20/01/2020

# Plasma Operating Manual

Elettro c.f. srl

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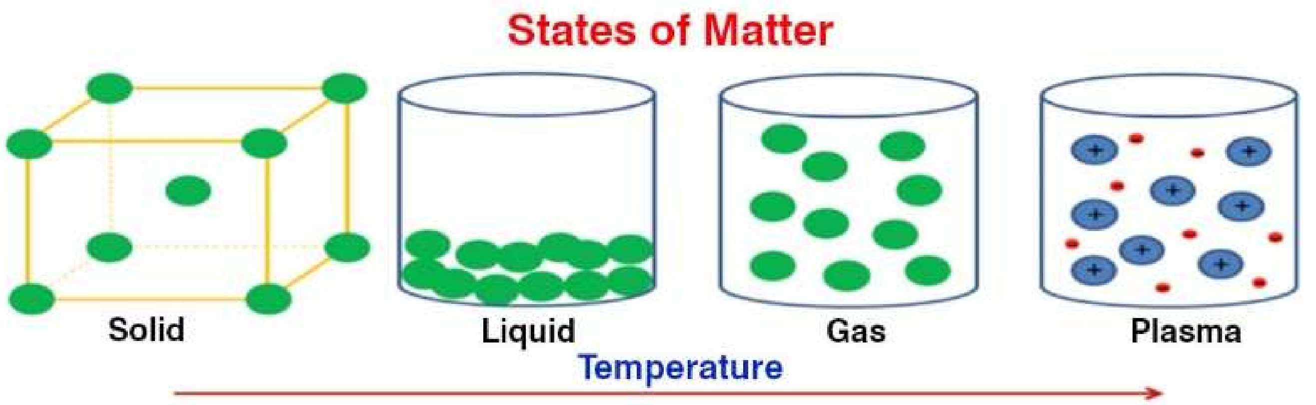
## 1 PLASMA CUTTING

### 1.1 What is plasma?

To properly explain how a plasma cutting generator works, we must start by answering the basic question "What is plasma?" Simply put, plasma is the fourth state of matter. It is commonly thought that matter has only three states: solid, liquid and gaseous. In fact, matter is able to change its form by passing from one state to another through the introduction of energy, such as heat or electricity. For example, water changes from its solid state (ice) to its liquid state when a certain amount of heat is applied and its temperature increases. If more heat is added, the water will again change its state from liquid to gas (vapour). Now, if the heat level increases further, the gases that make up the vapour will become ionized and electrically conductive, becoming plasma.

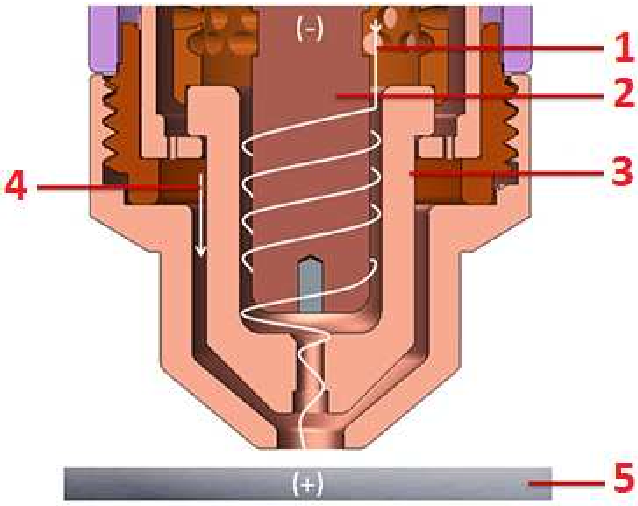



A plasma cutting system uses this electrically conductive gas to transfer energy from a generator to any conductive material, resulting in a cleaner and faster cutting process than oxycutting. Plasma arc formation begins when a gas such as air or nitrogen is forced through a small orifice inside the torch and simultaneously an electric arc is introduced into this high-pressure gas stream, resulting in what is commonly called a "plasma pilot arc". The plasma pilot arc immediately reaches temperatures of up to 30,000 °C, rapidly penetrating the workpiece and blowing away the molten material during the torch feed.
The scientific explanation lies in the fact that all matter is composed of atoms, which are essentially the basic particles of any material. Atoms are made up of protons (positively charged), electrons (negatively charged) and neutrons (with no electrical charge). Atoms combine or can combine to form molecules. A typical gas atom contains an equal number of both positive and negative charges. Therefore, the positive charges in the nucleus are surrounded by an equal number of negatively charged electrons, and thus every atom of every material, whether solid, liquid, or gaseous, is electrically neutral. Plasma is formed when the addition of heat (or other energy) causes a number of atoms to release some or all of their electrons. The remaining parts of those atoms are left with a positive charge and the detached negative electrons are free to move. Those atoms and the resulting electrically charged gas are said to be "ionized". When enough atoms are ionized to significantly affect the electrical characteristics of the gas, the latter becomes plasma. Normally, the gas flowing through the nozzle also acts as a means for removing the molten metal heated by the ionized gas. A portion of the gas is actually ionized (under optimal conditions) while the remainder is used to remove and cool material and consumables. Some types of plasma normally occur in nature, such as the sun, static electricity and lightning. There are also other types of plasma that are common in our daily lives, such as neon lights, fluorescent light bulbs and plasma televisions.

### 1.2 Components of a plasma cutting system

A plasma cutting system, also called Plasma Arc Cutting (PAC) consists of the following components:

- 1 Cutting gas
- 2 Electrode (negative pole -)
- 3 Nozzle (positive pole +)
- 4 Cooling gas
- 5 Plate to be cut (positive pole +)

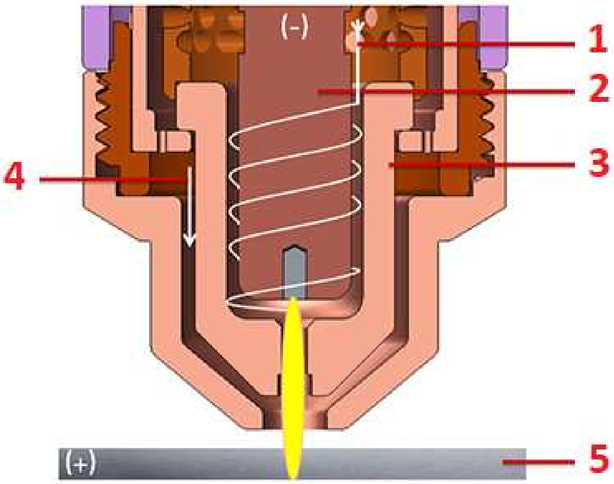



a) **Generator**: converts single-phase or three-phase AC line voltage to a regular and constant DC voltage between 200 and 400 VDC. This DC voltage is responsible for maintaining the plasma arc during cutting. The generator also adjusts the required output current according to the type of material and thickness to be cut.

b) **Plasma torch**: the function of the plasma torch is to provide proper alignment and cooling of consumables. The main consumable parts required for plasma arc generation are the electrode, the swirl ring and the nozzle. An additional protective screen can be used to further improve cut quality and protect the integrity of the nozzle during initial cutting and piercing.

c) **Plasma types**: not all plasma cutting systems are the same, there are in fact various types, depending on how they have been designed (generator, torch and relative consumables) and how, consequently, they use energy and feed gas.

   - Common Plasma: common plasma systems typically use only air as the feed gas and the shape of the plasma arc is essentially defined by the nozzle orifice. The current density of this type of plasma arc is the minimum necessary for operation, i.e. 12,000-20,000A per square inch. All cheap portable systems still use common plasma. This solution is still in use in applications where the quality of the parts and their speed of execution is not important.
   - High-Density Plasma: the latest-generation plasma systems produced by Elettro c.f. belong to the high current density type and are designed to produce the cleanest and highest quality cuts obtainable with air plasma. The torch and consumables are much more complex to allow the system to shrink the arc even further to dramatically reduce the Kerf, increase maximum thicknesses and cutting speeds. The current density of a high-density plasma arc is about 40,000-50,000A per square inch.




**1.3 The role of gas in plasma**

The gas flowing inside the torch is forcibly swirled by the insulating swirl ring placed between the electrode and the nozzle. The vortex that is created increases the cooling capacity of the entire torch during operation. Non-ionized gas atoms are heavier/cooler and during the rotation they concentrate outside the rotating gas stream, cooling the inner walls of the nozzle and protecting it from heat. As the current increases, the amount of ionization increases and cooling decreases, shortening the life of the nozzle. The nozzles are designed to operate within a specific current (A) range. If the plasma gas was not swirled, the cutting results would be modest and would show a large bevel and a steep slant on both sides of the cut (5-8 degrees).

**1.4 Purity class of plasma gas**

Gas purity is essential for good cutting quality and long electrode life. The minimum purity requirements can be found in charts 1, 2, 3, 4 on page 6. If purity levels are below the recommended minimum value, the following may occur:

- The arc cannot penetrate the metal or this operation takes longer than it should.
- Change in the quality of the cut, depending on the degree of contamination.
- Extremely short electrode life.
- With the same current, the cutting speed decreases (up to -40%), the cutting quality worsens, the cutting thickness decreases (up to -30%) and the service life of consumables decreases (up to -70-80%).
- Each nozzle is designed to operate in an optimal current range based on a given gas pressure/stream. Increasing or decreasing this pressure may result in a reduction in electrode life.
- A low gas pressure generally can cause double arcs and consequent early wear of the parts.
- To optimise the generator performance and ensure a long service life of consumables, compressed air must have a minimum purity class of 1.2.2 in accordance with ISO8573-1:2010, see the following charts:

Chart 1 (Purity class ISO8573-1:2010)

| Class | Relevant chart |
|---|---|
| 1 | Solid particles |
| 2 | Water |
| 2 | Oil |

Class charts: SOLID PARTICLES, WATER and OIL.

Chart 2

**SOLID PARTICLES**

| class | Maximum number of particles per m³ particle size (d) µm | | | Concentration mg/ m³ |
|---|---|---|---|---|
| | 0.1 – 0.5 | 0.5 - 1 | 1 - 5 | |
| 0 | Complies with user specifications, more restrictive than class 1 | | | |
| 1 | ≤ 20.000 | ≤ 400 | ≤ 10 | - |
| 2 | ≤ 400.000 | ≤ 6.000 | ≤ 100 | - |
| 3 | - | ≤ 90.000 | ≤ 1.000 | - |
| 4 | - | - | ≤ 10.000 | - |
| 5 | - | - | ≤ 100.000 | - |
| 6 | - | - | - | ≤ 5 |
| 7 | - | - | - | 5 - 10 |
| 8 | - | - | - | - |
| 9 | - | - | - | - |
| X | - | - | - | > 10 |

Chart 3

**WATER**

| class | Pressure dew point | Liquid g/ m³ |
|---|---|---|
| 0 | Complies with user specifications, more restrictive than class 1 | |
| 1 | ≤ -70 °C | - |
| 2 | ≤ -40 °C | - |
| 3 | ≤ -20 °C | - |
| 4 | ≤ +3 °C | - |
| 5 | ≤ +7 °C | - |
| 6 | ≤ +10 °C | - |
| 7 | - | ≤ 0.5 |
| 8 | - | 0.5 - 5 |
| 9 | - | 5 - 10 |
| X | - | > 10 |

Chart 4

**OIL**

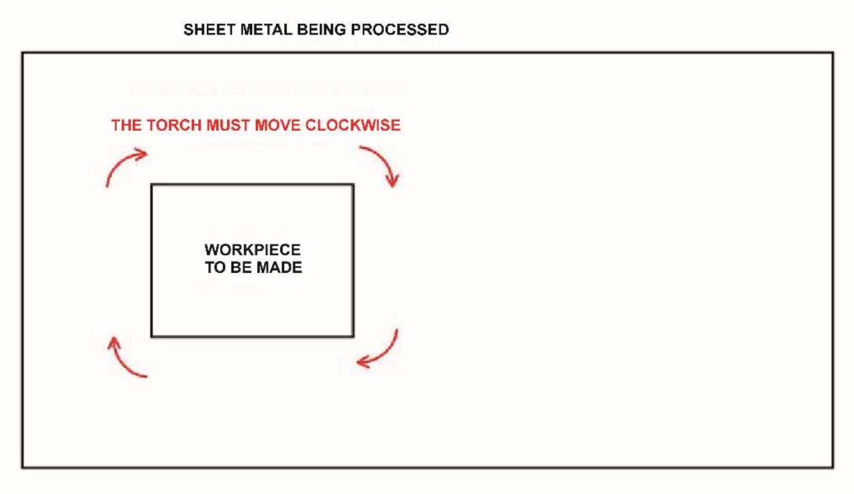
| class | Total oil concentration (aerosol, liquid, vapour) mg/ m³ |
|---|---|
| 0 | Complies with user specifications, more restrictive than class 1 |
| 1 | 0.01 |
| 2 | 0.1 |
| 3 | 1 |
| 4 | 5 |
| 5 | - |
| 6 | - |
| 7 | - |
| 8 | - |
| 9 | - |
| X | > 10 |

### 1.5 Cut quality and direction of torch feed

By rotating the gas, the arc is distributed evenly along one side of the cut, according with the direction of rotation. As the ionized gas (plasma arc) is swirled, the electric arc "sticks" evenly to the leading edge of the cut. These multiple attachment points provide a more even distribution of power through the workpiece during cutting. This homogeneous distribution of power from top to bottom results in a squarer side on the right side with respect to the direction of torch feed, allowing obtaining a cutting angle between 1 and 3 degrees. The other side, the left one, will have each time an angle between 5 and 8 degrees and will always be the worst side of the cut.

**Example 1**

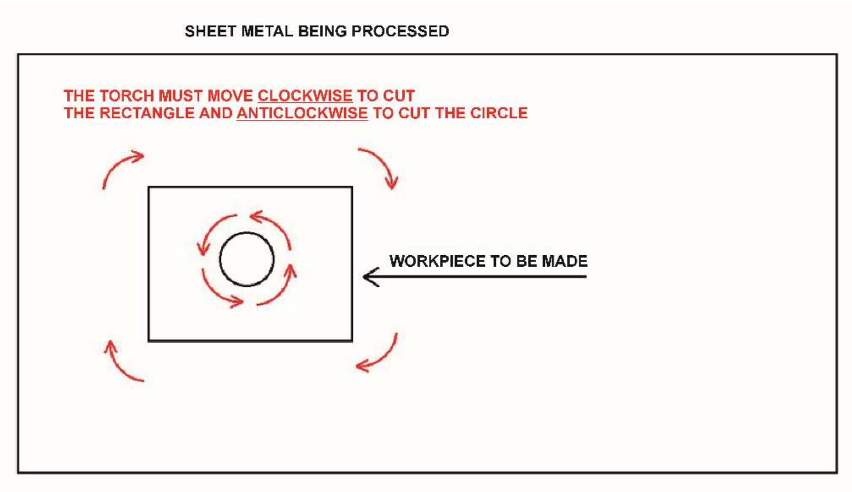
If it is necessary to cut a rectangular-shaped workpiece in a metal sheet, the torch will have to move clockwise, so that the best side of the cut with respect to the direction of the torch feed, i.e. the right side, is that of the cut workpiece. On the contrary, in the "mother" sheet metal the four sides of the cut will be characterized by an accentuated tilt between 5 and 8 degrees.




**Example 2**

If, on the other hand, it is necessary to make a rectangular workpiece like the previous one, but with a hole inside, the torch will have to move in two different directions depending on the path and the figure to be obtained.

The torch should move clockwise to make the rectangle and anticlockwise to make the hole inside it. In both cuts in fact, the right side with respect to the direction of the torch feed will always be that of the workpiece to be obtained.

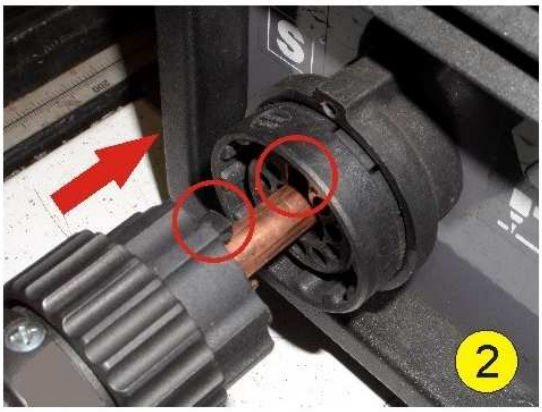


## 2 RULES AND CHARACTERISTICS FOR USING A PLASMA CUTTING GENERATOR

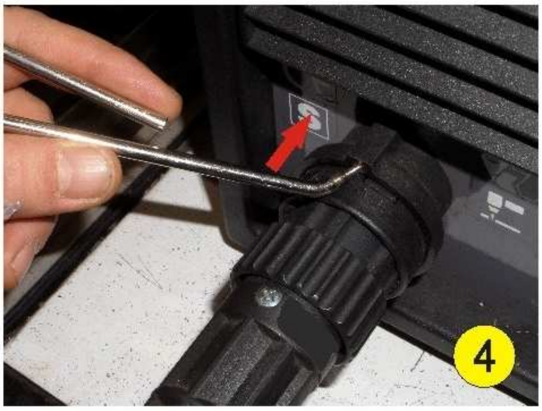
### 2.1 Torch installation

Torch installation sequence (during these operations, the generator MUST be de-energised):

- Insert the torch male adapter in the corresponding female connector on the front panel (Fig.1). Be careful to align the black nylon pin (circled in red in Fig.2) with the corresponding hole in the adapter.


- Fully press the male adapter (Fig.3), then insert the corresponding chrome-plated wrench in the female adapter hole (Fig.4) and firmly press the inner unlocking tab.


- While holding the female adapter inner unlocking tab pressed by means of the corresponding chrome-plated wrench, turn the ring nut of the torch male adapter clockwise (Fig.5) until it is fully seated (Fig.6). The torch is now ready for use.


### 2.2 Generator settings for manual cutting

- Press the torch trigger for a very short time to open the gas stream. Check that, in this condition, the pressure indicated on the pressure gauge corresponds to the values indicated on the machine; if not, adjust it by turning the knob on the reducer, then lock the knob by pressing downwards. If the generator used is synergic, pressure regulation is automatic and dynamic, i.e. it takes place independently before, during and after the pilot arc and cutting phases.
- Connect the grounding clamp to the workpiece to be cut, making sure that they have a good electrical contact, especially with painted, oxidized or insulated sheet metal.
- Do not connect the clamp to the part of the material that is to be removed.
- If the machine used is not synergic, select the cutting current according to the thickness to be cut, following the instructions below:

- Aluminium:

  5 ÷ 8 mm 40 ÷ 50A

  8 ÷ 20 mm 80 ÷ 90A

  20 ÷ 30 mm 110 ÷ 120A

  30 ÷ 50 mm 160 ÷ 180A

- Mild steel and stainless steel:

  up to 10 mm 40 ÷ 50A

  up to 25 mm 80 ÷ 90A

  up to 40 mm 110 ÷ 120A

  up to 60 mm 160 ÷ 180A

  Current values higher than those indicated do not affect the proper functioning of the machine or torch and can sometimes improve the quality of the cut by reducing scraps on the edges of the workpiece.
- If the machine used is synergic, it is sufficient to set the type of material and its thickness. This allows the generator to automatically adjust all the parameters necessary for operation and to indicate to the operator the cutting speeds to be used according to the torch and the desired process.

