a positive charge) and free electrons. Under these conditions, the matter now exists in a fourth state... the PLASMA state.

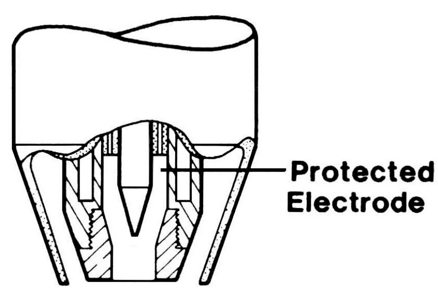
Plasma has many properties that are similar to those of a gas but also some special properties that make it unique. The most important property of the plasma, as far as welding is concerned, is that it contains free electrons which allows it to easily carry an electrical current. The plasma welding process does not have an exclusive on the use of plasma as it also exists in all other arc welding processes. Plasma welding utilizes the developed hot gases to provide unique benefits to the welding operation.

PROCESS ADVANTAGES

Plasma welding is not a new process to the industry, but only in the past few years has it gained significant acceptance. Until recently, the process was considered exotic and difficult to understand. This was mainly due to the applications it was being adapted to. PLASMA NOW HAS PROVEN ITS VALUE IN THE AREA OF HIGHLY REPETITIVE AUTOMATED WELDS. THE PROCESS PROVIDES INCREASED RELIABILITY AND REPEATABILITY TO MEET TODAY'S HIGH STANDARDS OF PRODUCTIVITY.

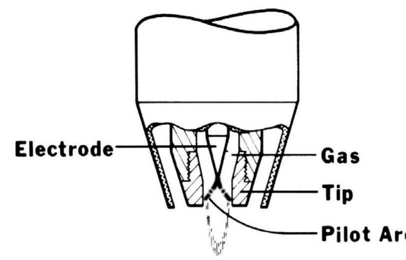
It is must frequently used as an alternate to the gas tungsten process (GTAW) . For most applications, the plasma arc process offers increased electrode life, reliable arc starting, improved arc stability, better penetration control and reduced current levels. In some cases, plasma offers increased travel speeds, improved weld quality, and less sensitivity to operating variables.

PROTECTED ELECTRODE -- The tungsten electrode, which is secured inside the plasma torch and behind the orifice, is protected from outside impurities that would normally attack its hot surface. With this protection, it normally needs to be changed approximately every eight (8) hours for most operations. With the GTAW (TIG) process the electrode is secured externally. This exposes the electrode to the contaminants (stamping and forming oils, degreasers, oxides, etc.) present on the surface of the base material to be welded.

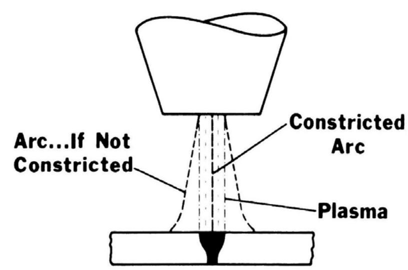


These contaminants, under intense temperatures, will attack the tungsten electrode. Also the high frequency used to start the arc can contribute to the erosion of the electrode by constantly etching its surface. if these phenomena continue, inconsistent arc starting and loss of arc directability can result, causing significant downtime and rejection of parts due to poor welds. It is not uncommon many applications for the electrode in the GTAW torch to require changes 1 to 2 times per hour depending on part cleanliness and production levels. The time required to change the electrode depends on the accessibility of the torches on the fixture apparatus. Five minutes or more may be spent on each electrode change in some cases, eating away costly production time. Multiplying the number of electrode changes required in an 8 hour shift by the time required for each change, and dividing by the total amount of production time available, will yield the percentage of lost production time. Based on that number, it is now easy to figure parts lost due to frequent electrode changes.

RELIABLE ARC STARTING -- Arc initiation is provided by a pilot arc which resides in the tip area of the torch. The pilot arc is an arc that transfers between the tungsten electrode and the tip. It is started by imposing high frequency (from a small high frequency generator inside the control console) on a low DC current for a short duration of time to ionize the gas. Once the pilot arc has been established, the requirements for high frequency are no longer needed. The pilot arc now remains on to assist the starting of the main transferred welding arc from a separate DC power source.



CONSTRICTED ARC -- An orifice (also called a nozzle, or a tip) which is inserted into the front end of the torch body provides for the laminar flow of the plasma gas and constriction of the arc. The magnitude of this constriction is normally controlled by three variables ... the orifice diameter, the plasma gas flow rate, and the electrode setback (the distance the electrode is recessed within the tip). The arc will be most constricted when the torch is operated at higher plasma gas flow rates and the electrode placed at maximum setback. This type arc is typically used when trying to achieve keyhole single pass welds requiring maximum penetration, narrower weld beads, minimized heat affected zone, and reduced base material distortion. Keyhole welding is generally used on material thickness' ranging from .090 (2.3 mm) to .250 (6.4 mm).



By reducing the electrode setback and plasma gas flow rates, a softer, less constricted arc will occur. This type arc is typically used for the melt-in fusion (non-keyhole) mode and allows for faster travel speeds on reduced base material thickness' .010 (.3 mm) to .187 (4.7 mm).

All metals amenable to the GTAW process can be welded with the plasma arc process. PLASMA ARC WELDING SHOWS ITS GREATEST ADVANTAGES IN THE WELDING OF HIGH VOLUME REPETITIVE PRODUCTION OPERATIONS. THESE APPLICATIONS INCLUDE SPOT FUSION WELDS, CORNER EDGE WELDS, LAMINATION WELDS AND CIRCUMFERENTIAL / SEAM WELDS ALL USING THE MELT-IN (FUSION) MODE. These applications normally demand repeatable welds on a near continuous basis. The pilot arc, which provides reliable arc starting and a protected electrode, which minimizes electrode changes, are the features, which allow for the increased productivity in these applications.