### 2.3 Manual cutting

- Press the torch trigger to strike the pilot arc.
- If cutting does not begin within 3-5 seconds (depending on the models), the pilot arc goes out automatically; press the trigger again to re-strike it.
- Hold the torch vertically while cutting.
- When you have finished cutting and released the trigger, air continues to come out of the torch to allow it to cool down.
- Do not turn the machine off before this operation is ended.
- Should you need to make holes or begin cutting from the centre of the workpiece, you must hold the torch at an angle and slowly straighten it so that molten metal is not sprayed on the nozzle (see pict.1).

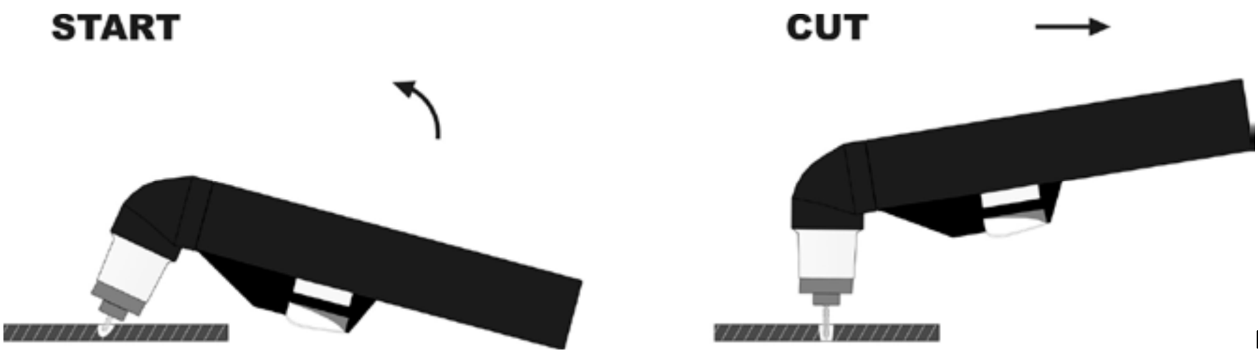



Fig.1

- This must be done when perforating workpieces more than 3 mm thick.
- During operation in automatic mode (see fig.2) keep the torch 10/11 mm away from the workpiece and, if possible, after making the hole, bring it closer to the size recommended by the cutting charts.

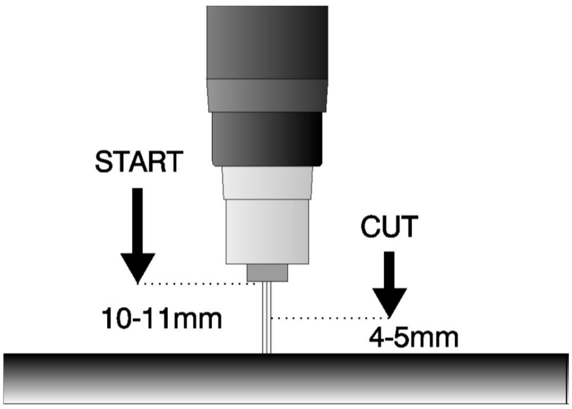



Fig.2

- If circular cuts have to be made, it is advisable to use the special compass supplied on request.
  It is important to remember that using the compass could require the use of the starting technique described above.
- Do not keep the pilot arc lit in the air when not needed, to avoid unnecessary consumption of the electrode, swirl ring or nozzle.

### 2.4 Common cutting problems and solutions

**1) Insufficient penetration**

This problem may be caused by:

a) High speed: always make sure that the arc fully penetrates the workpiece to be cut and is never held at a forward angle of more than 10° ÷ 15°. This will avoid incorrect consumption of the nozzle and burns to the nozzle holder.
b) Excessively thick workpiece.
c) Grounding clamp not in good electrical contact with the workpiece.
d) Worn nozzle and/or electrode.
e) Nozzle hole too large in relation to the set current value.
f) Cutting current too low.

Warning: When the arc does not fully penetrate the material, the molten metal scraps can damage the nozzle hole and compromise cutting quality, performance and speed.

**2) The cutting arc goes out**

This problem may be caused by:

a) Worn nozzle, electrode or gas swirl ring.
b) Air pressure too high.
c) Supply voltage too low.
d) Feed rate too low.
e) Cutting current too high in relation to the thickness of the workpiece to be cut.

**3) Slanted cut**

If the cut appears slanted, turn the machine off and replace the nozzle.

Do not allow the nozzle to come into electrical contact with the workpiece to be cut (including through molten metal scraps).

This condition causes rapid, sometimes unexpected, destruction of the nozzle hole, resulting in a poor quality cut.

**4) Excessive or early wear of consumable parts**

The above-mentioned problem may be caused by:

a) Gas pressure too low compared with the recommended level.
b) Starting from billet material with high thickness or without following the procedure described in Fig.1 or Fig.2
c) Too high cutting speed that causes a rejection of molten material on the nozzle, damaging it.

### 2.5 Automatic cutting

#### 1) Starting a plasma arc

There are three main components inside the body of the torch:

• Electrode

• Swirl ring

• Nozzle

These components are called consumables. They are consumed by the switching on and off of the pilot and cutting arc, are active during the plasma process and must be replaced periodically. Always consult the exploded view of the torch used to properly choose and configure the consumable to be mounted.

The electrode is connected to the negative pole of the plasma generator. The nozzle, on the other hand, is connected to the positive pole only during the pilot arc phase. At the time of transfer, the nozzle is electrically disconnected and replaced by the workpiece to be cut, which is always connected to the positive pole through the generator grounding socket.

The following occurs when a start input is given to the plasma system:

• The inverter is activated and generates a high negative voltage on the electrode.

• The gas begins to flow towards the torch and is swirled by the swirl ring.

• The nozzle circuit closes and provides a path to the positive pole of the generator.

• As the short circuit between the electrode and the nozzle is interrupted by the pneumatic pressure inside the torch head, the electrode moves and moves away from the inside of the nozzle with which it was in contact. This causes an initial small arc between the nozzle and electrode, which as the electrode moves away, ionizes the gas and creates a conductive path inside.

• Along this ionized path, a higher power electric arc begins to flow between the electrode and the nozzle and exits from the torch through the hole in the latter. This is called a pilot arc.

• The pilot arc is ejected from the nozzle by the gas stream and is ready to make contact with the workpiece.

• The main cutting arc is created when the pilot arc moves over the work material (if the torch is close enough). The nozzle circuit is opened removing the nozzle from the circuit. A transferred arc condition has been established and cutting can begin.

• The generator can provide, through the CNC connector (DDK or AMP) the transferred arc signal (clean NO contact that closes at the moment of the transfer) and a distributed arc voltage reference (fixed from 1/25 or 1/50V or electronically adjustable on the display from 1/20V up to 1/100V).

### 2.6 Double arc and prevention

A double arc is an abnormal condition that allows the nozzle to remain connected to the electrical circuit during plasma cutting. As described above, the nozzle should only be in the circuit during the pilot arc phase. If left in the circuit, the nozzle will carry a cutting current that will destroy it immediately.

Double arc can be caused by:

• **Residual molten material**. The torch should be positioned close enough to the workpiece to allow the pilot arc to make contact with the workpiece so that the main arc can be transferred. The splash of molten material during piercing is ejected at a low angle during initial piercing. As the arc penetrates the material, the splash becomes more vertical. This debris can electrically connect the workpiece and the nozzle, keeping it active in the circuit even when disconnected from the generator. This condition can damage the torch parts.

• **Torch in contact with the plate when cutting thin material**. All automatic torch positioning systems use an initial height detection method to position the torch over the plate. One method is the “touch and retract” method. The torch moves until it touches the plate and retracts to its original height. If the touch is not detected correctly, the torch may still be in contact with the material due to flexing or thermal deformation of the material. The nozzle will remain in the plasma circuit conducting cutting current, damaging itself.

• **Pilot arc malfunction**. This can occur if the pilot arc circuit fails to remove the nozzle. Once again the nozzle is left connected to the cutting circuit and will conduct more current than expected, damaging itself.

**Double arc prevention**

The double arc usually occurs during the piercing sequence.

Some techniques that can help prevent double arc are:

• **Gradual movement**. The cutting table can be programmed at a reduced speed to start torch movement at arc transfer. This speed is typically 5 to 10% of the normal cutting speed and is maintained for a specified period of time. During this time, splashes of molten material are more easily ejected from the nozzle during perforation. This reduces the possibility of double arc.

• **The torch goes up during the piercing**. Upon transfer of the arc the torch begins to detach from the workpiece. This prevents the molten metal splashes resulting from the perforation from hitting the nozzle. This retraction continues for a defined period of time, after which the torch waits for the metal to be pierced completely and then lowers to the correct cutting height to begin the cutting movement.

## 2.7 Process variables in plasma cutting

The variables involved in plasma cutting must all be carefully controlled to achieve maximum cut quality, maximum nozzle/electrode life and maximum production. It is necessary to maintain a balance between them.

- **KERF:**

  This is the width of the material (perpendicular to the torch and cutting axis) removed during the plasma cutting process. The kerf is influenced by three main variables.
  - Cutting speed. Higher cutting speeds with other constant variables will result in a narrower cut. The kerf will continue to reduce until a loss of penetration occurs. A slower cutting speed will result in a wider cut until arc loss occurs.
  - Cutting current. Increasing the cutting current with the other two constant variables will result in a wider cut. Continuing to increase the current widens the kerf until the nozzle is destroyed. Reducing the current will result in a narrower cut, a more positive cutting angle until the loss of metal penetration, even at lower speeds.
  - Cutting height. It is the distance kept between the torch and the workpiece after piercing (during cutting). Most modern systems use an arc voltage feedback system. Increasing the arc voltage increases the cutting distance and widens the kerf. Continuing to increase the distance will lead to a loss of cutting capacity. Reducing the distance will result in a narrower cut, but in a loss of cut quality.

**Chart of estimated cut width compensation (Kerf)**

<table>
<tr><td>Thickness</td><td colspan="7">CUTTING CURRENT</td></tr>
<tr><td>mm</td><td>50A/ECF-71</td><td>70A/ ECF-71</td><td>80A/ECF-131</td><td>100A/ ECF-131</td><td>125A/ ECF-131</td><td>150A/ ECF-181</td><td>180A/ ECF-181</td></tr>
<tr><td>1</td><td>1,4</td><td>1,4</td><td>1,4</td><td>1,5</td><td>1,2</td><td>1,3</td><td>1,4</td></tr>
<tr><td>2</td><td>1,4</td><td>1,4</td><td>1,5</td><td>1,8</td><td>1,3</td><td>1,4</td><td>1,5</td></tr>
<tr><td>3</td><td>1,5</td><td>1,5</td><td>1,6</td><td>2,0</td><td>1,7</td><td>1,8</td><td>1,9</td></tr>
<tr><td>5</td><td>1,6</td><td>1,7</td><td>1,8</td><td>2,1</td><td>1,8</td><td>2,2</td><td>2,2</td></tr>
<tr><td>10</td><td>1,8</td><td>1,9</td><td>2,1</td><td>2,4</td><td>2,1</td><td>2,4</td><td>2,5</td></tr>
<tr><td>15</td><td>1,8</td><td>2,1</td><td>2,3</td><td>2,7</td><td>2,5</td><td>2,6</td><td>2,6</td></tr>
<tr><td>20</td><td>2,0</td><td>2,2</td><td>2,5</td><td>3,0</td><td>2,9</td><td>2,8</td><td>2,9</td></tr>
<tr><td>25</td><td>2,1</td><td>2,2</td><td>2,7</td><td>3,3</td><td>3,2</td><td>3,1</td><td>3,2</td></tr>
<tr><td>30</td><td rowspan="11">N/A</td><td>2,4</td><td>2,7</td><td>3,5</td><td>3,4</td><td>3,5</td><td>3,6</td></tr>
<tr><td>35</td><td>2,5</td><td>2,8</td><td>3,6</td><td>3,6</td><td>3,8</td><td>3,9</td></tr>
<tr><td>40</td><td rowspan="9">N/A</td><td>3,0</td><td>3,7</td><td>3,8</td><td>4,1</td><td>4,1</td></tr>
<tr><td>45</td><td rowspan="8">N/A</td><td>3,8</td><td>3,8</td><td>4,2</td><td>4,2</td></tr>
<tr><td>50</td><td>4,1</td><td>4,1</td><td>4,4</td><td>4,5</td></tr>
<tr><td>55</td><td rowspan="6">N/A</td><td>4,8</td><td>4,8</td><td>4,9</td></tr>
<tr><td>60</td><td>5,0</td><td>5,1</td><td>5,2</td></tr>
<tr><td>65</td><td rowspan="4">N/A</td><td>5,3</td><td>5,4</td></tr>
<tr><td>70</td><td>5,5</td><td>5,6</td></tr>
<tr><td>75</td><td rowspan="2">N/A</td><td>5,8</td></tr>
<tr><td>80</td><td>6,0</td></tr>
</table>

- **ARC VOLTAGE:**

  Arc voltage is not an independent variable, but depends on:

  - Cutting current
  - Nozzle hole size
  - Distance from the workpiece
  - Gas pressure

- **CUTTING SPEED**

The cutting speed affects the quality of the cut and the formation of burrs at the top and bottom of the cut workpiece:

Burr is resolidified oxidized molten metal that has not been completely ejected from the cut width during the cutting. Burr may form a metal build-up along the bottom edge of the sheet metal (low-speed burr), a small rigid rib of uncut material (high-speed burr), or a thin coating along the top surface of the sheet metal (upper molten metal splash).

Burr formation depends on numerous process variables including torch speed, distance between torch and sheet metal, current, voltage and conditions of consumables. It is also affected by material variables such as material thickness and type, chemical composition, surface condition, flatness and even changes in material temperature as it is cut. However, the most critical variables to consider in burr formation are cutting speed, current, and distance between torch and sheet metal.

1) Low-speed burr
If the cutting speed is too low, the plasma jet begins to search for more material to cut. The arc column grows in diameter, expanding the width of the cut to the point where the high-speed portion of the plasma jet no longer ejects molten material from the cut. This results in the molten material beginning to accumulate along the bottom edge of the sheet metal in a thick, globular shape. This is called low-speed burr. At extremely low speeds the arc will go out because there is not enough metal to support a transferred arc. Increasing the current or decreasing the distance between the torch and the sheet metal (while maintaining constant material thickness and speed) has a similar effect on the cut as slowing down the cutting speed. Both of these variations result in more energy from the plasma jet making contact with a given area of the material over a given period of time. Excessive current or a short distance between torch and sheet metal can cause a low-speed burr. Some low-speed burr at the corners of a plasma cut is normal since the speed does not remain constant on tight turns.

To eliminate low-speed burr:

- Increase the cutting speed in 50mm/minute increments
- Increase the distance between torch and sheet metal in 5V increments
- Reduce current in 5A decrements
- If cutting does not improve with any of these measures, consider using a smaller nozzle size

2) High-speed burr
If the cutting speed is too high, the arc will lag along the cut width causing a small burr rib or along the bottom edge of the cut workpiece. This high-speed burr is more resistant and usually requires careful machining to be removed. At extremely high speeds, the arc becomes unstable and begins to oscillate up and down the cut width resulting in projections of sparks and molten material. At these speeds the arc may fail to penetrate the metal or go out.

An excessive distance between torch and sheet metal or a low current (for a given material thickness and cutting speed) can also result in high-speed burr because both of these variations result in a reduction in plasma jet energy.

To reduce high-speed burr:

- First check the nozzle for signs of wear
- Decrease the cutting speed in 50mm/minute decrements
- Decrease the distance between torch and sheet metal in 5V decrements
- Increase the cutting current in 5A increments up to the maximum allowed by the nozzle

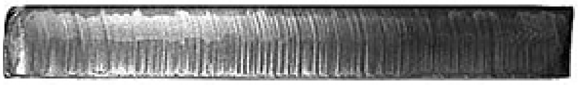
3) Top burr

The top burr is an accumulation of resolidified metal along the top of the cut workpiece. It is usually very easy to remove. Usually it is caused by a worn nozzle, excessive cutting speed or excessive distance between torch and sheet metal. This is caused by the swirling flow of the plasma jet, which at a given attachment angle spreads the molten material in front of the cut width rather than downward across it.

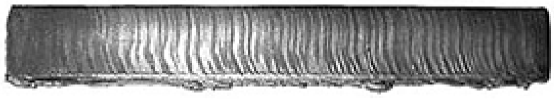
To remove the top burr:

- Check the nozzle for signs of wear
- Decrease the cutting speed in small decrements of 50mm/minute
- Decrease the distance between torch and sheet metal in 5V decrements

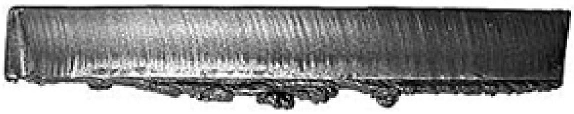
**Examples:**



**The cutting speed is correct**



**The cutting speed is too high**



**The cutting speed is too low**

**Burr-free range**

Between the high- and low-speed burr extreme limits there is a range for cutting with no or minimal burr. Finding this range is critical to reducing the need for secondary operations on plasma cut workpieces.

The range varies depending on the plasma gas used: for example nitrogen and air plasma gases have a relatively burr-free range on carbon steel

The burr-free range is also influenced by the type of material. For example, cold-rolled steels have a cleaner cut than hot-rolled steels and pickled steels have a cleaner cut than non-pickled steels.

**To assess the optimal cutting speed:**

- **Method 1:** Make a series of test cuts at different cutting speeds and choose the speed that produces the cleanest cut. Delay lines (small ridges on the surface of the cut) are a good indicator of cutting speed. Low cutting speeds produce vertical delay lines that are perpendicular to the plane of the sheet metal. High cutting speeds create S-shaped slanted delay lines parallel to the sheet metal along the bottom edge. By examining the delay lines, the operator can determine whether an increase or decrease in speed is needed to find the burr-free range. Many operators tend to slow the machine down at the first appearance of burr but often an increase in speed is necessary.
- **Method 2:** Observe the arc (wearing suitable welding goggles) while cutting and change the speed dynamically to produce the arc with the optimum characteristics. To do this, observe the angle of the arc as it comes out from under the workpiece. If cutting with air plasma gas, the arc should be vertical as it exits the underside of the cut. With nitrogen or nitrogen/hydrogen, a slightly rearward arc is the best solution.

- **QUALITY OF CUTTING MOVEMENT**

The plasma torch can ideally be considered as a mechanical tool (e.g. milling cutter) which, by moving forward, removes the material inside the plate (KERF) during the cutting phases.

This metal removal is performed by melting the metal through the ionization of the gas and the consequent high temperature generated by the passage of electric current supplied by the generator.

The melting of the cut metal is performed by a torch in mechanized motion through the use of an automatic or semi-automatic machine.

These machines use electrical and mechanical movements that affect the quality of the (melted) surface cut and consequently resolidified after the passage of the plasma torch.

In fact, a not perfectly linear movement at a constant speed produces different removals of material depending on the time spent at a precise point.

Here are some examples of electrical movements:

**Stepper motor**

It is the most economical and widely used solution in cutting tables for small machining operations and rapid prototyping. It combines inexpensiveness and reliability with ease of operation and use.

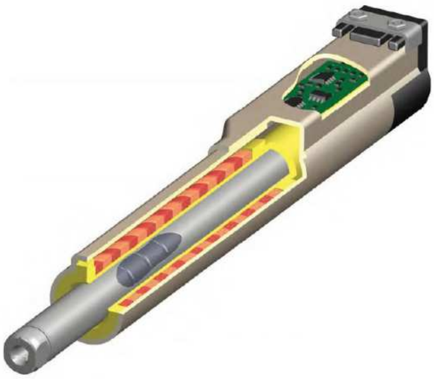
The disadvantage of this type of electric motor is the "jerky" movement which, although imperceptible to the naked eye, can leave obvious marks in the surface of the cut workpiece, as a physical trace of the irregularities in the continuity of movement

**Brushless motor**

It is the most professional, reliable and commonly used solution in professional cutting tables for intensive and continuous production. It combines its quality of movement and reliability over time with good value for money.

The disadvantage of this type of electric motor is in its electronic control, which must also be of high quality in order to allow a smooth and precise movement, without movement irregularities, which if too evident, could be reflected and be visible on the surface of the cut workpiece.

**Linear Motor**



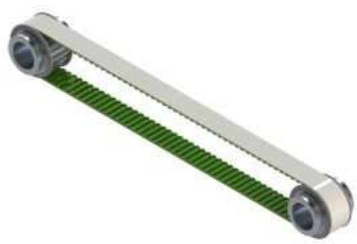
It is the most innovative and performing solution. It is characterised by a uniform and homogeneous movement, combined with strong accelerations with extreme positioning accuracy.

The disadvantage of this type of electric motor is in its cost, but the cutting surfaces do not show signs derived from the electric movement of the axes. Great for THC management as the response, acceleration and movement times are extremely fast.

As for electrical movements, mechanical movements are equally important in defining the cutting surface during melting and movement.

In fact, there are various types and qualities, the following are the most common and used:

**Belt drive**



It is the most economical solution used in the old handling systems. It is a system subject to mechanical deformation, poor precision of movement, vibration, early wear and frequent maintenance.

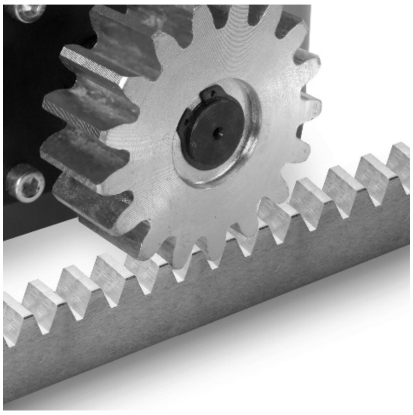
Little used as there are much better performing systems available at competitive prices.

**Screw-type drive**

It is a widely used solution in small tables due to its excellent value for money. Easy to maintain, excellent movement, and various types available, the best performing of which is the ball recirculation variant with helical screw.

The disadvantage of this solution is that commercial parts have a tendency to flex if they are very long, and, due to wear, they can show mechanical "play" that can affect the cutting quality with small vibrations or unwanted movements.

**Straight-toothed gear rack drive**



This too is a widely used solution in tables of all sizes due to its excellent value for money. Ease maintenance, good movement and excellent resistance to wear over time.

The disadvantage of this solution is that during the movement, there is a moment between one tooth and the other in which there is no mechanical contact between the parts. This causes a small pause in the movement, a sort of short hop that will be seen in the cut surface, identifiable as a knurling whose spacing will be directly traceable back to the toothing of the rack.

**Helical-toothed gear rack drive**

It is the best solution in all respects. It is the most widely used in high quality and precision cutting tables. Easy maintenance, excellent movement and resistance to wear over time.

The disadvantage of this solution is only the high cost, but combined with a good electrical movement, normally brushless, it allows obtaining perfectly smooth cutting surfaces with very low roughness values and excellent surface appearance

## 2.8 Types of feed gas

Depending on the type and thickness of the material, different gases are used to achieve the optimum balance of cut quality, life of consumables, productivity and total running costs.

**Air**

Air is the most versatile plasma gas, offering good speed and cutting quality on carbon steel, stainless steel and aluminium. Air also reduces operating costs because it does not require the purchase of gas. However, air is not free of charge. The factory compressed air must be cleaned to remove contaminants such as particulate matter, oil vapours and moisture. The best solution for plasma systems is a dedicated air compressor of the right size, a refrigerated dryer and a filter set to extract particulate matter, oil vapours and any residual moisture. Another concern with air plasma is the weldability of the cut edge. With air plasma, some nitriding or oxidation of the cut surface can occur, which can cause porosity in welds. Air is a good alternative for many factories to achieve versatility, good speed, low burr levels and durable life of consumables.

**Nitrogen**

Nitrogen is the best choice for those who cut a lot of aluminium and stainless steel as it is very economical. The cut quality and durability of the consumables are excellent. In the case of stainless steel, the resulting surface is smooth, but oxidized (blackened).

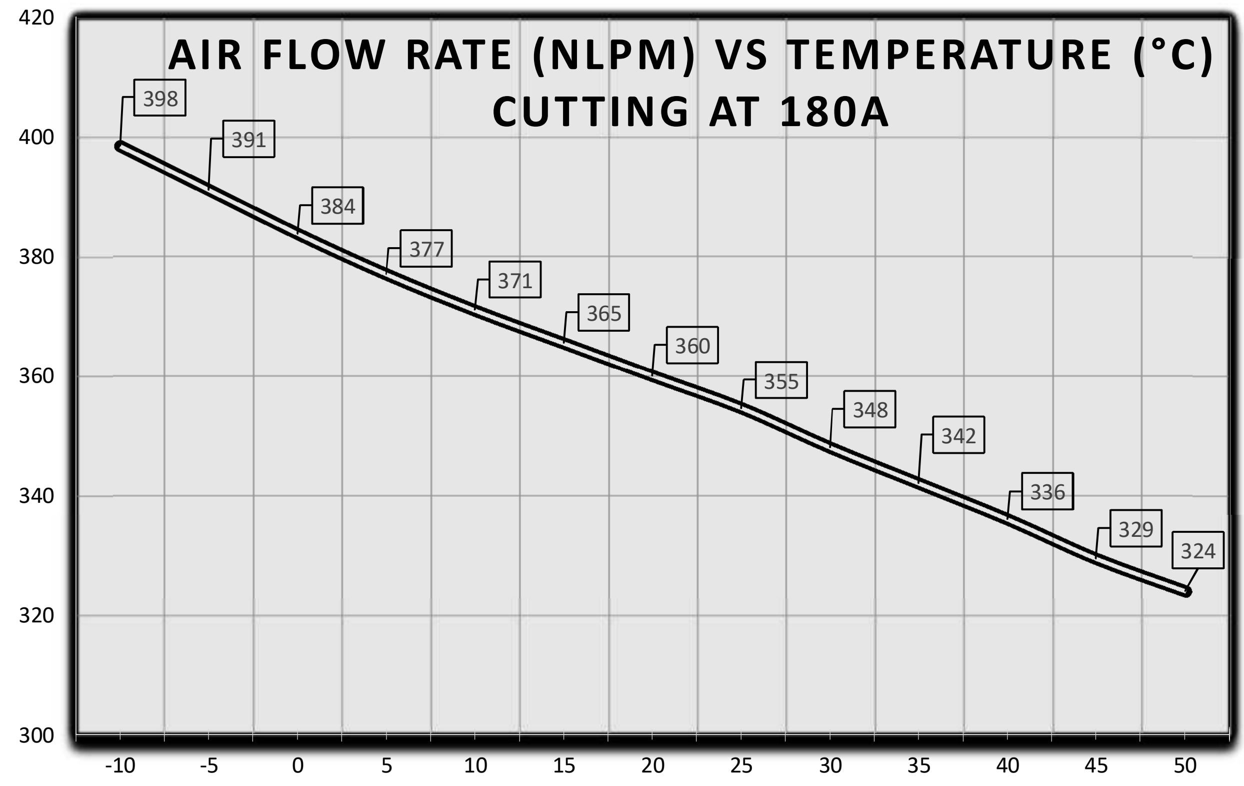
**F5 (N95)**

Composed of 95% N2 (nitrogen) 5% H (hydrogen) it is an expensive but extremely high performance gas for cutting noble materials such as stainless steel. The use of this gas makes it possible to prevent the oxidation of the molten surface while maintaining an excellent glossy surface appearance, which cannot be obtained with other common gases such as air or nitrogen.

## 2.9 Characteristics of the feed gas

### Feed gas flow rate

The air flow rate consumed during cutting is inversely proportional to the ambient temperature and is automatically and synergistically regulated by the power source.
The following chart shows the machine consumption value in NLPM (Normal litre per minute) during operation at the temperature of the reference gas.




**Conclusions:**

Choosing the best gas depends on three factors: cut quality, productivity and cost.

- For good cutting quality on stainless steel and aluminium, use nitrogen gas to get the right balance of cutting quality and affordable price.
- For an excellent cutting quality on thick stainless steel and aluminium use F5 (N95) which will give an excellent aesthetic result of the cut surface, but at much higher running costs.
- For maximum cutting economy, clean and dry factory air is the best choice for carbon steel, stainless steel and aluminium.

### 2.10 Determining the cutting quality

The quality of thermal cutting can be determined according to the requirements of UNI EN ISO 9013

The standard specifies the geometric characteristics of the product and the tolerances for the quality of the materials suitable to be cut with the plasma system. It is applied for plasma cuts from 0.5 mm to 150 mm thick.

The types of measurements and quality ranges are described in detail in order to define which class can be assigned to a cut workpiece.

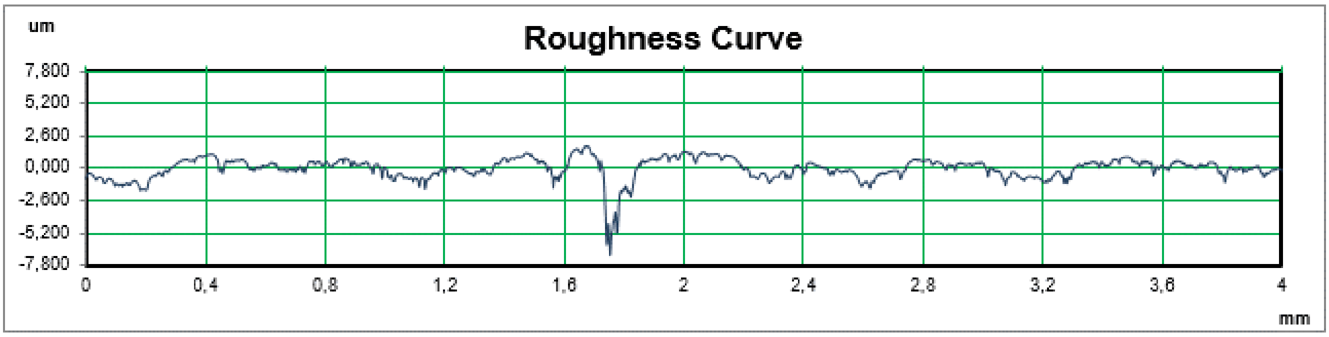
Normally an air plasma cut is classified on a scale of values according to the quality level starting from level 1 for the best cuts up to 5 for the worst cuts.

Normally, air plasma cutting produces a cut with quality level 4 or 5, while quality levels 1 and 2 are typically only found in laser cutting systems.

Currently, with its innovative and performing cutting systems, Elettro c.f. is able to obtain quality levels 3, well above the current average of the sector.

One of the reference parameters of surface quality is, for example, roughness, which can be measured with special instruments capable of defining in detail the quality of the surface and scientifically measuring its absolute value.

With instruments of this type it is in fact possible to keep the quality of the cuts obtained under control and consequently classify the actual quality level



# 3 GENERATOR AND SYNERGIC PLASMA CUTTING METHOD (PATENTED)

## 3.1 Technical characteristics of the system

**Scope of application**

This invention applies to any generator for plasma metal cutting, or to external systems used to control generators.

**Previous state of the art**

Plasma cutting generators are generally used to cut, mark or remove excess material or welds from metals in general. Each generator can be equipped with a single torch, but of various sizes and lengths, which can be configured in different modes, depending on:

- Type of application and processing
- Cutting power, measured in Amperes
- Thickness to be cut or amount of material to be removed
- Intended final quality
- Processing time
- Mechanised or manual cutting system
- Possible control of the cutting height

During the operation of the generator, a plasma arc is generated inside the torch between the electrode and the nozzle, which, moved out through the injection of compressed gas from the latter, produces a jet of ionized gas at high speed and very high temperature capable of melting the metal and simultaneously blowing away the molten part. Before making the cut, it is necessary to carefully evaluate each time the type of application and adequately choose, according to the type of metal and its thickness, the cutting current and the feed speed of the torch, as these two latter parameters are inter-linked and decisive in determining the quality and speed of the processing to be carried out. In fact, an excessive cutting speed produces thin burrs in the lower part of the cut workpiece that are difficult to remove and are re-melted on the edges of the workpiece, forcing a subsequent reprocessing or in some cases the scrapping of the processed workpiece. Reduced speeds, on the other hand, produce heavy, porous burrs that can be easily removed with further reprocessing, but almost always avoiding the scrapping of the workpiece. Currents which are excessive or reduced compared to the optimal value can also produce slanted cutting angles, inwards or outwards, or other production defects, leading to rejects and/or the need to examine, check, verify each production and possibly repeat it.

It is therefore common practice to carry out multiple preventive tests before starting the processing of the raw material, in order to find and identify the ideal conditions and parameters to obtain the highest quality of the finished workpieces or the maximum production speed (sometimes slightly reducing the quality of the cut surface). To date it is necessary to manually enter or load cutting setup parameters obtained from paper, computer or electronic archives, through manual compilation or loading of saved, dedicated and/or previously tested work programs. This common use of the plasma cutting system causes the need for a certain amount of time to equip and set up the system each time the production target is changed, which in fact requires:

- Non-productive operator time
- Useless consumption of electricity and compressed gas
- Degradation and wear of torch spare parts
- Processing waste from sample workpieces produced to optimise the process
- Saving and archiving of the parameters obtained related to that production process (recipe)

## Description

The system is composed of a generator for plasma metal cutting equipped with a controller for the SYNERGIC adjustment of the parameters necessary for its operation and optimised to achieve the maximum performance desired or possible.

Through a display interface (Fig.a), this controller asks the operator for the type (A) and thickness (B) of the metal to be cut and then communicates, through the user interface:

- the maximum cutting current (C) at which the generator automatically sets itself
- the optimal cutting speed (D) to obtain the highest quality of the cut workpieces.
- the maximum possible cutting speed (E) to increase productivity and the number of workpieces cut per unit of time.
- The correct nozzle type (F) to optimise performance and minimise the consumption of spare parts.

Finally, the generator confirms and indicates the start of cutting by the appearance of the ON symbol (G)

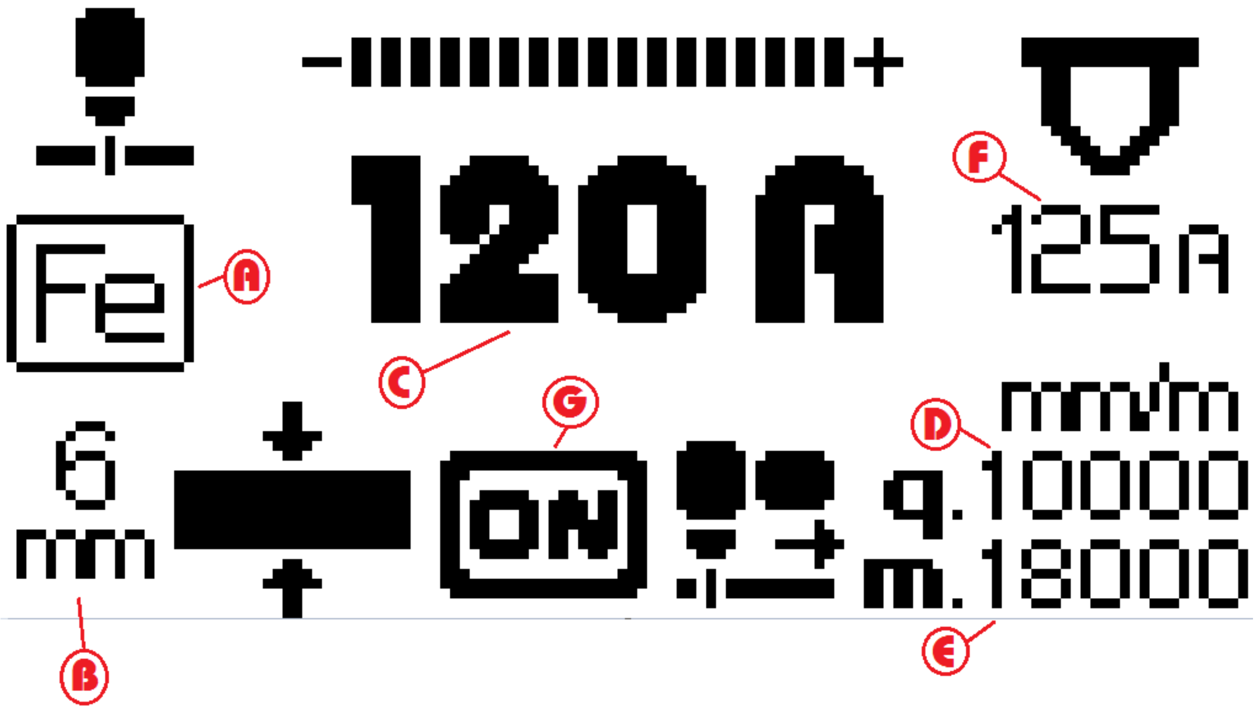



Fig.a

Consequently, the parameters:

(A) Type of material, selected from the menu below (Fig.b)

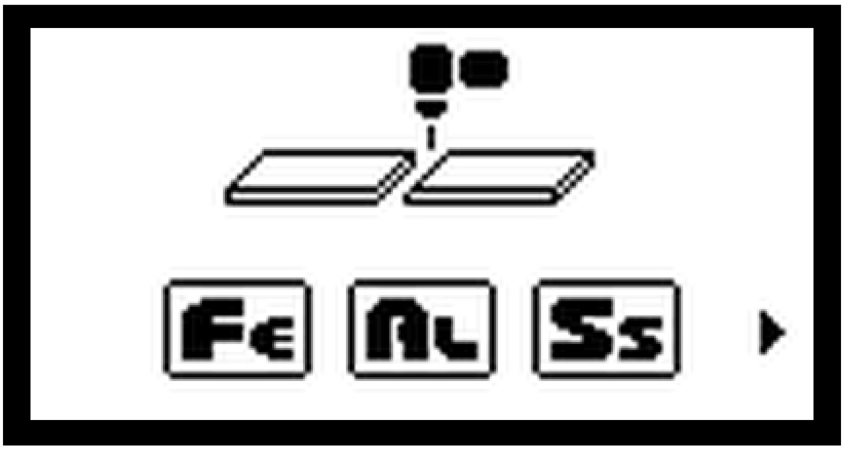



Fig.b

(B) Thickness
(C) Cutting current
(D) Quality cutting speed
(E) Maximum cutting speed

can be modified at will by the operator according to the production to be carried out and when one of these parameters changes, the synergic controller automatically modifies all the other parameters displayed according to the relative diagram, and correctly sets the current sensors and the pressure regulator to optimise the new parameter entered.