EQUIPMENT

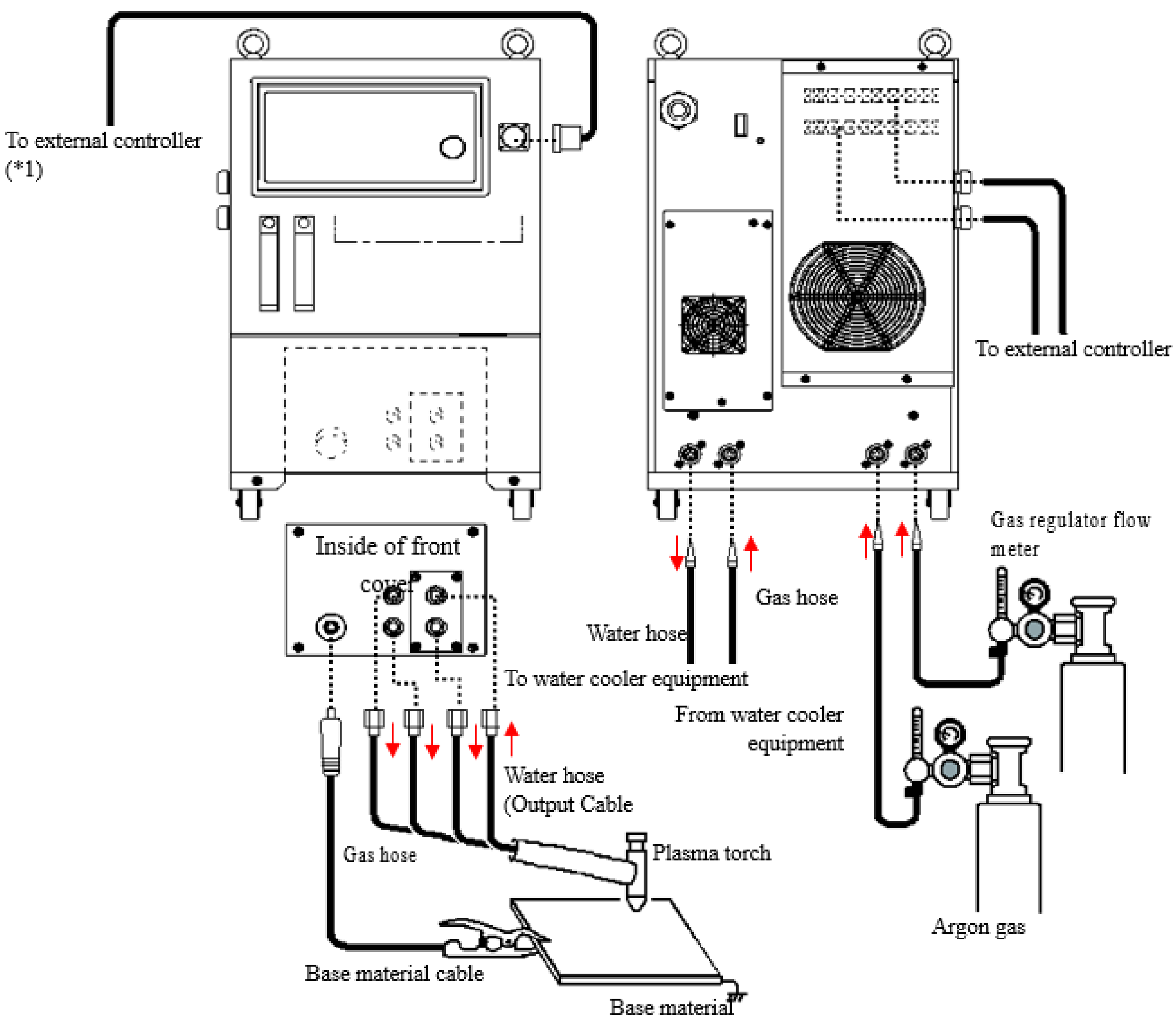
A typical plasma welding system consists of a pilot arc control console, a DC power supply with a suitable welding range, a plasma welding torch (manual or mechanized) and a closed loop coolant recirculator.

PILOT ARC CONTROL CONSOLE -- The control console is the 'mixing box' into which the power, gases and coolant are controlled and monitored. It also contains a small DC power supply for the pilot arc. Some control consoles provide additional controls and meters to assist in weld parameter control.

POWER SUPPLY -- Plasma arc welding is done with the use of straight polarity (DCEN) or VP (Variable Polarity) power source. The use of a DC power supply is recommended for the welding of ferrous metals. Were a VP power supply is recommended for the welding of non-ferrous metals such as aluminum or aluminum alloys. A typical DC or VP power supply with constant-current characteristics, remote contactor/current control, and suitable welding range is recommended for most operations. A solid-state power supply with a non-mechanical contactor is recommended when performing high duty cycle short duration welds. A sequence programmer, consisting of current or gas slope (taper), pulse, and weld time is required for many automated welding applications.

<u>TORCH</u> -- A plasma welding torch suitable for the particular welding operation should be used. Torches are available with various head and size configurations. Most are liquid cooled. The orifices of some torches are also liquid cooled to provide improved orifice life and higher current carrying capacity. Most torches are designed with an orifice that is inserted into a water jacket. These torches cannot operate at the higher (above 250 amps) current levels but do allow the "changing out" of the orifice without disturbing a water seal. Plasma torches use tungsten electrodes, which are normally 2% thoriated. The diameter varies with the current. Lower current levels (below 150 amps) require smaller electrode diameters (3/32', 2.4 mm) and higher current or high duty cycles require larger electrodes (3/16', 4.8 mm) to withstand the heat loads.

<u>COOLANT RECIRCULATOR</u> -- A coolant recirculator of a nonferrous design must be used. The use of deionized water to prevent the establishment of electrolysis in the torch is required.



EQUIPMENT DIAGRAM

GAS SELECTION

The selection of the plasma and shielding gases for the melt-in and keyhole weld modes are listed below.

PLASMA GAS

Argon

Argon is the preferred plasma gas. It is totally inert meaning it will not for chemical compounds with other materials at any temperature or pressure. Its low ionization potential assures reliable arc starting and a dependable pilot arc. It provides good arc stability and an excellent protective blanket for the tungsten electrode.

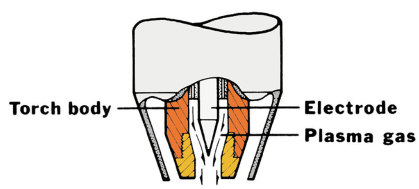
Flow rates range approximately .25 SCFH (.18 lpm) - 5.0 SCFH (2.4 lpm)

Argon/Hydrogen (95/5%)

Addition of small amounts of Hydrogen to Argon is sometimes recommended. This increases the heat input to the weld puddle. Argon/Hydrogen will provide a hotter arc assisting in both penetration and weld puddle fluidity. Torch parts life will be lower when using Argon/Hydrogen mixtures versus argon.