The three fundamental values of plasma cutting (material thickness/cutting current/cutting speed) are thus synergistically linked together (Fig.c) in order to always guarantee the correct generator self-adjustment at every variation of one of them.

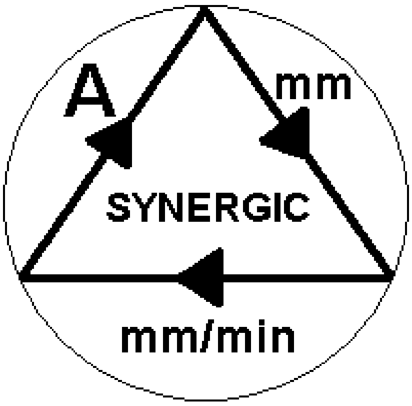



Fig.c

Therefore, it is no longer necessary to save, load or set the cutting parameters manually or electronically, as they are all already contained in the generator memory and a mathematical link has been created between them (see cutting chart or diagram) (Fig.d)

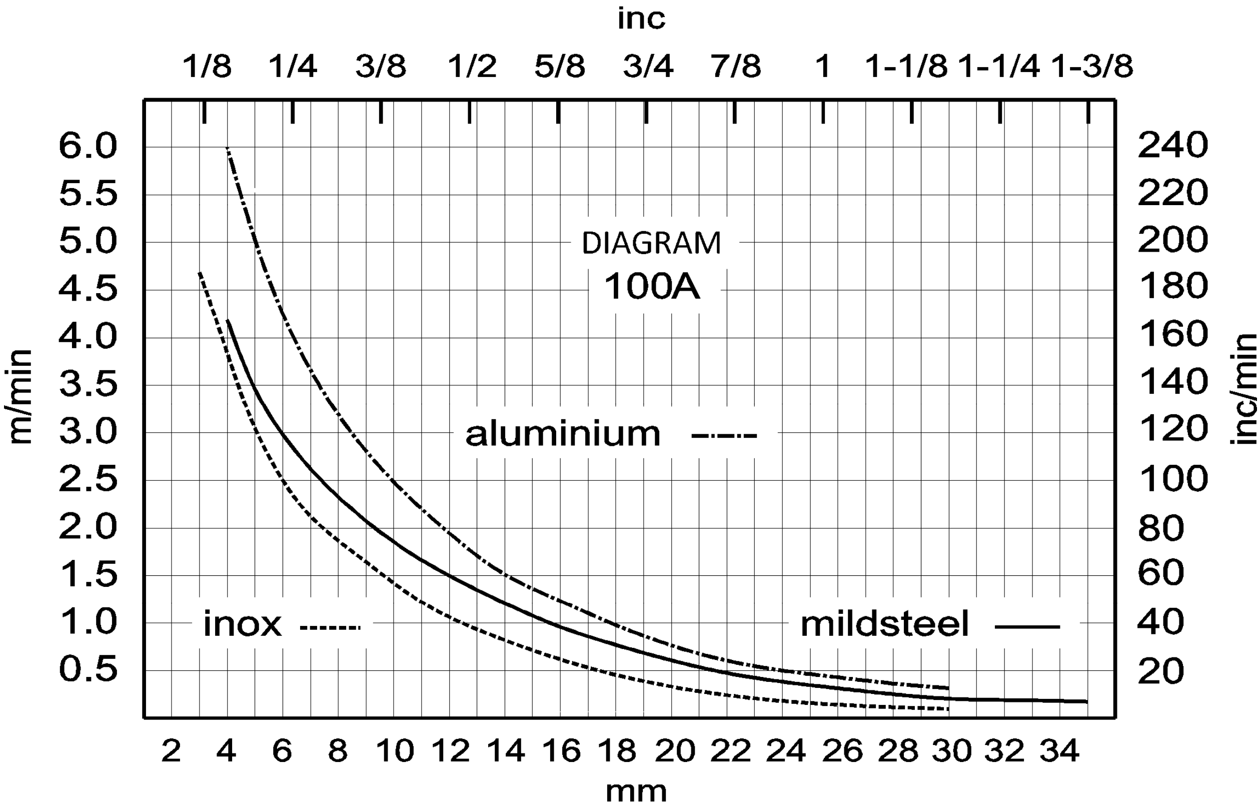



Fig.d

Upon insertion of the torch into the generator, the machine automatically recognises the size and/or length and:

- Automatically sets the minimum and maximum operating values.
- Regulates the quantity of gas required, through the control of an electric actuator (Fig.f) composed of a micrometric pressure regulator, a gear motor, two pressure transducers and two safety limit switches.
- Automatically displays the basic parameters, selecting first those related to the maximum productivity (Fig.a).

As a result, at each variation of the production target, it is sufficient to select the thickness and the type of material (only if different from that already set) and the generator is already ready to perform mass production without the need to carry out preventive tests.

When turning on the machine the operator can select the type and thickness of the material to be cut and the machine will automatically show the relative current, nozzle and cutting speed values.

Once this operation is carried out, you can select and modify at your discretion the suggested values of current and/or speed and the machine will modify, in a synergic way, the other value, (Fig.e) automatically following the ideal cutting curve to perform the type of machining required (Fig.d).

In fact, the main objective of the machine is to achieve the highest possible productivity according to the thickness and type of material set.

For this reason, at each change of material or thickness of the same, the machine modifies and always proposes the maximum possible cutting current, combined with the two cutting speeds recommended for maximum quality (D) or maximum speed (E).

This is because in plasma cutting the important thing is not to know the current value relative to a certain thickness or a certain material but rather the speed of the cut, which determines the quality of the cut surface and the formation or not of cold or hot burrs.

Using the cutting speed information provided by the synergic interface, it is thus possible to immediately optimise each cut by choosing the correct speed and to avoid as much as possible the formation of the aforementioned burrs.

If, on the other hand, the automatic cutting system cannot reach the cutting speeds proposed by the synergic interface, it is possible to modify the speed by decreasing it and at that point the machine will have automatically decreased the cutting current in order to optimise again the cutting quality.

It follows that for each material and each thickness, the proposed and set cutting current will always be the maximum allowed by the generator according to the maximum possible feed speed of the automatic cutting system.

### 3.2 Energy saving and environmental impact

The new synergic plasma cutting system was born to solve the problems related to the normal and typical use of the systems on the market. It performs preventive tests for the sole purpose of identifying the best parameters to be used for production and requires software or hardware loading operations more or less fast and / or complex, inevitably involving consumption of human resources, materials or energy for their execution. With the application and use of this synergic technology, four benefits are immediately achieved:

1) Energy saving due to the absence of prior testing and setup of the cutting system before production.
2) Saving of raw material used during testing and reduction of waste derived from production with non-optimal cutting parameters.
3) Reduced emission of fumes and production of slag from plasma cutting during non-production activities.
4) Economic saving derived from the operator time normally dedicated to manual system setup, loading and/or saving of job/machine setup, now no longer necessary.

### 3.3 Synergic Plasma Cutting System Flow chart

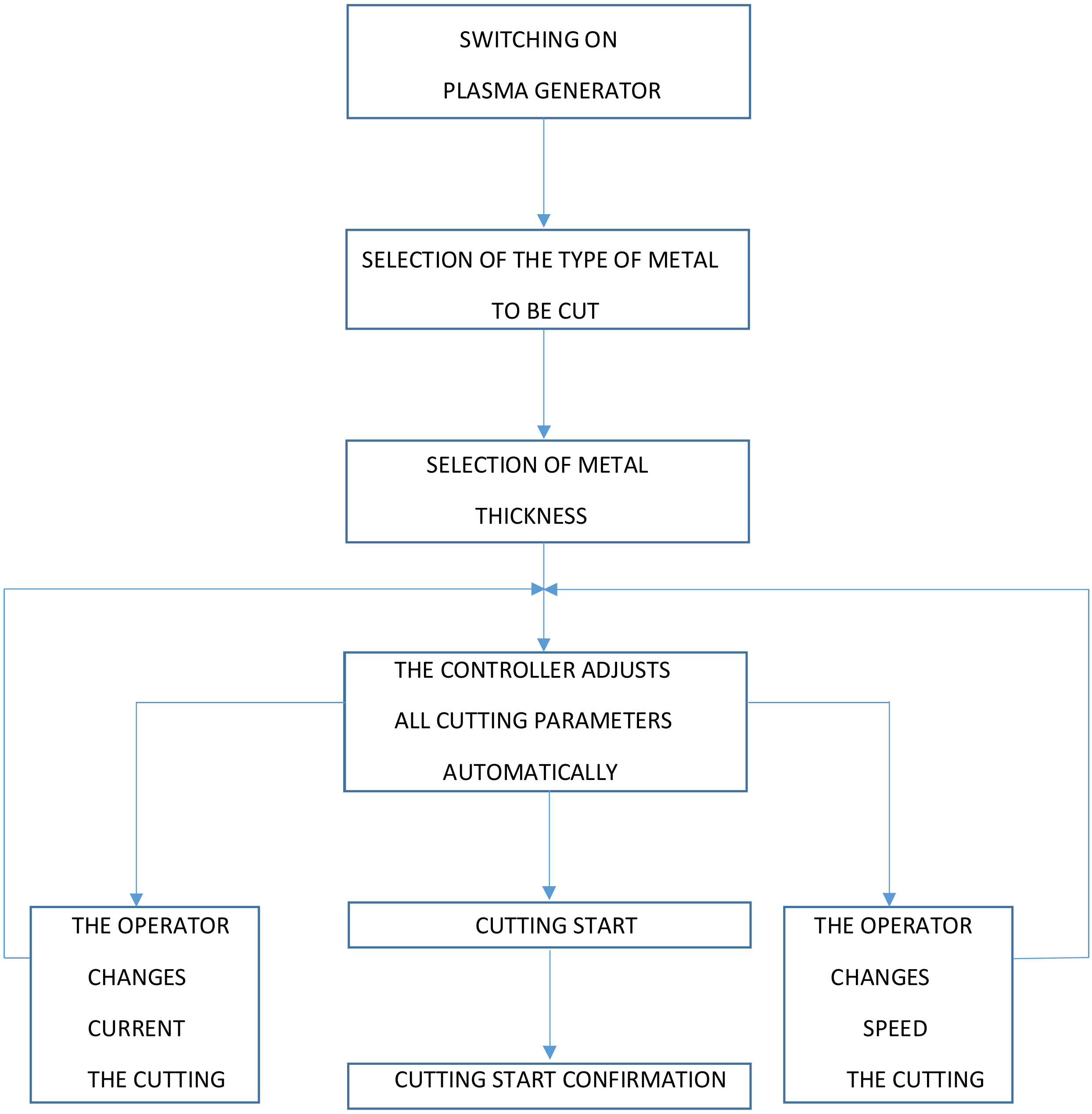



Fig.e

### 3.4 Electric actuator for cutting gas self-regulation

This synergic generator is also equipped with a system for the automatic regulation of the feed gas pressure (compressed air or special gases) and is able to optimise the performance under all the working conditions even without the intervention of the operator.

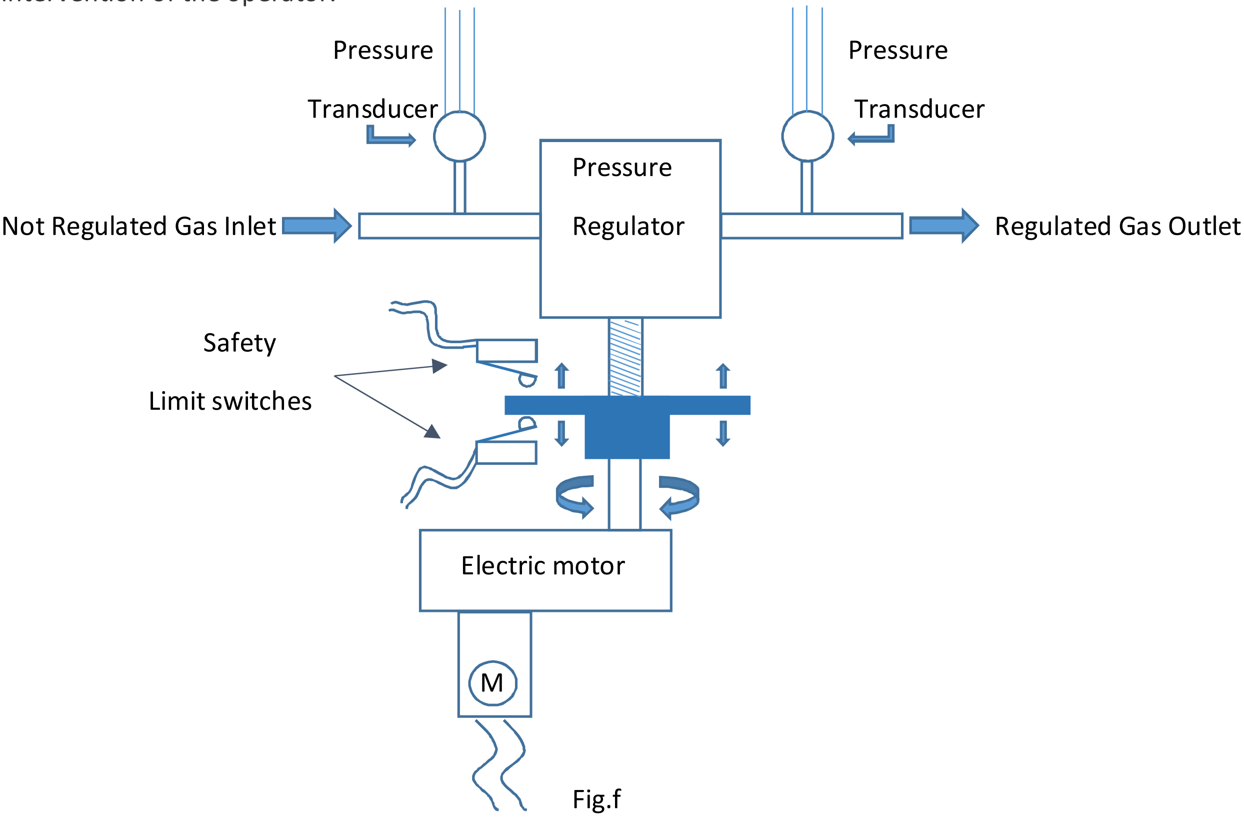



Fig.f

Thanks to this system the machine can automatically manage three different torches with the possibility of different lengths without the need for any adjustment: ECF-71, ECF-131, ECF-181.

The synergic generator is particularly suitable and performing for applications in heavy carpentry and for continuous working cycles, for manual and automatic industrial and handicraft productions.

For the SYNERGIC PLASMA 1880 LCD INVERTER model the recommended thickness on steel is 46 mm up to a maximum of 60 mm, the separation thickness is 80 mm.

The generator is designed to provide a working service of 100% at 165A at 400V and 140A at 230V to ensure continuous operation even in large automatic cutting applications and on wide thicknesses. Pilot arc triggering without HF allows you to operate in the vicinity of computers or, in any case, equipment sensitive to high frequency emissions such as electro-medical equipment.

It can be powered by motor-generators of suitable power.

It also features:

- a double microprocessor control system for cutting parameters and functions.
- Ability to activate security passwords
- Possibility of setting metric or Anglo-Saxon units of measurement
- Safety systems on the torch head and in the machine-side adapter.

### 3.5 Cutting functions and technologies

**Auto-Set** function, which allows automatic selection of the supply voltage in the ranges: 3x208/220/230V and 400/440V.

**Low Pilot Arc** technology which, thanks to a particular conformation of the plasma chamber, together with an innovative generator and an ignition system without high frequency, allows keeping the pilot arc on for a longer time without compromising the life of the consumables.

**Time Pilot Arc** function, which manages the duration of the pilot arc in an automatic or adjustable mode

**Length Pilot Arc** function, which manages the length of the pilot arc in automatic or adjustable mode

**Exhaust Electrode** function, which manages the consumption of the electrode, and notifies the operator of the need to replace the consumables, which can be set automatically or adjusted according to percentage values.

**Save Post Gas** function, which manages torch cooling and gas consumption, in automatic or adjustable mode

**Out Voltage CNC** function, which allows managing an electronic voltage divider of the output cutting voltage adjustable from 1/20V to 1/100V

**Remote Current CNC** function to manage the cutting current adjustment remotely with 0-10V isolated voltage

**Input Power** function, which allows setting the input absorbed power, automatically limiting the output cutting current, thus adapting the generator to any power sizes of industrial plants

**Self Restart Pilot** function for cutting meshes and grates.

**Synergic Interface** function, which allows the generator to self-adjust all the cutting parameters

**Synergic Gouging** function, which allows gouging by automatically adjusting all the working parameters according to the speed of execution and the amount of material to be removed

**Synergic Marking** function, which automatically sets all operating parameters according to the width and depth of the desired marking groove.

**Automatic Pressure Work** technology, which manages the pressure of the cutting gas in automatic or adjustable mode before and during cutting, with the aim of optimising the quality of the cut and maximising the life of the parts.

**Cartridge Spring** technology, which allows eliminating the mobile parts inside the torch by moving them into a convenient external cartridge easily replaceable according to need and consumption.

**Ultra Cut Capacity** technology, which increases the cutting capacity on wide thicknesses.

**Innovative Thin Cut** technology, which allows obtaining higher quality cuts and reduced Kerfs (quantity of material removed).

**Hyper Speed Cut** technology, which increases the cutting speed.

**Multi Piercing** technology, which allows piercing on wide thickness in less time and with less wear of consumables.

**Extra Life** technology to increase performance and durability of consumables.

**Long Tip Cut** technology

### 3.6 Cutting Specifications (Plasma 1880 LCD Inverter)

| | |
|---|---|
| Cutting capacity with manual torch (on carbon steel) | |
| Recommended cutting capacity at 400 mm/min | 46 mm |
| Recommended cutting capacity at 200 mm/min | 60 mm |
| Recommended separation thickness at 100 mm/min | 80 mm |
| Piercing capacity (on carbon steel) | |
| Piercing capacity for manual cutting or automatic cutting with 3-axis control for torch height management during piercing | 35 mm |
| Piercing capacity for automatic cutting with 3-axis control without torch height management during piercing | 25 mm |
| Maximum thickness / cutting speed (on carbon steel) | |
| 5 mm | 13254 mm/min |
| 10 mm | 4644 mm/min |
| 15 mm | 2785 mm/min |
| 20 mm | 1563 mm/min |
| 25 mm | 1105 mm/min |
| 30 mm | 726 mm/min |
| 35 mm | 623 mm/min |
| 40 mm | 519 mm/min |
| 45 mm | 450 mm/min |
| 50 mm | 400 mm/min |
| 55mm | 350 mm/min |
| 60 mm | 200 mm/min |
| **Gouging capability** | |
| Amount of metal that can be removed on carbon steel (at 180A) | 20 Kg/h |

### 3.7 Working method

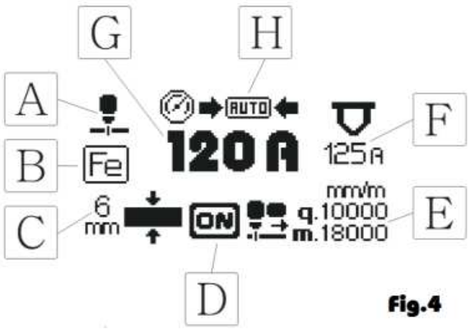
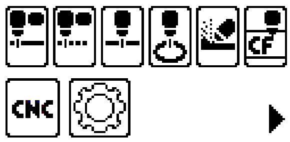



Figure 4

Turn the encoder of the machine until selecting the ref.A icon in Fig.4, then press the knob to enter the following menu and choose the desired working method:

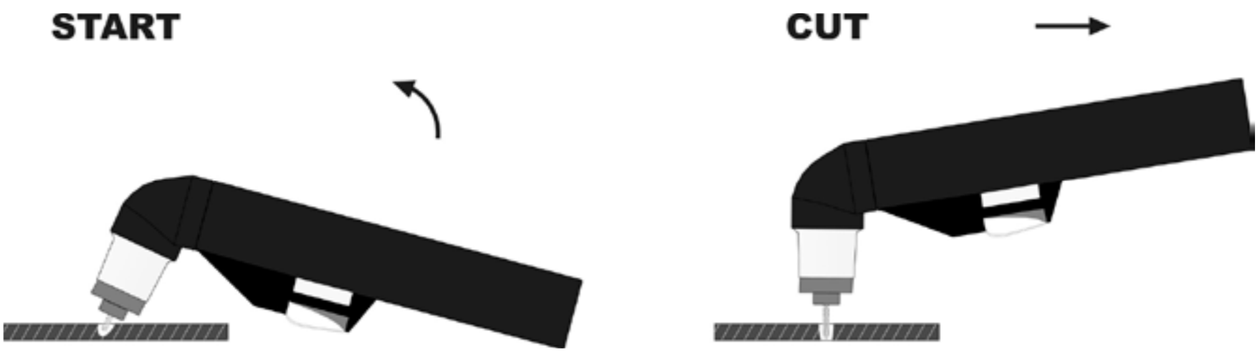



The selected working method remains highlighted until a different one is chosen.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

### 3.8 Manual cutting

Mode that allows the operator to freely choose the cutting current and that requires the use, by installing it on the torch, of the nozzle suggested by the synergic screen and suitable for the set current.
When the torch trigger is pressed, the pilot arc lights up for 5 seconds.
If cutting does not begin within 5 seconds, the pilot arc goes out; press the trigger again to re-strike it.
Hold the torch vertically and as perpendicular as possible to the workpiece when cutting.
At the end of the cut it may be useful to tilt the torch slightly forward to facilitate the cutting of the lower part of the workpiece and allow the detachment of the
When you have finished cutting and released the trigger, air continues to come out of the torch for the amount of time required to cool the torch. (POST GAS).
**Do not to turn the machine off before this time is ended.**
If holes are to be drilled or cutting is to be started from the centre of the workpiece, the torch must be set in the following tilt
position (START) and slowly straightened so that molten metal is not sprayed onto the nozzle.




Do not keep the pilot arc lit in the air when not needed, to avoid unnecessary consumption of the electrode, swirl ring or nozzle.
When the work is finished, wait for post gas to finish and turn the machine off.

### 3.9 Grate cutting (automatic restart)

To cut perforated sheet metals or grates, activate the special function via the main menu. At the end of the cutting, by holding down the button, the pilot arc will automatically turn back on. Use this function only when necessary to avoid unnecessary wear on the electrode and nozzle.

### 3.10 Synergic linear automatic cutting

This new cutting mode takes advantage of a synergic interface that helps the user to set the cutting parameters. When this icon is selected, the operator must select the type and thickness of the material to be cut, the machine will automatically display the current value and the relative cutting speed, as well as showing the size of the nozzle to be mounted on the torch. Once this operation is carried out, you can select and modify at your discretion the suggested values of current and/or speed and the machine will modify, in a synergic way, the other value, automatically following the ideal cutting curve to perform the type of machining required.
Each time the thickness is changed, which is in fact the parameter that controls the selection of the desired cutting curve, the machine will always propose the maximum possible cutting current for the torch and the selected processing, in order to achieve maximum productivity. Obviously, after this automatic default setting, you can change the cutting parameters to your liking and the machine will reset the others synergistically.

### 3.11 Automatic cutting sheet metal piercing

When used in automatic mode, different piercing techniques are possible, depending on the type of automation available:

1) 2 AXIS system: The piercing is performed at a fixed distance that also corresponds to the cutting distance as it is not possible to change the height of the torch. In these conditions, the maximum piercing thickness for the reference machine must be halved to maintain a good service life of the consumables, otherwise, piercing the maximum thickness will significantly shorten their service life (up to 80% less).
2) 3 AXIS system without management of the piercing phases: In these systems the torch automatically positions itself at the piercing distance (greater than the cutting distance), strikes the arc, waits for the piercing time and then moves down to the cutting height. The ideal piercing distances for each power source are indicated in the relevant charts, but it is possible to increase them further in particular cases, but without exceeding the maximum transfer distances indicated in the chart below.

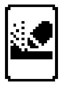
| MAXIMUM TRANSFER DISTANCE (mm) TORCH (SCREEN) - SHEET METAL | GENERATOR ART. |
|---|---|
| 4 | 452-454-455 |
| 7 | 456-457-458-459 |
| 12 | 441-443-453-461 |

3) 3 AXIS system with management of the piercing phases: In these systems the torch automatically positions itself at the piercing distance, strikes the arc, transfers it to the workpiece and once feedback is received from the arc-on generator (ARC-ON/OK TO MOVE) it raises by 5mm to allow the arc to complete the perforation of the sheet metal without hitting the torch with molten material. When the perforation is complete, the torch lowers again, positioning itself at the cutting height and continues to work. This system is the most performing and professional, and is the one that ensures the longest life of consumables. The benefits of its use are much more evident when cutting sheet metals with a thickness of more than 15mm. The maximum automatic piercing thickness values for ECF power sources are:

| MAXIMUM PIERCING THICKNESS (mm) | GENERATOR ART. |
|---|---|
| 10 | 452-454-455 |
| 20 | 456-457 |
| 25 | 441-458-459 |
| 30 | 443-453 |
| 35 | 461 |

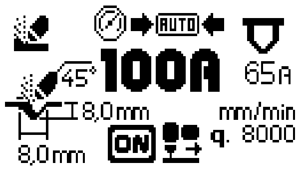
In order to automatically cut a material having a thickness value greater than those in the list, it is necessary to pre-drill it (minimum D.6mm) and start cutting from the inside of the hole itself.

### 3.12 Synergic gouging (only for art. 441 and 461) GOUGING



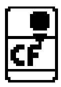
Selecting this method allows you to perform material gouging in synergic mode.

The main screen will appear as follows:



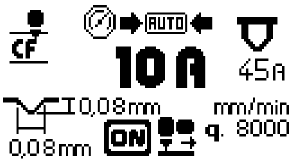

The generator automatically displays the width and depth of the groove obtainable with the current values (ref.G, Fig. 4) at the relative working speed (ref.E, Fig. 4) set by the operator and indicates the nozzle to be used (ref.F, Fig.4) and the tilt in degrees at which the torch must be maintained during feed.

### 3.13 Synergic marking (only for art. 441 and 461)




Selecting this method allows you to perform material marking in synergic mode.

The main screen will appear as follows:

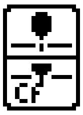



The generator automatically displays the width and depth of the groove obtainable with the current values (ref.G, Fig. 4) and relative working speed (ref.E, Fig. 4) set by the operator and indicates the nozzle to be used (ref.F, Fig.4).

### 3.14 Synergic circular automatic cutting

By selecting this method, it is possible to cut workpieces with curved or circular sections.
This function uses the synergic interface and, as previously described, by setting the material thickness, the power source automatically sets the nozzle current and relative cutting speed values (with a reduction of about 40% to allow a quality cut).

### 3.15 Cutting + Marking (COMBI)



**(Optional function only for art. 441 and 461)**

Selecting this method makes it possible to perform cutting and marking at the same time, without selecting the two processes separately from the menu. With the function selected to activate the marking it will be sufficient to decrease the current to a value lower than 40A. Conversely, increasing the current above 40A will automatically return the machine to the cutting mode. The current can be increased or decreased manually or from CNC (with appropriate I-CNC function activated).

### 3.16 Safety devices

Plasma cutting generators equipped with synergic display interface are provided with the following safety devices:

**Thermal:**

 To avoid overloading.

**Pneumatic:**

 Located on torch feed to prevent insufficient air pressure. If the icon is shown on the display, it means that the pressure has fallen below the minimum limit allowed for the selected process.

**Electric:**

Located on the torch body (microswitch) to prevent dangerous voltages on the torch when replacing the nozzle, swirl ring, electrode or nozzle holder;

- **ALWAYS DISCONNECT POWER** to the cutting generator in order to perform maintenance work on the torch (e.g. remove/replace and/or check the condition of the consumables and screens).
- **ALWAYS WAIT** until the post gas is finished before turning off the generator.
- Do not remove or short circuit the safety devices.
- Use only original ELETTRO C.F spare parts.
- Always replace any damaged parts of the equipment or torch with original ELETTRO C.F. material.
- Do not operate the unit without the covers.

This would be dangerous for the operator and people in the work area and would prevent the unit from cooling properly.

**Password Lock**

⊘ If the password function is active and the code is not entered correctly, the machine will lock, this icon will appear and access to the cutting parameter settings menu will no longer be possible.

**Power supply phase missing**

PHASE

MISSING

If this message is displayed, the machine signals that one of the 3 supply phases is missing.

**Torch trigger pressed when switching on**

RELEASE

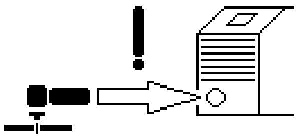
START

BUTTON

If this message is displayed, the machine signals that the start command (manual or from CNC) is already active.

To restore correct operation, deactivate the start command, switch the generator off and on again.

**Torch lock (missing or not recognised)**

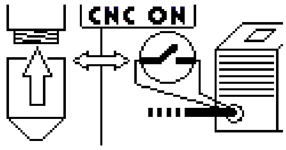


If this image appears, the machine signals that no torch has been connected or that an invalid torch has been connected.

To restore correct operation, switch off the machine, connect a valid and original torch among those available and switch the machine on again.

| **Generator** | **ART.441 and 461** | **ART.443** |
|---|---|---|
| VALID | ECF-71 | ECF-71 |
| TORCHES | ECF-131 | ----------- |
| | ECF-181 | ECF181 |

**Nozzle holder lock removed or CNC contact open**




### 3.17 Electrical and pneumatic connections of the generator

All connections must be made in accordance with current standards and in full compliance with accident prevention laws (see CEI 26-23 / IEC-TS 62081).

Connect the air supply to the gas inlet connection with a pipe with an **INTERNAL DIAMETER NOT LESS THAN 13mm**.

Ensure that the inlet pressure is at least **7 bar** and that the flow rate of the compressed gas system is at least **360l/min at such pressure**.

If the air supply comes from a pressure reducer of a compressor or a centralised system, the reducer must be set at an outlet pressure not exceeding 8 bar (0.8 MPa).

If the air supply comes from a compressed air cylinder, it must be equipped with a pressure regulator.

**Never connect a compressed air cylinder directly to the pressure reducer of the unit!**

**The pressure could exceed the capacity of the reducer, which could then explode!**

Connecting the power cable:

the yellow-green conductor of the cable must be connected to an efficient grounding socket of the system; the remaining conductors must be connected to the power supply line through a switch placed, if possible, close to the cutting area to allow a quick switch-off in case of emergency.

The capacity of the circuit breaker or fuses connected in series to the circuit breaker must be equal to the current $I_1$ eff absorbed by the unit.

The current $I_1$ eff absorbed can be deduced by reading the technical data on the unit near the available supply voltage $U_1$.

Any extensions must be of a section suitable for the maximum current $I_1$ absorbed.

## 3.18 Use

Make sure the start button is not pressed.

Switch the unit on using the switch. This operation will be indicated by the display lighting up.

**Art.443**

Adjust the pressure indicated by the pressure gauge to the pressure indicated for the torch connected to the generator:

5bar for ECF-71

5.7-.8bar for ECF-131

6.4bar for ECF-181

by turning the knob on the reducer, then lock the knob by pressing downwards.

**Art.441 and 461**

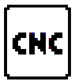
In this generator the gas pressure is fully automatic and is regulated according to the connected torch and the selected process, thus not requiring any adjustment by the operator.

Connect the ground terminal to the workpiece to be cut.

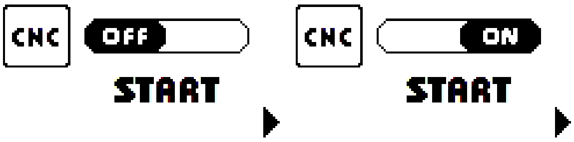
The cutting circuit must not be deliberately placed in direct or indirect contact with the protective conductor except in the workpiece.
If the workpiece is deliberately grounded through the protective conductor, the connection shall be as direct as possible and made with a conductor of at least the same cross-section as the cutting current return conductor and connected to the workpiece at the same point as the return conductor using the return conductor terminal or using a second ground terminal located immediately next to it.

Every precaution must be taken to avoid stray currents.
Make sure that the ground terminal and the workpiece have a good electrical contact especially with painted, oxidized or insulated sheet metals.
Do not connect the ground terminal to the part of the material that is to be removed.

### 3.19 CNC cutting, START management (optional for art. 443)



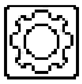

Selecting this function allows accessing the menu for selecting the CNC START mode



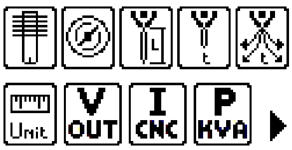

Setting this function to ON activates the CNC START mode corresponding to pins 3 and 4 of the AMP connector on the back of the generator and simultaneously deactivates the manual start control on the front adapter of the machine.

To exit the menu after setting the desired values or without making any setting, position the cursor on the arrow on the bottom right and press the encoder to confirm the exit.

### 3.20 Cutting settings submenu



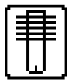
Selecting this function allows accessing the cutting settings menu



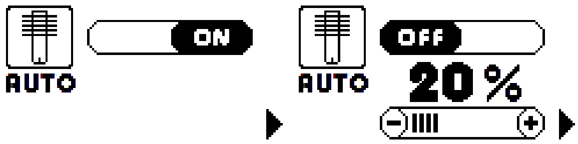

All activated automatic or optional settings remain highlighted until you change their functionality.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

### 3.21 Automatic lock adjustment for finished parts

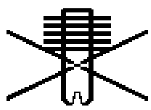


By selecting this icon, it is possible to enter the menu pertaining to automatic adjustment to detect finished parts.




The factory default setting is AUTO ON which allows the generator to interrupt operation independently when electrode and nozzle need to be replaced. It is nevertheless possible to set this mode to OFF, which does not mean completely disabling the function, but makes it possible to raise or lower the tripping sensitivity of this protection. By raising the percentage, the machine stops cutting before the standard condition; by lowering it the machine will be able to continue cutting for longer than the standard amount of time.

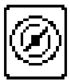
When the generator reaches the automatic or required finishing threshold of the parts, it will stop and show the following screen:



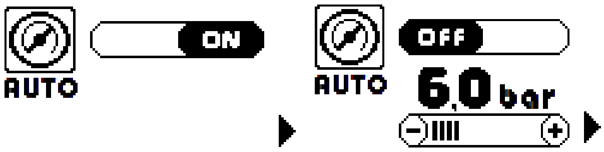
Then, wait for post gas to finish, turn the power source off and replace the finished parts to start cutting again.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

### 3.22 Automatic cutting gas regulation (only for art. 441 and 461)



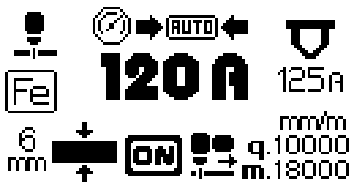
By selecting this icon, it is possible to enter the menu pertaining to automatic adjustment of cutting gas pressure.