Flow rates range approximately .25 SCFH (.18 lpm) - 5.0 SCFH (2.4 lpm)

N0TE: See section on Argon/Hydrogen in Shield Gases.



SHIELDING GASES

Argon

Argon may be used for all metals. It provides good arc stability and effective cleaning at the lower current levels (less than 20 amps). It is also recommended for use in the welding of aluminum, copper alloys, titanium and reactive metals.

In some cases, argon may not perform satisfactorily due to the higher arc voltages that are used in plasma welding (18-32V). Where the weld puddle is not fluid, slight undercutting occurs, and/or surface oxidation of the weld is noticed. The use of argon/hydrogen, helium or argon/helium mixtures may be necessary.

Argon/Hydrogen (95/5%)

Argon/Hydrogen mixtures are used to provide increased heat input to the weld. The addition of Hydrogen to Argon reduces surface tension of the molten pool resulting in increased travel speeds. By reducing the surface tension of the molten metal, degassing of the weld pool is also facilitated so that the danger of gas inclusions in the form of porosity is lessened. At higher welding speeds, undercutting is also avoided and a smoother weld surface is achieved.

In addition to the increased arc heating efficiency, hydrogen has a fluxing effect that reduces the amount of oxides formed when joining stainless steels, nickel and high nickel alloys. When welding nickel or nickel alloys, the presence of hydrogen actually helps by preventing porosity. Nickel oxides formed by the entry of oxygen from the air are reduced by the hydrogen. The hydrogen 'attacks' any stray oxygen before it can form nickel oxides.

The permissible percentage of Hydrogen varies up to 15%. It is indirectly related to the thickness of material being welded. With increased current welds and reduced travel speeds on thicker materials, the Hydrogen can become entrapped in the weld. This causes embrittlement of the weld.

In general, the thinner the work-piece, the higher the permissible percentage of Hydrogen in a gas mixture that can be used. in automatic welding, a higher percentage of hydrogen can increase travel speeds on these thinner materials (.062, 1.6 mm or less).

Flow rates range approximately 10 SCF@I (4.7 lpm) - 20 SCFH (9-4 lpm).

Helium

The use of helium as opposed to argon increases the weld heat by approximately 25%. This is due to the higher ionization potential of helium, which in turn increases the arc voltage. Helium is commonly used when welding aluminum alloys, copper alloys and thicker sections of titanium. These materials will dissipate heat more rapidly and need the assistance of the helium.

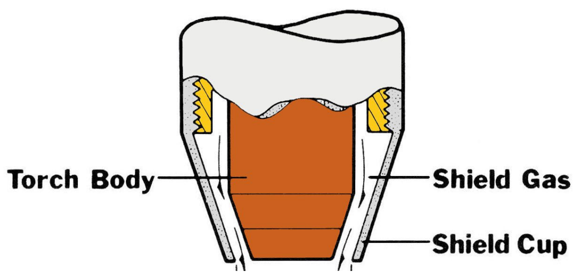
Flow rates range approximately 15 SCFH (7.1 lpm) 40 SCFH (18.8 lpm).

Helium/Argon (75/25%)

The addition of Helium to Argon produces a hotter arc for a given amount of welding current. A Mixture must contain at least 40% Helium before a significant change in heat can be detected. The argon has a tendency to stabilize the arc. Mixtures containing more than 75%, Helium will provide results very similar to pure Helium. A mixture of 75% Helium 25% Argon is used in applications like thicker segments of titanium or copper alloys.

Flow rates range approximately 15 SCFH (7.1 lpm)40 SCFH (18.8 lpm).

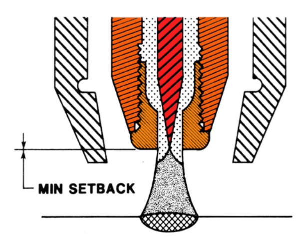
NOTE: Arc starting may become more difficult with the use of helium or helium mixtures. Trailing shield addition may be required when welding titanium or reactive metals to minimize oxidation to the weld bead surface.



MODES OF OPERATION

Plasma welding is commonly used in two modes of operation, melt-in fusion welds and keyhole fusion welds.

MELT-IN FUSION WELDING -- This type weld mode is the most often used with the plasma arc welding process. It is accomplished with a softer, less constricted arc, using lower plasma gas flow rates, a reduced electrode setback, and current levels in the range of approximately 1 to 200 amps. The minimum electrode setback distance is obtained with the electrode point set flush with the face of the tip. This technique of setting the electrode allows the plasma gas flow rate to be decreased while maintaining higher current ratings of the tip. This normally provides a slightly wider weld bead in most cases allows for increased travel speeds. This type weld mode is very similar to that of gas tungsten arc welding with additional advantages in many applications.



ADVATAGES:

1) Reliable arc starting
2) Protected electrode
3) Less sensitive to stand-off changes
4) Improved arc stability at low current
5) Lower current levels required
6) Reduced heat input or distortion
7) Arc is more directional (less arc wander)
8) Improved weld geometry and penetration control

TYPICAL WELDS/JOINT CONFIGIRATION:

1) Spot fusion welds
2) Corner/edge fusion welds
3) Flange fusion welds
4) Square butt fusion welds
5) Surface fusion welds
6) Lap fusion welds

SPOT WELDING -- Plasma arc welding is well suited for spot fusion welding because of its reliable arc starting characteristics and high response time. It is typically used for tacking, joining, or sealing operations. All metals amenable to the gas tungsten arc process can be spot welded with plasma arc process.

FUSION WELDING -- Plasma arc welding can be used in all positions when using the melt-in mode. Typically, circumferential and longitudinal seam welds are welded in the flat positions. Corner/edge and surface fusion (lamination welds) provide improved travel speeds and reduced heat input in the vertical down position. Typical procedures and operating parameters are on page 14 of this section.

<u>JOINT DESIGN AND FIXTURING</u> -- In many cases the common practices in joint design and fixturing typically used with gas tungsten welding can also be incorporated with plasma arc welding. The use of copper or aluminum heat sinking in many applications can enhance the welding operation. When thin metals are welded, both joint edges must be in continuous contact and must melt simultaneously to fuse together into a single weld puddle. Separation between the joint edges before or during welding will allow the edges to melt separately and remain separate.

Much larger tolerances for joint fixturing can be obtained by flanging the edges. Turned-up edges act as pre-placed filler wire to fill the gap and ensure melt contact of the sides of the joint. They also stiffen the joint edges to minimize warpage from heat built up during welding. Flanging is recommended for all butt joints in foil thicknesses below 0.010' (0.25 mm).

<u>FILLER METAL ADDITION</u> -- Filler wire can be added to the leading edge of a plasma weld puddle, as in the gas tungsten arc process. Wire-height adjustments are not generally as critical with plasma arc welding because the wire can lift off the plate and melt into the plasma stream without contaminating the electrode. However, wire placement is still important because the wire can ball-up when lifted from the plate.

MELT-IN FUSION WELDS

Suggested Starting Parameters for Mechanized (Non- Keyhole)
Circumferential, Seam, and Spot Fusion Welds

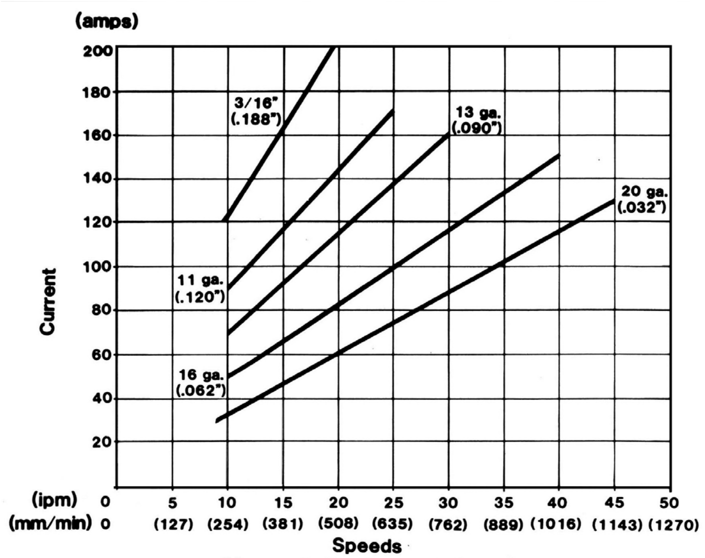


Figure 3-C Current Levels

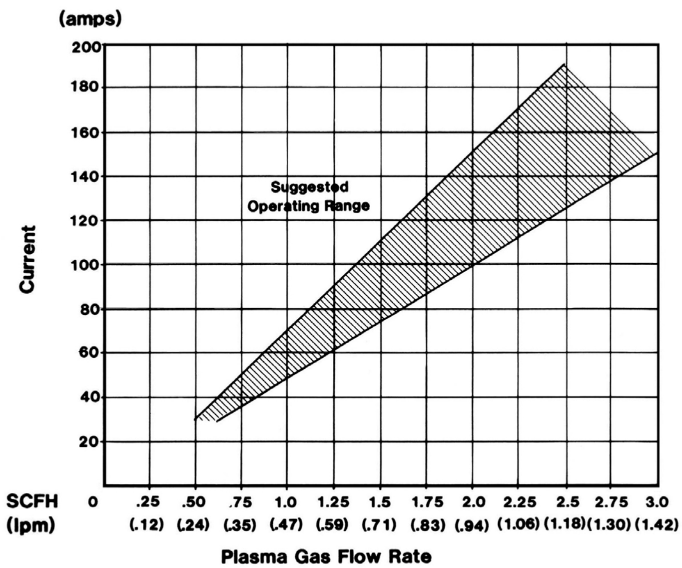


Figure 3-D Plasma Gas Flow Rates

Materials

Stainless Steels
Carbon Steels
Alloy Steels
Nickels

Joint Types

Butts
Corner*
Edge*
Flanged*

Electrode setback at minimum

Standoff set at 3/32-5/32" (2.4-4.0 mm).