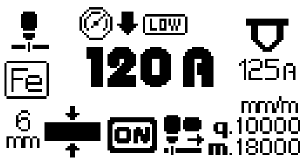

The factory default mode is AUTO ON, which allows the generator to keep the working pressure of the torch constant and at the optimal value, even in the presence of variations in the inlet pressure. This system, set in automatic mode, does not allow any pressure adjustment. The generator will set the correct value according to the torch inserted and the selected work.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

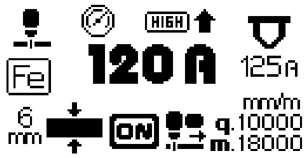
With the function ON the display will appear as follows:




If the inlet pressure is insufficient to reach the optimal cutting value, but still sufficient for the selected process, the machine will display the message LOW with an arrow pointing downwards

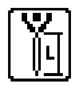


If the output pressure is excessive compared to the optimal value, but still within the operating limits, the machine will display the message HIGH with an arrow pointing upwards and the display will appear as follows:

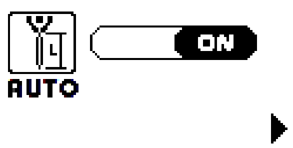


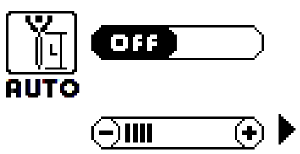

However, it is possible to set the function to OFF, so that you can read and adjust the working pressure of the torch to the desired value (within certain preset limits) directly from the main panel which will appear as follows:


### 3.23 Automatic pilot arc length adjustment (only for art. 441 and 461)



By selecting this icon, it is possible to enter the menu pertaining to automatic adjustment of pilot arc length

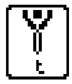


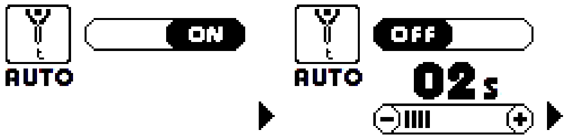

The factory default mode is AUTO ON which allows the generator to automatically and synergistically adjust the length of the pilot arc according to the torch inserted, the consumables installed and the machining process selected. You can still set this function to OFF, so you can manually adjust the length of the pilot arc. Decreasing the length will result in longer life of consumables, but may cause difficulties when transferring the arc. On the contrary, by increasing the value, it will be possible to perform arc transfer in difficult conditions (e.g. in tight corners and hard to reach places), but the life of the consumables will be shorter.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

### 3.24 Automatic pilot arc duration adjustment (only for art. 441 and 461)



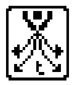
By selecting this icon, it is possible to enter the menu pertaining to automatic adjustment of pilot arc duration



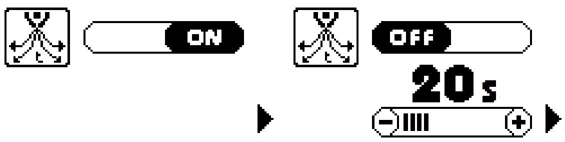

The factory default mode is AUTO ON which allows the generator to automatically and synergistically adjust the duration of the pilot arc according to the torch inserted and the machining process selected. You can still set this function to OFF, so you can manually adjust the duration of the pilot arc. Decreasing the duration will result in longer life of consumables, but may cause difficulties when transferring the arc. On the contrary, increasing the arc duration will make it easier to perform the arc transfer, but the life of the consumables will be shorter.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

### 3.25 Automatic post gas adjustment (only for art. 441 and 461)



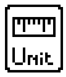
By selecting this icon, it is possible to enter the menu pertaining to automatic adjustment of post gas duration.



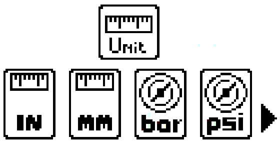

The factory default mode is AUTO ON, which allows the generator to automatically and synergistically adjust the duration of the post gas according to the torch inserted, the current value set and the machining process selected. However, it is possible to set this function to OFF, so that you can manually adjust the post gas duration (within certain preset limits). This can help if special gases are used for cutting, which are often expensive and for which careful management of consumption can bring economic benefits.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press knob S1 (Pict.1), to confirm exiting.

### 3.26 Selecting the unit of measurement

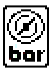



By selecting this icon it is possible to enter the menu concerning the adjustment of the units of measurement,




in which it is possible to select the icon relative to the units of measurement and thus choose the desired one among:

millimetres  inches 

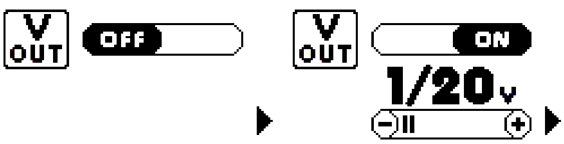
bar  and psi .

The selected unit of measure will remain highlighted until a different one is chosen.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

### 3.27 Selecting output voltage divider for CNC (V OUT optional for art.443)


By selecting this icon it is possible to enter the menu concerning the selection of the voltage divider for CNC.



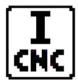
The factory default mode is OFF which means that there is no voltage between output pins 5(-) and 6(+).

If the CNC used is equipped with arc voltage control, it is possible to set this function to ON, in order to adjust at will the output divider values between a minimum of 1/20V and a maximum of 1/100V. (e.g. 1/20, 1/21, 1/22, 1/23, 1/24… up to 1/100V).

This voltage is supplied between pins 5(-) and 6(+) of the AMP connector on the back of the generator and is galvanically isolated from the cutting voltage.

To exit the menu without making any selection, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

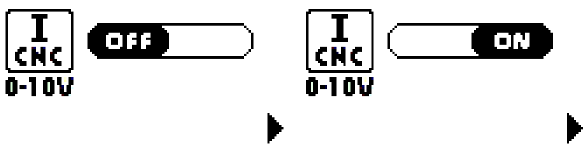
### 3.28 Selecting current adjustment enabling from CNC (I CNC optional for art.443)




By selecting this icon it is possible to enter the menu concerning the enabling of the cutting current adjustment from CNC.

**This function is activated and has an effect on the cutting current setting only if the CNC start function has also been set to ON**.

With the I CNC function active, the possibility to adjust the cutting current by means of the knob on the front panel of the generator will be automatically disabled.




The factory default mode is OFF which means that there is no possibility of adjusting the cutting current remotely between pin 1 (0V) and pin 2 (10V).

In case you want to adjust the cutting current remotely (CNC) ,it is necessary to:

1) Set the CNC Start function to ON
2) Turn this function ON and apply an **<u>ISOLATED VOLTAGE BETWEEN 0V AND 10V</u>** between pin 1 (0V) and pin 2 (10V max) of the AMP connector on the back of the generator.

The current value set from CNC is ABSOLUTE, therefore independent of the operating range of the inserted torch.

If the current required by CNC is higher than the maximum allowed by the inserted torch, the current will be reduced to the maximum possible value for the inserted torch (see example no.2)

EXAMPLES:

1) ECF-181 torch, cutting current 10-180A

Voltage between pins 1-2 = **5V**

Remotely adjusted current=10+[(180-10)/10x**5**]=95A

2) ECF-71 torch, cutting current 10-70A

Voltage between pins 1-2 = **5V**

Remotely adjusted current=10+[(180-10)/10x**5**]=**95A <u>which will be reduced to 70A</u> automatically by the generator as the inserted torch cannot go any further.**

To exit the menu after setting the desired values or without making any setting, position the cursor on the arrow on the bottom right and press the encoder to confirm the exit.

### 3.29 Input absorbed power limitation (P KVA)


By selecting this icon it is possible to enter the menu concerning the input absorbed power limitation.


The factory default mode is OFF which means that there is no input absorbed power limitation.

However, if necessary, it is possible, by setting this function to ON, to select the maximum absorbed power value to adapt the generator to the system to which it will be connected. In this way it will be possible to connect it easily to any industrial plants avoiding overloads or the tripping of the relative protections.

All you have to do is set the available power value and the machine will adjust all the cutting parameters accordingly, offering the highest possible cutting current.

To exit the menu after setting the desired values or without making any setting, position the cursor on the arrow on the bottom right and press the knob to confirm the exit.

### 3.30 Fan management

The fan management is fully automatic.

The generator constantly monitors the temperature of the internal components and manages the fan rotation speed accordingly.

The speed increases as the internal temperature increases and vice versa.

When the generator remains unused and the temperature of the internal components normalises, the fan stops automatically.

### 3.31 OK to move automatic cutting (optional for art.443)

If the generator is used in combination with an automatic cutting system that requires consent to the movement of the torch, it is possible to use the transferred arc command.

In fact, the machine provides a normally open dry contact (NO relay) that closes only when the arc transfer has taken place (ref.D, Fig.4), between pins 12 and 14 of the AMP connector on the back of the generator.

### 3.32 Generator memory

The generator saves the settings made and the last cutting condition actually used, therefore when it is switched off and on again it shows the last working conditions

### 3.33 Supply voltages

The generator is equipped with a self-regulating system that allows it to work, without any modification, with different three-phase voltages, i.e. 208V-220V-230V-400V-440V ±10%. When switched on, the generator detects the type, quality and presence of the three phases and automatically adjusts itself for optimal operation.

# 4 PRACTICAL TIPS AND TROUBLESHOOTING

## 4.1 Insufficient penetration

This problem may be caused by:

- high speed. Always make sure that the arc fully penetrates the workpiece to be cut and is never held at a forward angle of more than 10 -15°. This will avoid incorrect consumption of the nozzle and burns to the nozzle holder.
- Excessively thick workpiece.
- Ground terminal not in good electrical contact with the workpiece.
- Worn nozzle and electrode.
- Cutting current too low.

NOTE: When the arc does not pierce the workpiece, molten metal scraps can clog the nozzle and compromise its functionality, durability and performance.

## 4.2 The cutting arc goes out

This problem may be caused by:

- Worn nozzle, electrode or swirl ring
- Air pressure too high
- Supply voltage too low

## 4.3 Slanted cut

If the cut appears slanted, turn the unit off and replace the nozzle.

When the cutting current exceeds 45A prevent the nozzle from coming into electrical contact with the workpiece to be cut (even through molten metal scraps), this condition causes rapid, sometimes instantaneous, destruction of the nozzle hole resulting in a very poor quality cut.

## 4.4 Excessive wear of consumables

This problem may be caused by:

a) Air pressure too low compared with the recommended level.

b) Excessive burns on the end of the nozzle holder.

c) Insufficient piercing clearance between torch and sheet metal.

d) One or more parts mounted on the torch are not original marked ELETTRO C.F

e)Impurities (water, oil or other) in the feed gas

### 4.5 Practical tips

- If the air in the system contains a large amount of moisture and oil, it is advisable to use a filter dryer to prevent excessive oxidation and wear of the consumables, damage to the torch and a reduction in the cutting speed and quality.
- The impurities present in the air favour the oxidation of the electrode and the nozzle and can make it difficult to strike the pilot arc. If this condition occurs, clean the end of the electrode and the inside of the nozzle.
- If the quality of the gas supply is not good, the cutting speed decreases, the cutting quality deteriorates and the service life of the consumables is reduced.
- Make sure that the new electrode and nozzle that are about to be installed are well cleaned and degreased.

### 4.6 Password

To activate the password function, immediately after switching on, when the display shows press the knob and select, by turning it, the icon .

The password will be requested the next time the device is turned on and must be entered by rotating the knob until the correct digit is reached, confirming and pressing the knob again. If the code is wrong, the generator will freeze displaying the symbol ⊘ and it will be necessary to switch the generator off and on again to re-enter the password. To remove the password function, once the correct password has been entered, press the knob when the display shows and select the icon , the password will no longer be required the next time it is turned on.

### 4.7 Generator maintenance

Always disconnect the power supply to the unit before any intervention, which must be carried out by qualified personnel. In case of maintenance inside the unit, make sure that the power switch is in the "O" position and that the power cable is disconnected from the mains.
Also check that there is no voltage at the ends of the capacitors in the IGBT assembly.
Even if the unit is equipped with an automatic device for draining the condensate, which comes into operation every time the air supply is closed, it is a good idea to periodically check that there are no traces of condensate in the reducer tray and, if any, remove them. Periodically, it is necessary and permitted to remove metal dust from inside the generator using a jet of compressed air free of oil or moisture, following the procedure described below.

1) **First of all disconnect** the generator from the mains by removing the plug from the electrical panel to which it is connected, wait at least 10 minutes to allow the internal capacitors to discharge completely.
2) Remove handles and band.
3) Check that the power capacitors are actually discharged.
4) Thoroughly clean the interior.

**If the generator is used intensively (production), it is necessary to clean the inside of the unit from accumulated metal dust, using compressed air at least every 3 MONTHS.**

**If the generator is not used intensively, but only occasionally, it is still necessary to clean the inside of the unit from accumulated metal dust, using compressed air at least every 6 MONTHS.**

## 4.8 Torch maintenance

**Replacement of consumables**. The parts subject to wear are the electrode, the swirl ring and the nozzle. The replacement of one of these parts is only possible after unscrewing the nozzle holder. The electrode should be replaced when it has a crater in the centre about 1.5 mm deep. The nozzle should be replaced when the central hole is damaged or enlarged compared to the new part.

When the electrode is worn, the nozzle wears out very quickly. When the electrode is worn, the machine loses cutting power. Delayed replacement of the electrode and nozzle will cause excessive heating of the parts, which will affect the life of the insulating swirl ring. Make sure that after replacement, the nozzle holder is tightened sufficiently.

Each time the **SWIRL RING** and/or the **NOZZLE HOLDER** is removed and reinserted, it is necessary to lubricate the relevant O-Ring (**using the lubricant supplied**) to ensure correct operation of the torch

**To avoid damaging the torch, always use original ELETTRO C.F. spare parts.**

**ATTENTION! The nozzle holder should be screwed onto the head only with the electrode, swirl ring and nozzle mounted.**

## 4.9 Things to do after a repair

After making a repair, take care to rearrange the wiring so that a safe insulation is ensured between the primary and secondary sides of the machine. Do not allow the wires to come into contact with moving parts or parts that become hot during operation. Refit all clamps as on the original unit so that if a conductor accidentally breaks or disconnects, a connection between the primary and secondary sides can not occur.

In addition, reinstall the screws with the toothed washers as on the original unit.

## 4.10 Practical tips for automatic cutting

The information in the following sections will be useful to optimise the cutting quality and maximise the useful life of consumables.

## 4.11 Checking the correct torch and table configuration

Position the torch at right angles to the sheet metal.
..................................................................................................................................................If you clean, check and "optimise" the guides and drive system of the cutting table, the movement of the torch is facilitated. An irregular movement of the machine can cause undulations on the cutting surface.
..................................................................................................................................................Make sure that the torch does not touch the sheet metal during cutting. Contact may damage the screen and/or nozzle and affect the quality of the cutting surface.

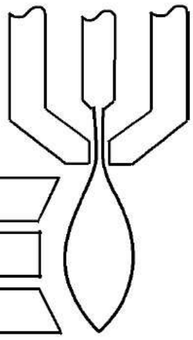
## 4.12 Information and optimization of cutting quality

Several factors must be taken into account for the cutting quality:
1) Cutting angle: the angle of the cutting edge.
2) Burr: the molten material that solidifies on the top or bottom of the sheet metal.
3) Straightness of the cutting surface: the cutting surface can be concave or convex.

The following sections explain how these factors can affect the cutting quality.

### 1) Cutting or tilt angle

..........................................................................................................................................................A positive cutting angle is achieved when material is removed mostly from the top of the cut rather than from the bottom.
..........................................................................................................................................................A negative cutting angle is obtained when material is removed mostly from the bottom of the cut.



| Problem | Cause | Solution |
|---|---|---|
| Negative cut angle | The torch is too low. | Raise the torch; or if you are using a torch height control, increase the arc voltage. |
| Cut OK | | |
| Positive cut angle | The torch is too high | Lower the torch; or if you are using a torch height control, decrease the arc voltage. |
| Notes: the right cut angle will be on the right side with respect to the forward motion of the torch. The left side will always have some degree of bevel. | | |

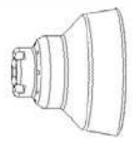
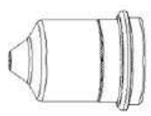
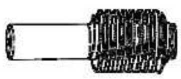
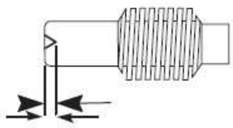
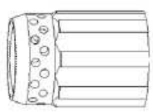
### 2) Burr

When air plasma cutting is performed, some burr will always form. However, you can minimise the amount and type of burr by properly adjusting the system according to the application.
Burrs appear on the upper edge of both sheet metal parts when the torch is too low or the voltage is too high, if a torch height control is used. Adjust the torch or the voltage in small increments until the burr is reduced.
Low-speed burr forms when the torch cutting speed is too low and the arc fires forward. It forms a heavy deposit and bubbles at the bottom of the cut and can be easily removed. Increase the speed to reduce this type of burr.
High-speed burr forms when the cutting speed is too high and the arc remains behind. It forms a thin, linear bubble of solid metal attached very close to the cut. It sticks firmly to the bottom of the cut and is difficult to remove.
To reduce high-speed burr:
• Decrease the cutting speed.
• Decrease the distance between the torch and the sheet metal.

### 3) Straightness of the cutting surface

| | |
|---|---|
|  | A typical plasma cut surface is slightly concave.<br><br>The cut surface may become more concave or convex. Correct torch height is required to keep the cut surface acceptably close to straight. Worn consumables also affect the straightness of the cut. |
|  | A strongly concave cut surface occurs when the torch-to-work distance is too low. Increase the torch-to-work distance to straighten the cut surface. |
|  | A convex cut surface occurs when the torch-to-work distance is too great or the cutting current is too high. First, try lowering the torch, then reduce the cutting current. |

### 4.13 Inspection of consumable parts

| Consumable part | | Examine | Action |
|---|---|---|---|
|  | Shield cup | The centre hole for roundness.<br>The space between the shield cup and the nozzle for accumulated debris. | If the hole is no longer round, replace the shield.<br>Remove the shield cup and clean any material away. |
|  | Nozzle | The centre hole for roundness.<br><br>Good Worn | If the centre hole is not round, replace the nozzle and the electrode together. |
|  | Electrode | The centre surface for wear and verify the pit depth<br><br>Maximum 1.5 mm | If the surface is worn or the pit depth is greater than 1.5 mm deep, replace the nozzle and the electrode together. |
|  | Insulating diffusor | The internal surface of the diffusor for damage or wear and the gas holes for obstructions. | Replace if the internal surface is damaged or worn or any of the gas holes are obstructed. |
|  | O-ring for torch head | The surface for damage, wear or a lack of lubrication. | If the o-ring is dry, lubricate it and the threads with a thin layer of silicone lubricant. If the o-ring is cracked or worn, replace it. |

### 4.14 Consumables life

The life of consumables is influenced by a number of external factors such as:

1. Thickness of the sheet metal: as the thickness increases, the service life decreases
2. Distance between the torch (screen) and the sheet metal during cutting: by increasing this distance (compared to the nominal distance) the cut worsens and the life of the parts is reduced in an inversely proportional way: more distance = less life.
3. Set cutting current: using a lower current increases the life of the parts, but decreases the cutting speed and the piercing capacity from the billet.
4. Type of sheet metal piercing: the service life is reduced when starting from the billet and increased when starting from the edge.
5. Use of automatic re-strike for the cut (grate cutting function): Using this function reduces the service life since the number of times the arc is turned on and off increases.
6. Number of times the pilot arc is turned on and off or transferred: turning it on and off many times, even without transfer, increases the wear of electrode and nozzle by 50%.
7. Length of the cuts: making longer cuts on average increases the life of the consumables, as the number of times the arc is turned on and off is reduced.