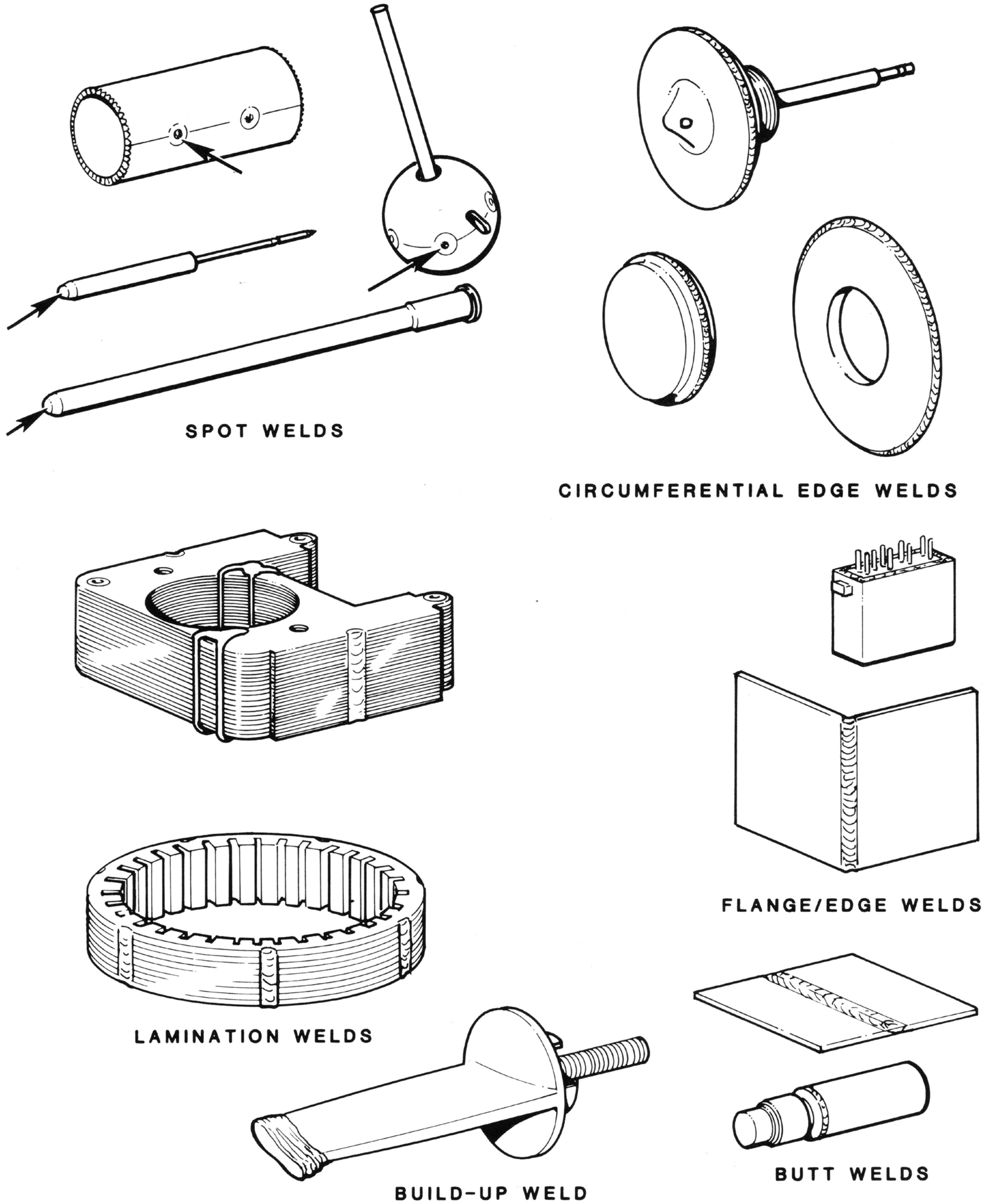
Argon- Plasma Gas

Argon- Hydrogen-Shield Gas at 10-20 SCFH (4.7-9.4 lpm)

Most steels require approximately 10- 15 % higher current at equal travel speed.

* Faster travel speeds may be required for these welds.

The maximum current rating of each tip is established using maximum electrode setback and maximum plasma gas flow rates. Lower plasma gas flow rates can be used with the maximum current rating of the tip if the electrode setback is set at minimum.



PLASMA WELDING APPLICATIONS

THE USE OF PLASMA WELDING FOR OUTSIDE CORNER, EDGE, OR FLANGE JOINT APPLICATION

The Plasma Welding process has been successfully used for the welding of these joint configurations. Plasma provides increased productivity and reduced downtime. It is especially suited to automated systems, although some manual systems are used in specialized smal1lot applications.

PROCESS ADVANTAGES,

The most important reasons for using the plasma welding process are its repeatability and productivity. These benefits are obtained by having two major features: a protected electrode and a pilot arc. Both the pilot arc and protected electrode will provide higher efficiencies and reduced downtime in most applications. Because the welding of outside corners or edge joints is a fusion process, the need for post weld grinding or refurbishing is minimal.

Listed below are some typical welding applications that were accomplished very successfully with the Plasma welding process over the years.

Computer cabinets

Copying machines

Filing cabinets

Capacitor canisters

Formed sheet metal boxes

Door/window panels

small battery canisters

Home appliances (Refrigerators, freezers, washers, dryers, etc.)

PLASMA ARC WELDING PARAMETERS

Material	**Thickness**	**Current AMPS**	**Plasma Gas Flow Rate SCFH (lpm)**	**Shield Gas Flow Rate SCFH (lpm)**	**Travel Speed IPM (mm/min)**	**TIP Size**
Stainless Steel, Mild Steel	20 ga. (.035)	40 - 60	.75 – 1.25 (.35 - .59)	10 – 20 (4.7 – 9.4)	20 – 25 (51 – 64)	.062 / .081
Stainless Steel, Mild Steel	16 ga. (.062)	50 – 70	.75 – 1.25 (.35 - .59)	10 – 20 (4.7 – 9.4)	20 – 25 (51 – 64)	.081 / .093
Stainless Steel, Mild Steel	13 ga. (.089)	90 – 100	1.0 – 1.5 (.47 - .71)	10 – 20 (4.7 – 9.4)	25 – 30 (64 – 76)	.093
Stainless Steel, Mild Steel	11 ga. (1.20)	100 - 115	1.0 – 1.5 (.47 - .71)	10 – 20 (4.7 – 9.4)	25 – 30 (64 – 76)	.093

* The automatic welding of outside corners or edge weld joints requires adequate fit-up and clamping to achieve optimum performance.

* In most applications welding in the vertical down position will provide maximum travel speed.

* Circumferential edge or flange welds are best achieved in the flat position.

* Weld joint backup, either with an inert gas or copper, can be used for improved under-bead formation.

* Cold-rolled or mild steel will provide the best weld bead appearances and travel speeds when welding steels.

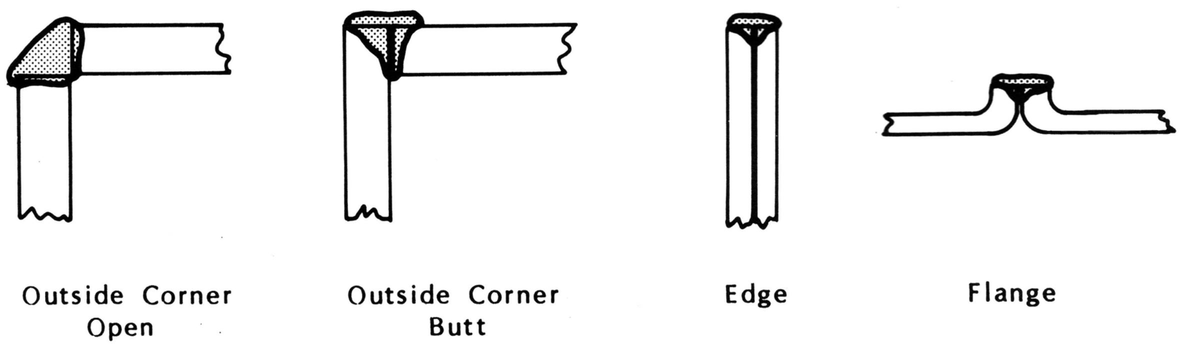
* Electrode setback is at minimum to allow for maximum travel speeds.

* The plasma gas used is typically Argon, though the use of Argon/Hydrogen (95/5) on coated steels may provide improved performance.

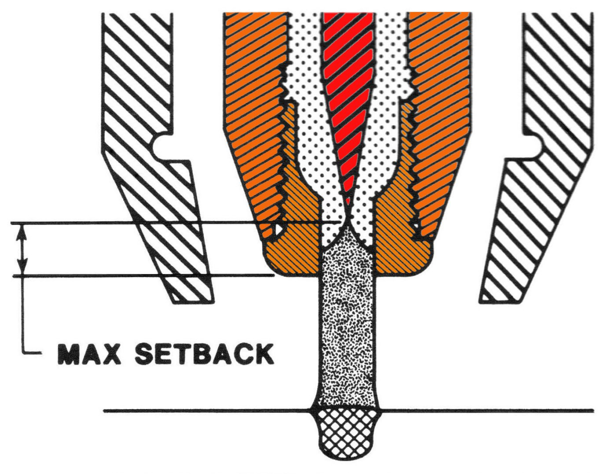
* Argon can be used as the shield gas in many cases, though it may not provide optimum weld cleanliness or travel speeds. The use of Argon/Hydrogen (95/5) will support improved weld puddle fluidity and cleanliness.

* Torch standoff is set at approximately 1/161 to 3/32' for optimum results.

Common Types of Corner/Edge joints

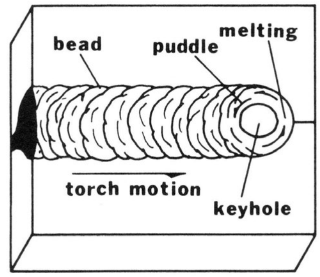


KEYHOLE FUSION WELDING -- This type weld is generally obtained by using a stiff, constricted arc. In the keyhole mode penetration is obtained by the combination of plasma and gas momentum with thermal conduction. With increased plasma gas flow rates and electrode setback, a hole known as the keyhole is pierced through the entire metal thickness at the leading edge of the weld puddle, where the forces of the plasma jet (column) displace the molten metal. As the torch travel progresses at a consistent speed, the molten metal, supported by surface tension, flows behind the keyhole to form the weld bead. Keyhole welding is almost exclusively performed in the automated mode. Typically this technique is used for square butt welds on material thickness from .093 (2.4 mm) to .250 (6.4 mm) requiring 100% penetration in a single pass. Manual keyhole welding is not recommended because of difficulties in maintaining consistent travel speeds, torch position, or filler material addition.



ADVANTAGES:

1) Reduced current levels
2) Single-pass welds
3) Minimized weld preparation
4) Narrower weld beads
5) Visual proof of 100% weld penetration
6) Improved weld geometry
7) Less filler material required



KEYHOLE WELD

DISADVANTAGES:

1) Limited to flat, horizontal, and vertical-up positions
2) More sensitive to variable changes
3) Limited to automated operations

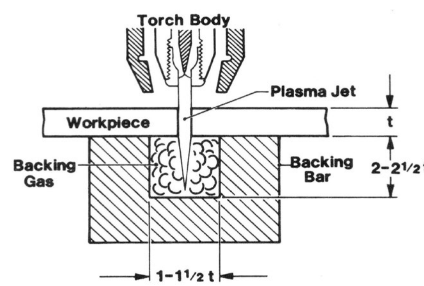
TYPES OF WELDS/JOINT CONFIGURATION:

1) Typically square-butt welds

KEYHOLE STARTING -- In material thicknesses under .090 (2.4mm), circumferential and longitudinal seam keyhole welds can generally be started at full operating current, plasma gas flow rate, and travel speed. In this thickness range, the keyhole is developed with little disturbance in the weld puddle, and the weld surface and under-bead are kept fairly smooth. However, in material thicknesses greater than .090 (2.3mm) the operating parameters can produce a tunneling or gouging effect underneath the surface of the molten puddle just prior to piercing the weld joint and starting the keyhole. Because this tunneling or gouging action may cause gas porosity or surface irregularities, starting tabs for longitudinal welds and programmed taper (upslope) of plasma gas and current for circumferential weld is normally recommended.

KEYHOLE ENDING -- If the welding current is turned off abruptly at the end of a keyhole weld, the keyhole may not close. This is not usually objectionable when stopping on ending tabs that are typically used on. longitudinal welds- Plasma gas and weld current taper (downslope) is recommended for the ending of the keyhole on circumferential welds. This *allows* for lowering of the arc force and heat input so that the molten metal can gradually flow into the keyhole and solidify.

UNDERBEAD GAS BACKING -- If a particular keyhole welding application requires an underbead backing, it is recommended that a rectangular shaped groove be used. This provides underbead shielding gas, and allows for the venting of the plasma column. Groove dimensions of approximately 1 to 1-1/2 T (metal thickness) wide and 2 to 2-1/2 T deep. Shallow grooved backing bars will cause the weld to become inverted toward the surface.



FILLER MATERIAL ADDITION -- The exceptional penetration capabilities of a constricted arc reduce the amount of filler wire, the number of passes, and the total arc time needed to join metal thicknesses requiring multipass welds. Filler wire added to the leading edge of the puddle of a keyhole weld will flow around the keyhole to form a reinforced weld bead. This technique can be used on single-pass welds in materials up to about 1/4' (6.4mm) thick, generally with a square-butt-joint preparation. Filler wire is not generally added on the root pass of a multipass weld because the plasma jet melts the maximum amount of base metal that can be supported by surface tension.

MULTIPASS WELDING -- In multipass welding, the root pass is usually a keyhole weld, followed by one or more non-keyhole weld passes with filler metal. In the fill and cover passes, the force of the plasma jet is adjusted for suitable penetration by regulating the type and flow rate of plasma gas. Helium in the argon shielding gas is favored for some fill and cover passes because it provides a broader heat pattern and produces a flatter cover pass.