8 Quality level of the feed gas: pollutants such as water and oil can lead to early wear of the electrode and/or nozzle.
9 One of the most common and frustrating problems associated with plasma arc cutting is the short life of consumables. This problem affects the manufacturer both through increased expenditures on consumables and through the passive time required to replace components and for troubleshooting. Usually, the operator is the first to know if a component is not lasting as long as expected. Below are some tips to help the operator or person in charge of maintenance troubleshoot problems with the life of consumables.

The electrode carries the negative charge of the DC current from the generator. It consists of a copper support that contains an emitting element made of hafnium, a metal with a very high melting point capable of supporting an arc. Hafnium is slowly eroded by the heat of the arc and the high velocity plasma gas stream. During the normal wear process, a small crater forms on the end of the component which slowly wears out. If the crater becomes too deep (maximum depth 1.5mm), the arc will stick to the copper support and melt it. It is a good idea to replace the electrode a little before the erosion depth reaches the maximum allowed value.

The plasma jet is concentrated inside the nozzle hole. This must be perfectly circular and concentric. Both the diameter and the length of the hole are fundamental: any damage to the orifice affects the shape of the arc and, therefore, the quality of the cut workpiece. The arc shapes through the nozzle without touching the copper material because the nozzle walls are protected by a peripheral layer of cold swirling gas. If the arc comes into contact with the nozzle it can immediately melt some of the material it is made of. A normal level of nozzle wear is a slight chamfering or widening of the hole at the outer edge of the latter. The nozzle should be replaced every time the electrode is replaced or when it no longer produces a straight arc and/or a good clean cut.

The normal life of original consumables for Elettro c.f. plasma systems depends primarily on how they are used, but other variables such as gas quality, power source, etc., may also influence the life of consumables

**Troubleshooting**

The first step in troubleshooting issues concerning the life of consumables is to carefully and periodically examine the components and determine which component shows abnormal wear characteristics. The components usually show clear indications of the causes of the abnormal consumption.

**Possible cases:**

**1) Electrode in poor condition and nozzle in poor condition**

If inspection of the components reveals that both the electrode and nozzle are severely worn, it is possible that the electrode has caused the nozzle to wear out. Since the electrode is upstream, this can cause damage to the nozzle when molten material bursts at the end of the component and settles inside the nozzle. All consumables will have this type of wear if used up to the end of the hafnium pad, i.e. well beyond the allowed erosion depth (max 1.5mm).

If the electrode has a deep and wide crater and the copper has turned a golden, blue or black colour due to overheating, the possible cause is a reduced gas flow rate. In extreme cases the end of the electrode may melt. Check the feed gas pressure. If it is within the normal range, check for torch problems, kinks, leaks, clogged filters, or other limitations on gas passage.

If the electrode has small melts all over the end containing the hafnium pad with corresponding damage to the inside of the nozzle, this means that the gas stream is reduced. This results in an uncontrolled arc between the nozzle and the electrode. Check the gas pressure as it escapes the torch (post gas).

If the electrode has a thick layer of black residue, check for gas contamination. The presence of water and/or oil inside the plasma gas can irreparably damage the consumables, the torch head and compromise cutting performance. The use of a drying and filtering system is strongly recommended to ensure proper gas quality.

2) **Electrode in good condition and nozzle in poor condition**

If the electrode looks practically new and the nozzle is severely damaged, the most likely cause of wear is double arc formation on the nozzle. This occurs if the arc makes contact with the nozzle and melts the inner edge of the hole.

Damage to the inside of the nozzle appears as a groove (e.g. keyhole) and indicates low pressure inside the plasma chamber. This allows the arc to transfer onto the nozzle and melt part of it. Check the gas system for leaks during the gas passage.

Damage to the outside of the nozzle, on the other hand, may indicate a problem with the distance between torch and sheet metal. Check the piercing height first; this should be twice as high as the cutting height to avoid splashing molten metal. A too low piercing is the number one cause of premature nozzle failure. Check that the torch height control is working properly. If the torch rests on the sheet metal when piercing, or scrapes the sheet metal while cutting, the nozzle can be destroyed instantly.

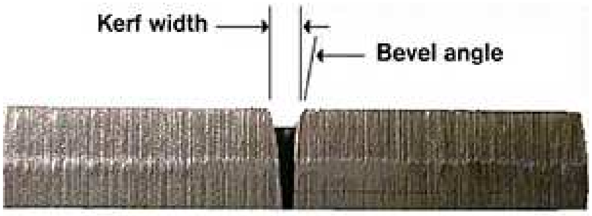
If the nozzle seems excessively hot, straw-coloured, blue, or black, check the screen gas stream. The screen gas helps cool the nozzle and protects the tip of the torch.

3) **Electrode in poor condition and nozzle in good condition**

If the nozzle is in good condition but the electrode has a deep, concentric crater, the plasma gas stream may be too strong. If the gas stream vortex is too intense, the electrode may undergo rapid erosion. Check the plasma gas pressure.

## 4.15 Cutting angle

Many production factories spend a lot of time and money reworking parts cut on a plasma machine to remove burr or correct size inaccuracies. Some of these problems in cutting quality are caused by electrical and mechanical problems of an old or poorly maintained cutting machine; others are related to the plasma process itself. By carefully controlling these variables, the operator has the opportunity to reduce or eliminate size issues and associated costs caused by secondary operations or waste materials.



### 4.16 Cut width (KERF)

This is the amount of metal removed from the plasma arc during the feed. The plasma arc is dynamic, i.e. it changes in shape and size according to the current, voltage, gas flow rate and speed of movement of the torch, and as the plasma arc column varies the cut width also varies. The size of the nozzle has a direct influence on the cut width because the nozzle hole forces the plasma gas jet within a certain diameter (nozzle sizes follow the current classification: the larger the hole, the more current it can carry). Refer to the chart on page 14 to obtain the relative Kerf values.

### 4.17 CNC

CNC plasma arc cutting systems normally have an adjustable parameter called cut width compensation. The operator or programmer enters a value for cut width compensation, (Kerf) and the CNC automatically calculates the torch path while maintaining the cut width on the scrap side of the workpiece. If the Kerf is too large (compared to the set one) and the workpieces relatively too small, it is necessary to make some tests, among which decreasing the torch distance (arc voltage), decreasing the cutting current, checking the gas pressure or increasing the feed speed. Each of these variables can result in increasing the volume of the plasma arc by increasing the cut width. Conversely, setting too high a value for cut width compensation may result in excessive workpiece size. This problem can be caused by excessive torch spacing (arc voltage), excessive current, incorrect gas pressure, or too high a feed rate. These variables can result in a decrease in plasma arc volume by reducing the cut width.

### 4.18 Tilt angle of the cut edge

A cut with a 0° slant is an ideal straight cut perpendicular to the plane of the material. Most plasma torches use a plasma gas stream that rotates clockwise and produces a straighter cut on the right side of the cut width than the torch feed movement. Typically, tilt angles for conventional plasma torches range from 1-3 degrees on the "good" side of the cut to 3-8 degrees on the "bad" side of the cut. There are different types of cut tilt angles and depending on which one is obtained you can intervene to improve it.

#### 1) Positive tilt (excessive)

**Positive tilt (upper part of the workpiece smaller than the lower part)**

This problem can be caused by an excessively worn nozzle, excessive torch spacing (arc voltage), incorrect current, excessive speed, or reversed cutting direction. These variables can result in arc lag causing more energy transfer on the top of the cut width than at the bottom. As a result, the cut width is greater on the top and narrower on the bottom.

2) **Negative tilt**

**Negative tilt (lower part of the workpiece smaller than the upper part)**

This problem can be caused by too much torch spacing (arc voltage), too much current, or too low a speed. These parameters result in greater material removal at the bottom of the sheet metal. Usually a constant negative tilt around the workpiece is accompanied by an abundant, porous low-speed burr.

3) **Irregular tilt**

**Positive and negative tilt on the same workpiece**

Generally this problem indicates that there may be several problems, including worn nozzle, out-of-square torch or misaligned electrode and nozzle. These variables can result in the deviation of the arc from a straight path through the material. Sometimes the cutting surface is not flat but concave on one side and convex on the other. Again, these are all signs of worn or misaligned components.

## 4.19 Hole quality

Small holes and jagged shapes such as grooves, sharp corners and very tight radii present special challenges for plasma cutting. In this context, a small hole can be defined as any hole with a diameter smaller than the thickness of the material. Generally a hole obtained with the plasma arc will always show a slight tapering (upper diameter larger than the lower one).

1) **Holes (e.g. for bolts)**

The diameter of the hole on the top and bottom should be almost the same, in order to ensure a proper fit with the bolt. A critical parameter that affects the cylindricity of the hole is the cutting speed. The CNC sets a cutting speed in millimetres per minute (mm/min), but during circular cutting the torch must slow down to compensate for the natural delay of the plasma arc during cutting. Most CNC controls automatically compensate for this phenomenon with an algorithm that brakes down into factors the hole cutting speed. Known as centripetal limitation, this calculation considers the length of the radius, the acceleration of the torch, and the minimum angular velocity to adjust the effective cutting rate around a circular section. The programmer or operator may be able to adjust the linear speed up or down to optimise the actual circular cutting speed for improved cylindricity. This implies different programming, lower cutting speeds for bolt holes than for straight cuts on the same workpiece (normally the speed is reduced by about 40%). The cutting height or voltage setting is another parameter that affects the cutting quality of bolt holes. For small holes, the cutting height should remain constant throughout the cut. With a voltage-adjusted Torch Height Control (THC), the cutting height is determined by the arc voltage settings. Depending on the responsiveness of the system, using THC for small holes could worsen rather than improve the quality of cut. It may be necessary to lock the THC when cutting small workpieces to prevent the torch from cutting too high or too low and to prevent the torch from performing an abnormal fast approach at the end of the cutting when the material inside the hole is "detaching" or running out. THC can be locked by switching to manual mode after completing the piercing or by reprogramming the workpiece to specify the slowdown on the angle without THC when cutting holes.

2) **Cutting lead-in and lead-out**

The type and size of the cutting lead-in and lead-out can greatly affect the cutting quality. Two common defects are grooves and bumps. Grooving occurs when the arc removes too much material at the end of the cut. At the end of the cut, as the plasma arc crosses the cutting lead-in width, the heat is transmitted to the small remaining area causing a small notch or sometimes a somewhat larger empty area. This results in the hole not being circular, but showing a small additional hollow.

Bumps occur when the cutting lead-in and lead-out do not overlap properly. Some of the hole material is not completely removed leaving a protrusion of uncut material that prevents the hole from housing a bolt.

Finding proper cutting lead-in and lead-out to reduce grooves and bumps on the start and end points can be challenging. Typically, a rounded cutting lead-in with a very small or negative cutting lead-out (negative over-burn) on the remaining part produces the best quality hole. Sometimes a straight cutting lead-in goes better with a small cutting lead-out (positive over-burn).

The cutting lead-in with outward spiral is a special design that can be very effective for cutting holes. An outward spiral cutting lead-in allows the machine to reach full speed and the arc to stabilise before cutting the perimeter of the hole, providing the smoothest machine motion throughout the cut and a significantly higher final quality.

### 3) Nozzle size and current

In general, a small nozzle suitable for a lower current used at a reduced speed will produce a smaller cut width and a thinner cut.

To get the best cut with a given nozzle, always set the cutting current between 95% and 100% of the rated current of the nozzle.

### 4) Rules for cutting holes

- Use a nozzle with a minimum nominal size to perform material piercing and cutting
- Ensure that the piercing delay allows for complete penetration of the arc before machine motion begins
- Lock the voltage-adjusted THC
- Use a rounded or spiral cutting lead-in
- Set a reduced cutting speed
- Use a short or negative cutting lead-out.

## 4.20 Workpiece piercing

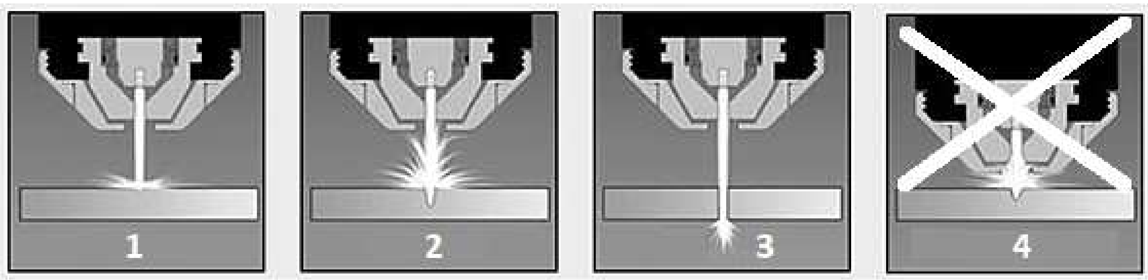
### 1) Piercing steps

**Step 1**: The arc transferred to the correct distance instantly melts the metal and begins to blow away the molten material.

**Step 2:** As soon as the plasma jet penetrates deeper into the material, a circular hole is formed. This hole starts directing the molten splash upward toward the torch.

**Step 3:** Once the sheet metal is pierced, the splash and molten material is ejected through the newly created hole. Once the perforation is complete the machine starts moving and the torch starts cutting. If the torch moves too early, the arc may not penetrate the material completely. If the torch delays too long, the arc continues to remove material by enlarging the hole until it is extinguished. See illustration below.

**Step 4:** If the piercing is carried out at too close a distance or the torch approaches the workpiece before having completely pierced the sheet metal (step 3), the molten material hits the nozzle and the protective screen, damaging them irreparably and compromising cutting performance.




### 2) Piercing problems

The most common piercing problems are double arc and arc extinction. They occur during the second piercing step when molten metal at over 3000 °C is blown backwards against the torch. Under normal conditions the plasma arc is controlled and directed by a swirling whirlwind of gas passing from the electrode through the nozzle onto the sheet metal. The swirling gas prevents the arc from touching the inside walls of the copper nozzle. If the arc comes into contact with the nozzle it cuts it as it does with any conductive metal.

### 3) Double arc

Double arc occurs when current flows through the nozzle or other conductive path to the sheet metal and not directly to the workpiece. This can happen due to low plasma gas pressure, excessive current, or deflection of the plasma jet. This deflection occurs when the torch pierces too close to the sheet metal (Step 4). Splashes of electrically conductive metal deflect the plasma gas jet, disturbing the electric field surrounding the arc and thus causing alternate paths for the plasma arc. It has been theorised that multiple paths of the arc develop through small metal particles, diverting the arc from its conventional axially symmetrical path. If the arc is pushed onto the side wall of the nozzle during double arc formation, a notch or sometimes a symmetrical bevel may be created along the nozzle exit hole. A damaged nozzle leads to serious problems with the cutting quality such as excessive tilt angle, burr, inability to pierce the material, etc.

## 4.21 Plasma gouging

Plasma gouging is the removal of metal using a plasma arc. A plasma arc between the torch and the workpiece melts the metal and a high-speed gas jet blows away the molten material. However, in gouging, specially designed consumables produce a significantly wider arc, the torch is held at an angle to the workpiece at a defined angle, and only a portion of the material is blown away.

Plasma gouging is suitable for all types of conductive metal including carbon steel, stainless steel, aluminium and copper. With a little practice, you can obtain a smooth, clean and even gouging. Plasma gouging can reduce the amount of noise and pollutants in the work environment when compared to other processes such as gouging with carbon electrodes and compressed air.

The gouging can be carried out freehand or on a fully automated CNC cutting table, thus obtaining a controlled removal according to the depth and width of the groove indicated in the synergic reference chart and shown on the generator display.

**Characteristics of plasma gouging**

- Need for high operating speeds and less time spent on grinding operations
- No contamination of the workpiece
- Ease of use
- Spot weld removal on any metal with precision engraving in width and depth

### 4.22 Plasma marking

Marking is used to engrave numbers or letters on a workpiece, to give end-use indications and for other operations. The Elettro c.f. plasma cutting generator completely self-adjusts all the parameters necessary for operation and, if used automatically, allows controlling the width and depth of the character used to write on the metal. Speed, pressure and marking current affect these characteristics, but the synergy of the generator makes it possible to control them simultaneously without prior testing, obtaining a professional result immediately.

**Examples of marking applications:**

- Workpiece marking with a specific serial number or batch number
- Engraving of names on a workpiece
- Marking lines for positioning welds or bends
- Engraving for holes or tapping

# 5 COMMON MISTAKES IN PLASMA CUTTING

## 5.1 Excessive use of consumables until they explode

Using consumables until they explode not only ruins a metal workpiece, but can cause costly torch failures and expensive and unwanted downtime. The signs of worn consumables are many; an experienced operator can often distinguish them by the noise or colour of the arc, but the most efficient way is to check the depth of hafnium pad erosion (maximum 1.5mm) and the quality of the nozzle hole (no deformation).

## 5.2 Using the wrong parameters and components during a job

The choice of consumables depends on the torch, the material and thickness to be cut, the current and pressure of the plasma gas used and other cutting parameters. The generator synergy automatically defines the size of consumables appropriate for the various types of material and thicknesses to be cut. Use of the wrong consumables can lead to reduced life of components and of the torch itself, and significantly reduced cutting quality. Systematically use the exploded view of the torch used and original Elettro c.f. components at every replacement/maintenance operation (ordinary and extraordinary). Using components with the right current is of paramount importance. Generally, the best cut quality and longest component life is achieved when this is set at 95% of nozzle capacity. If the current is too low, cutting is inaccurate; if it is too high, nozzle life may be compromised.