KEYHOLE FUSION WELDS

Suggested Starting Parameters for Mechanized Circumferential and Seam Keyhole Welding

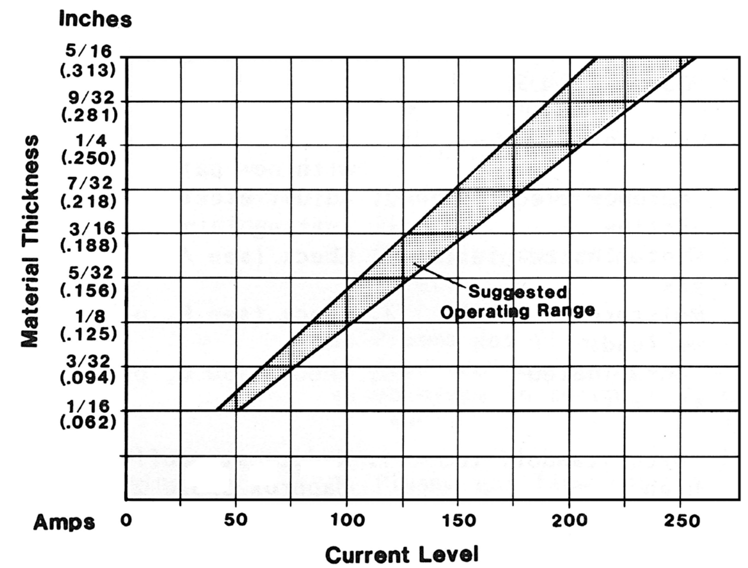


Figure 3-E Current Levels

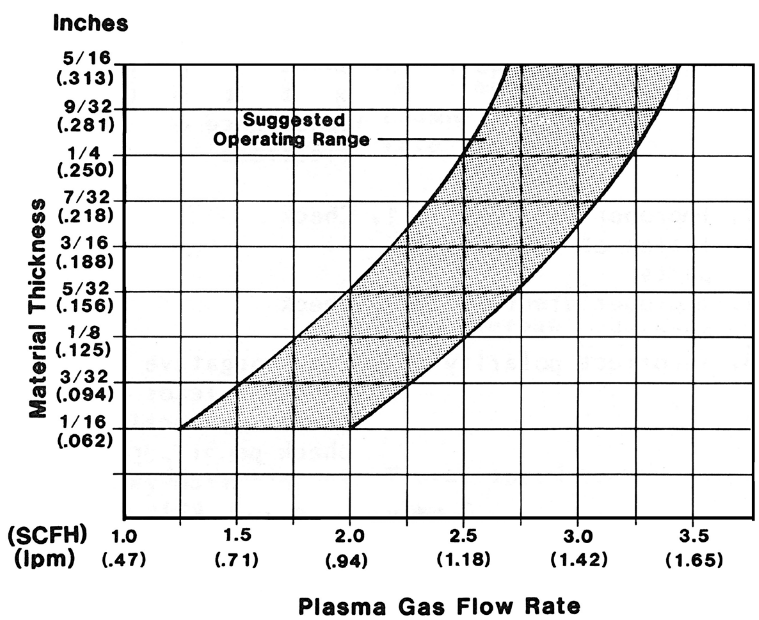


Figure 3-F Plasma Gas Flow Rates

Materials
- Stainless Steels
- Carbon Steels
- Alloy Steels
- Nickels

Joint Types

Square Butt

Electrode setback set at maximum.

Standoff set at 1/8-1/40 (3.2-6.4 mm).

Argon- Plasma Gas

Argon/Hydrogen- Shield Gas at 10-20 SCFH (4.7-9.4 lpm) with travel speeds approx. 10-12 ipm.

Most steels require approx. 10-15% higher current at equal travel speeds.

The maximum current rating of each tip is established using maximum electrode setback and maximum plasma gas flow rates.

Lower plasma gas flow rates can be used with the maximum current rating of the tip if the electrode setback is set at minimum.

TROUBLESHOOTING GUIDE

This guide provides information should a problem occur. The PROBLEM column is listed in the sequence of operation of the torch. The POSSIBLE CAUSE and REMEDY columns are listed beginning with the easiest to check and progressing to the more difficult to check.
Most problems related to the torch can be corrected within this section.

PROBLEM	POSSIBLE CAUSE	REMEDY
A. Erratic or poor appearing pilot arc	1. Worn torch parts	1. Check and replace with new parts
	2. Improper electrode setting	2. Adjust electrode setting
	3. Contaminated plasma gas	3. Check (see A, p 20)
	4. Moisture in torch or leads	4. Check (see B, p 20)
	5. Contaminated coolant	5. Check (see C, p 20)
B. Welding arc will not transfer	1. Torch standoff too high	1. Reduce standoff (approx 3/32, 2.4 rrTn-3/161, 5 mm) standoff for most applications)
	2. Power supply not properly connected	2. Check work lead, negative lead and contactor control cable
	3. Faulty electrode in torch	3. Check for sharp pint and clean appearance of electrode
C. Welding tip damaged	1. Improper installation of torch parts	1. Check on start up
	2. Improper electrode setback	2. Check
	3.Incorrect polarity	3. Check negative and positive leads for proper connection; check power supply range switch (see D, p 20)
	4. Plasma gas flow rate too low	4. Increase flow rate
	5. Excessive current level	5. Reduce current or use larger orificed tip
	6. Inadequate coolant flow	6. Check (see E, p 20)
	7. Contaminated gas	7. Check torch and system (see A,p 20)
	8. Moisture in torch	8. Check torch o-rings for coolant leaks; check gas hoses
	9. Contaminated coolant	9. Check coolant (see C, p 20)
	10.Tip touching workpiece	10. Increase standoff
D. Tip damaged after a period of welding	1. Inadequate coolant flow	1. Check (see E, p 20)

	2. Excessive current level	2. Reduce current or use larger orifice tip
	3. Plasma gas flow rate too low	3. Increase flow rate of plasma gas
	4. Moisture in torch leads	4. Check torch o-rings for leaks; check gas hoses
E. Not getting required penetration	1. Plasma gas flow too low	1. Increase gas flow
	2. Current too low	2. Increase current
	3. Electrode setback at minimum	3. Increase electrode setback
	4. Travel speed too high	4. Decrease travel speed
F. Porosity in welds	1. Contaminates on material	1. Clean material
	2. Plasma gas flow rate too high	2. Reduce (if plasma gas flow is too high but 100% penetration is not occurring, gas porosity may appear)
	3. Inadequate shield gas coverage	3. Increase flow rate or use additional 'trailer' shield to provide adequate gas shielding
G. Slight undercutting (in toe area of weld)	1. Travel speed too high	1. Reduce travel speed
	2. Plasma gas flow too high	2. Reduce flow rate
	3. Tip orifice size too small	3. Use larger orifice tip
	4. Electrode set at max setback	4. Reduce setback
	5. Current level too low	5. Increase current level

SERVICE TEST PROCEDURES

The following tests correspond with the torch section of the troubleshooting guide.

A. Contaminated plasma gas normally causes a bluing tint toward the front of the electrode. Check the plasma gas line for leaks by plugging the tip and letting gas flow with the console in 'SET' position. Check the plasma gas line using a soap and water solution on each connection. Appearance of bubbles signifies a leak at the connection.

B. Moisture in the plasma gas may cause a black sooty material to appear on the electrode or in the tip. Use of rubber hoses may be a cause of moisture entrapment. Synflex tubing is always recommended.

   To remove moisture from the torch, plug the tip and let gas pressure build before releasing. It may be necessary to repeat the procedure three or four times to remove contaminants.

C. Contaminated coolant gas can be caused by not using or maintaining proper coolant. Check the resistivity level of the coolant with a water tester. Replace coolant if indicated resistivity is below accepted levels. Purge the entire system.

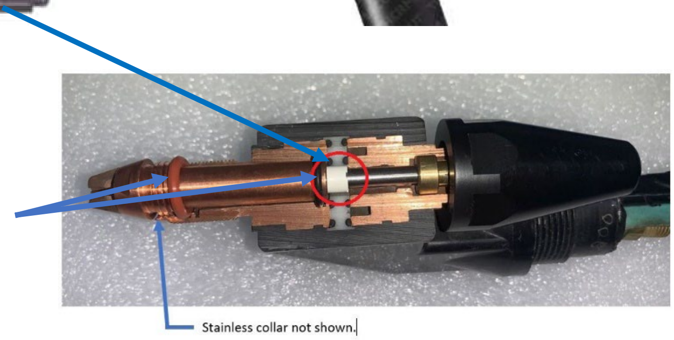
D. Reverse polarity operation causes excessive electrode deterioration which may cause formation of a large ball on the electrode tip.

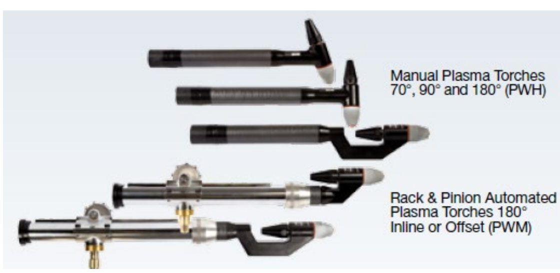
E. Inadequate coolant flow can cause excessive damage to the tip and liner. Check the 'return' flow rate against the GPM coolant requirement. If coolant flow is inadequate check the filter in the coolant recirculator. See instruction manual for that unit.

Torch Assembly

PWH/M P22 Torch Assembly Shown. P75. P15, P30 similar assembly shown below.

1. Cup
2. Standard Tip (Keyhole Process)
3. Extended Tip (Melt-in Process)
4. Electrode
5. Liner (Red and Black O-Ring inside of Torch).
6. Gas Distributor
7. Collar
8. Shield Gas Diffuser
9. Cup Gasket
10. Torch Head
11. Collet
12. Back Cap

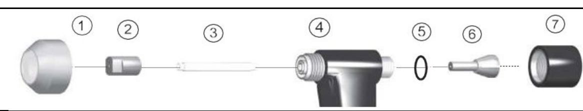
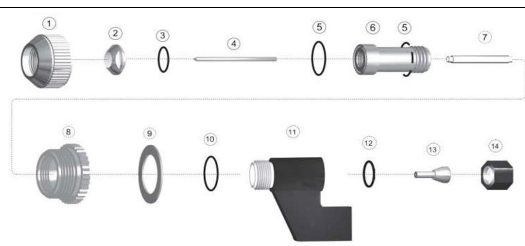




Torch configurations:

- Phenolic Handle or Rack and Pinion.
- 70°, 90°, 180° inline or offset head.

See Brochure for ordering information.

P75	
P15	
P30	

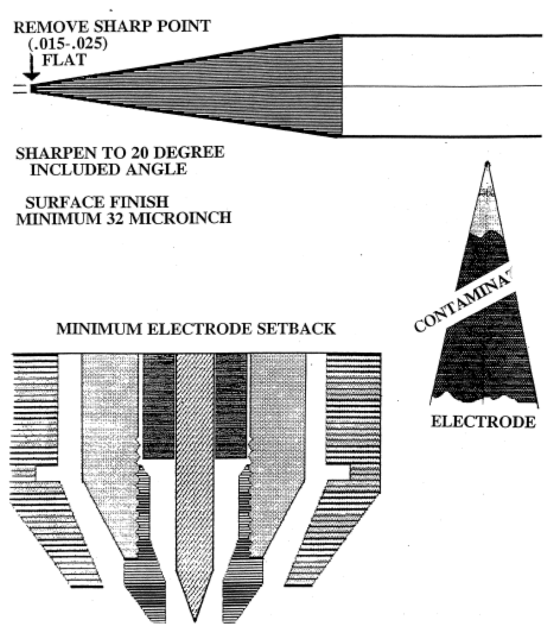
Plasma Welding Setup and Operation

Torch Operation

- Tip orfice designates current capability. The current rating on a tip is it's maximum current capability.
- Electrode is 2% thoriated tungsten. The point is centered and machined at a specific angle. The use of TIG Tungsten can cause damage or failure to the torch. Hand grinding of the point will cause damage or failure of the torch. Always use a Tungsten grinding station set to a included angle of 20 Degrees with a surface finish minimum of 32 microninch.

- Electrode Setback – Electrode setback is measured from the front of the tip orfice. Minimum setback would be the electrode flush with the front of the tip orfice. Use setback gauge when setting setback for Keyhole operation.

- When in operation always:
    - Use two separate regulated supplies of gas for each torch. Input pressure set to 35 to 40 psi. *DO NOT USE ONE GAS SUPPLY OR "Y" THE GAS TO MULTIPLE TORCHES!*
    - Purge Gases before starting pilot.
    - Leave pilot on between welds and throughout the work shift.



Below shows proper installation of the Torch, Shield Gas and Plasma Gas.