## 5.3 Incorrect torch assembly

Even if the components are correct, the torch must always be assembled in such a way that they are aligned correctly and fit together accurately. This ensures proper electrical contact and proper gas stream through the torch. When changing components, keep consumables in a clean area to prevent dirt or metal dust from contaminating the torch. When replacing the consumables, it is important to lubricate the O-rings with the grease provided. It is sufficient to use just enough grease to polish the O-ring. Excessive lubrication can cause clogging of the swirl ring and contamination of the torch with solid residues. This can lead to uncontrolled arc ignition in the plasma chamber and eventually torch failure. Never apply lubricant or grease to the torches as this can cause arc formation and burning inside the torches

## 5.4 Neglecting routine maintenance

Torches can last for months or even years if handled with care. Torch threads should be kept well cleaned and the seats checked for contamination or mechanical damage. Any residual dirt, metal dust, or excess lubricant on the O-ring should be promptly removed from the torch.

## 5.5 Failure to check feed gas pressure and quality

The gas pressure and quality must be checked frequently. Constant gas pressure and continuous quality over time are of paramount importance to maintain the quality of the cutting arc and the cut workpieces. Excessive gas pressure is a frequent cause of "hard ignition," a situation in which the torch fails to start an arc even though all other conditions for normal operation are correct. Excessive gas pressure can also cause rapid deterioration of the electrode. Similarly, plasma gas must be dried, de-oiled and filtered to prevent reduced life of the consumable part and of the torch itself. Compressed air production systems (piston, screw or vane compressors) are particularly susceptible to contamination by oil, moisture and solid particles.

## 5.6 Insufficient piercing

The distance between the torch and the workpiece is critical for the cutting quality and the life of consumables. Even a slight variation in the height of the torch can affect the mechanical and geometric characteristics of the cut workpiece. A common mistake is an insufficient piercing. This can result in molten metal splashing onto the front of the nozzle and screen, damaging components and causing immediate problems in the cutting quality.

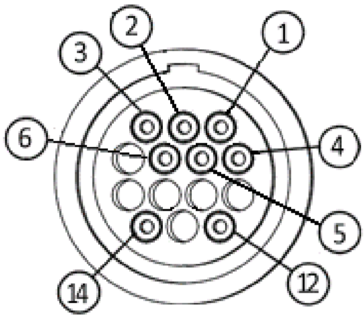
## 5.7 Cutting speed too high or too low

Too high or too low a cutting speed can cause cutting quality problems. If the speed is too low, the cut workpieces may develop a "low-speed burr," a build-up of porous burrs along the bottom edge. Low speeds can also result in widening of the cut with (KERF) and excessive amounts of molten metal splashes on the top of the workpiece. If the speed is too high, the arc will lag during the cutting forward movement causing bevelled edges, a narrow cut width (KERF) and a small burr rib along the bottom edge of the cut workpiece that is difficult to remove. Selecting an appropriate cutting speed produces a reduced burr, resulting in a clean edge that requires minimal rework before being subjected to the next step in the manufacturing process.

## 5.8 Excessive lifting or collision of the torch

"Lifting" and collisions can damage the torch beyond repair. Collisions of the torch with the workpiece can be prevented by programming the shape cutting system to pass around (rather than over) the cut workpieces. Torch height sensors on some CNC tables also offer protection against torch collision by correcting any changes in material shape or arc voltage. For example, at the end of a cut ,if the torch follows the cut too quickly to compensate for the increased voltage when the arc extends the torch may collide with the workpiece. Careful programming of the cutting lead-out and the torch height control feature can reduce or eliminate this side effect. Finally, the torch safety and emergency devices can help prevent damage in cases where a collision occurs.

# 6 CNC CONNECTOR (AMP 14 PINS)




## 6.1 Wiring diagram for AMP 14-pin model CNC connector

| Signal | Signal type | Notes | AMP connector pin |
|---|---|---|---|
| Start<br><br>(plasma start-up) | Input | Normally open.<br><br>To start the pilot arc it is necessary to close the circuit with an insulated contact (without external voltages).<br><br>NOTE:<br><br>If the control cable is present on the automatic torch adapter, short-circuit the two wires to activate the safety circuit on the torch head. | **3**, **4** |
| ARC-ON/<br><br>OK TO MOVE (signal for automatic start of cutting movement) | Output | Insulated normally open "dry contact".<br><br>The contact closes when the arc is transferred, the display shows "ON".<br><br>The contact rating is as follows:<br><br>8A-250VAC<br><br>8A-24VDC | **12**, **14** |
| Voltage<br><br>divider | Output | Electronic arc voltage divider, adjustable from 1/20V to 1/100V in steps of 1/100V.<br><br>Voltage galvanically insulated from the voltage of the plasma arc. | **5** (0V), **6** (+) |
| Remote current adjustment (I CNC) | Input | Remote adjustment of the cutting current.<br><br>By applying an isolated voltage between 0VDC and 10VDC it is possible to adjust the cutting current remotely (CNC) | **1** (0V),<br><br>**2** (0-10VDC MAX) |

## 7 CUTTING CHARTS

### 7.1 Cutting chart 45A

**CHART OF SPEED - CURRENT - IRON VALUES**

| | | 45A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | Mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 2 | 4 | 0.22 | 119 | 12550 | 120 | 16750 |
| 2 | | | 0.26 | 120 | 6275 | 121 | 8375 |
| 3 | | | 0.32 | 120 | 4183 | 121 | 5583 |
| 4 | | | 0.4 | 121 | 3138 | 122 | 4188 |
| 5 | | | 0.48 | 122 | 2510 | 123 | 3350 |
| 6 | | | 0.57 | 122 | 2140 | 123 | 2833 |
| 7 | | | 0.67 | 123 | 1770 | 124 | 2317 |
| 8 | | | 0.79 | 124 | 1400 | 125 | 1800 |
| 9 | | | 0.91 | 124 | 1150 | 125 | 1450 |
| 10 | | | 1.04 | 125 | 900 | 126 | 1100 |

**CHART OF SPEED - CURRENT - STAINLESS STEEL VALUES**

| | | 45A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | Mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 2 | 4 | 0.22 | 119 | 12550 | 120 | 16750 |
| 2 | | | 0.26 | 120 | 5705 | 121 | 9298 |
| 3 | | | 0.32 | 120 | 3369 | 121 | 5014 |
| 4 | | | 0.4 | 121 | 2856 | 122 | 3054 |
| 5 | | | 0.48 | 122 | 2045 | 123 | 2157 |
| 6 | | | 0.57 | 122 | 1427 | 123 | 1427 |
| 7 | | | 0.67 | 123 | 1176 | 124 | 1176 |
| 8 | | | 0.79 | 124 | 932 | 125 | 932 |
| 9 | | | 0.91 | 124 | 767 | 125 | 767 |
| 10 | | | 1.04 | 125 | 602 | 126 | 602 |

**CHART OF SPEED - CURRENT - ALUMINIUM VALUES**

| | | ALUMINIUM 45A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 2 | 4 | 0.22 | 119 | 15276 | 120 | 17067 |
| 2 | | | 0.26 | 120 | 6275 | 121 | 9878 |
| 3 | | | 0.32 | 120 | 3369 | 121 | 7124 |
| 4 | | | 0.4 | 121 | 3138 | 122 | 5709 |
| 5 | | | 0.48 | 122 | 2620 | 123 | 4564 |
| 6 | | | 0.57 | 122 | 2378 | 123 | 3866 |
| 7 | | | 0.67 | 123 | 1964 | 124 | 3168 |
| 8 | | | 0.79 | 124 | 1551 | 125 | 2460 |
| 9 | | | 0.91 | 124 | 1281 | 125 | 1979 |
| 10 | | | 1.04 | 125 | 1001 | 126 | 1498 |

## 7.2 Cutting chart 65A

**CHART OF SPEED - CURRENT - IRON VALUES**

| | | 65A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 2 | 4 | 0.11 | 123 | 18000 | 124 | 18000 |
| 2 | | | 0.18 | 123 | 9213 | 124 | 11688 |
| 3 | | | 0.23 | 124 | 6142 | 125 | 7792 |
| 4 | | | 0.3 | 124 | 4606 | 125 | 5844 |
| 5 | | | 0.48 | 125 | 3685 | 126 | 4675 |
| 6 | | | 0.55 | 125 | 3200 | 126 | 3975 |
| 7 | | | 0.62 | 126 | 2715 | 127 | 3275 |
| 8 | | | 0.67 | 126 | 2230 | 127 | 2575 |
| 9 | | | 0.73 | 127 | 1840 | 128 | 2138 |
| 10 | | | 0.82 | 127 | 1450 | 128 | 1700 |

## CHART OF SPEED - CURRENT - STAINLESS STEEL VALUES

| | | 65A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 2 | 4 | 0.11 | 123 | 18000 | 124 | 18000 |
| 2 | | | 0.18 | 123 | 7826 | 124 | 10648 |
| 3 | | | 0.23 | 124 | 7912 | 125 | 10556 |
| 4 | | | 0.3 | 124 | 5646 | 125 | 7054 |
| 5 | | | 0.48 | 125 | 4141 | 126 | 5042 |
| 6 | | | 0.55 | 125 | 3075 | 126 | 3499 |
| 7 | | | 0.62 | 126 | 2519 | 127 | 2816 |
| 8 | | | 0.67 | 126 | 1971 | 127 | 2152 |
| 9 | | | 0.73 | 127 | 1618 | 128 | 1785 |
| 10 | | | 0.82 | 127 | 1265 | 128 | 1417 |

## CHART OF SPEED - CURRENT - ALUMINIUM VALUES

| | | 65A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 2 | 4 | 0.11 | 123 | 18000 | 124 | 18000 |
| 2 | | | 0.18 | 123 | 8509 | 124 | 10973 |
| 3 | | | 0.23 | 124 | 8743 | 125 | 11235 |
| 4 | | | 0.3 | 124 | 6507 | 125 | 8426 |
| 5 | | | 0.48 | 125 | 4984 | 126 | 6592 |
| 6 | | | 0.55 | 125 | 4017 | 126 | 5391 |
| 7 | | | 0.62 | 126 | 3282 | 127 | 4278 |
| 8 | | | 0.67 | 126 | 2562 | 127 | 3184 |
| 9 | | | 0.73 | 127 | 2072 | 128 | 2520 |
| 10 | | | 0.82 | 127 | 1586 | 128 | 1866 |

### 7.3 Cutting chart 85A

CHART OF SPEED - CURRENT - IRON VALUES

| | | 85A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 3 | 5 | 0.07 | 138 | 18000 | 134 | 18000 |
| 2 | | | 0.12 | 138 | 12150 | 134 | 15000 |
| 3 | | | 0.17 | 139 | 8100 | 135 | 10000 |
| 4 | | | 0.22 | 139 | 6075 | 135 | 7500 |
| 5 | | | 0.28 | 140 | 4860 | 136 | 6000 |
| 6 | | | 0.34 | 140 | 4260 | 136 | 5117 |
| 7 | | | 0.4 | 141 | 3660 | 137 | 4233 |
| 8 | | | 0.46 | 141 | 3060 | 137 | 3350 |
| 9 | | | 0.53 | 142 | 2530 | 138 | 2825 |
| 10 | | | 0.6 | 142 | 2000 | 138 | 2300 |
| 11 | 4 | | 0.68 | 144 | 1786 | 140 | 2050 |
| 12 | | | 0.76 | 145 | 1572 | 141 | 1800 |
| 13 | | 7 | 0.88 | 146 | 1358 | 142 | 1550 |
| 14 | | | 1 | 146 | 1144 | 142 | 1300 |
| 15 | | | 1.15 | 147 | 930 | 143 | 1050 |

CHART OF SPEED - CURRENT - STAINLESS STEEL VALUES

| | | 85A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 3 | 5 | 0.07 | 138 | 18000 | 134 | 18000 |
| 2 | | | 0.12 | 138 | 13400 | 134 | 15000 |
| 3 | | | 0.17 | 139 | 8933 | 135 | 11395 |
| 4 | | | 0.22 | 139 | 6568 | 135 | 7709 |
| 5 | | | 0.28 | 140 | 5153 | 136 | 6204 |
| 6 | | | 0.34 | 140 | 4376 | 136 | 5348 |
| 7 | | | 0.4 | 141 | 3695 | 137 | 4322 |
| 8 | | | 0.46 | 141 | 3003 | 137 | 3299 |
| 9 | | | 0.53 | 142 | 2426 | 138 | 2709 |
| 10 | | | 0.6 | 142 | 1847 | 138 | 2114 |
| 11 | 4 | | 0.68 | 144 | 1607 | 140 | 1838 |
| 12 | | | 0.76 | 145 | 1344 | 141 | 1572 |
| 13 | | 7 | 0.88 | 146 | 1156 | 142 | 1339 |
| 14 | | | 1 | 146 | 956 | 142 | 1110 |
| 15 | | | 1.15 | 147 | 814 | 143 | 1043 |

**CHART OF SPEED - CURRENT - ALUMINIUM VALUES**

<table>
<tr><th></th><th></th><th colspan="2">85A</th><th></th><th></th><th></th><th></th></tr>
<tr><th>Material thickness</th><th>cutting distance</th><th>piercing distance</th><th>piercing delay</th><th>Quality cut voltage</th><th>Quality Speed</th><th>Maximum speed cutting voltage</th><th>Maximum Speed</th></tr>
<tr><th>mm</th><th>mm</th><th>mm</th><th>sec.</th><th>V</th><th>mm/min</th><th>V</th><th>mm/min</th></tr>
<tr><td>1</td><td rowspan="10">3</td><td rowspan="12">5</td><td>0.07</td><td>138</td><td>18000</td><td>134</td><td>18000</td></tr>
<tr><td>2</td><td>0.12</td><td>138</td><td>14291</td><td>134</td><td>15328</td></tr>
<tr><td>3</td><td>0.17</td><td>139</td><td>9529</td><td>135</td><td>12420</td></tr>
<tr><td>4</td><td>0.22</td><td>139</td><td>6996</td><td>135</td><td>9470</td></tr>
<tr><td>5</td><td>0.28</td><td>140</td><td>5410</td><td>136</td><td>6612</td></tr>
<tr><td>6</td><td>0.34</td><td>140</td><td>4493</td><td>136</td><td>5695</td></tr>
<tr><td>7</td><td>0.4</td><td>141</td><td>3868</td><td>137</td><td>4729</td></tr>
<tr><td>8</td><td>0.46</td><td>141</td><td>3243</td><td>137</td><td>3751</td></tr>
<tr><td>9</td><td>0.53</td><td>142</td><td>2761</td><td>138</td><td>3268</td></tr>
<tr><td>10</td><td>0.6</td><td>142</td><td>2282</td><td>138</td><td>2782</td></tr>
<tr><td>11</td><td rowspan="5">4</td><td>0.68</td><td>144</td><td>2036</td><td>140</td><td>2473</td></tr>
<tr><td>12</td><td>0.76</td><td>145</td><td>1776</td><td>141</td><td>2165</td></tr>
<tr><td>13</td><td rowspan="3">7</td><td>0.88</td><td>146</td><td>1529</td><td>142</td><td>1891</td></tr>
<tr><td>14</td><td>1</td><td>146</td><td>1275</td><td>142</td><td>1607</td></tr>
<tr><td>15</td><td>1.15</td><td>147</td><td>1027</td><td>143</td><td>1326</td></tr>
</table>

## 7.4 Cutting chart 105A

**CHART OF SPEED - CURRENT - IRON VALUES**

| | | 105 | | | | | |
|---|---|---|---|---|---|---|---|
| **Material thickness** | **cutting distance** | **piercing distance** | **piercing delay** | **Quality cut voltage** | **Quality Speed** | **Maximum speed cutting voltage** | **Maximum Speed** |
| **mm** | **mm** | **mm** | **sec.** | **V** | **mm/min** | **V** | **mm/min** |
| 1 | 5 | 5 | 0.06 | 156 | 18000 | 145 | 18000 |
| 2 | | | 0.1 | 156 | 15009 | 145 | 18000 |
| 3 | | | 0.14 | 157 | 10006 | 146 | 12353 |
| 4 | | | 0.18 | 158 | 7504 | 147 | 9265 |
| 5 | | | 0.22 | 158 | 6004 | 147 | 7412 |
| 6 | | | 0.26 | 159 | 5239 | 148 | 6358 |
| 7 | | | 0.31 | 159 | 4475 | 148 | 5304 |
| 8 | | | 0.36 | 160 | 3710 | 151 | 4250 |
| 9 | | | 0.41 | 160 | 3280 | 151 | 3725 |
| 10 | | | 0.46 | 161 | 2850 | 152 | 3200 |
| 11 | | | 0.52 | 161 | 2522 | 152 | 2850 |
| 12 | | | 0.58 | 162 | 2194 | 153 | 2500 |
| 13 | | 7 | 0.72 | 163 | 1866 | 154 | 2150 |
| 14 | | | 0.77 | 164 | 1538 | 155 | 1800 |
| 15 | | | 0.85 | 165 | 1210 | 156 | 1450 |
| 16 | | | 0.93 | 165 | 1146 | 156 | 1368 |
| 17 | | | 1.01 | 166 | 1082 | 157 | 1287 |
| 18 | | | 1.09 | 166 | 1018 | 157 | 1205 |
| 19 | | | 1.17 | 167 | 954 | 158 | 1123 |
| 20 | | | 1.25 | 167 | 890 | 158 | 1042 |

**CHART OF SPEED - CURRENT - STAINLESS STEEL VALUES**

| | | 105 | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.06 | 156 | 18000 | 145 | 18000 |
| 2 | | | 0.1 | 156 | 17650 | 145 | 18000 |
| 3 | | | 0.14 | 157 | 11768 | 146 | 14565 |
| 4 | | | 0.18 | 158 | 8826 | 147 | 10918 |
| 5 | | | 0.22 | 158 | 7060 | 147 | 8740 |
| 6 | | | 0.26 | 159 | 6161 | 148 | 7492 |
| 7 | | | 0.31 | 159 | 5127 | 148 | 6054 |
| 8 | | | 0.36 | 160 | 4095 | 151 | 4625 |
| 9 | | | 0.41 | 160 | 3457 | 151 | 3853 |
| 10 | | | 0.46 | 161 | 2827 | 152 | 3057 |
| 11 | | | 0.52 | 161 | 2384 | 152 | 2653 |
| 12 | | | 0.58 | 162 | 1943 | 153 | 2260 |
| 13 | | 7 | 0.72 | 163 | 1651 | 154 | 1912 |
| 14 | | | 0.77 | 164 | 1361 | 155 | 1575 |
| 15 | | | 0.85 | 165 | 1080 | 156 | 1229 |
| 16 | | | 0.93 | 165 | 1026 | 156 | 1132 |
| 17 | | | 1.01 | 166 | 960 | 157 | 1067 |
| 18 | | | 1.09 | 166 | 889 | 157 | 1012 |
| 19 | | | 1.17 | 167 | 822 | 158 | 953 |
| 20 | | | 1.25 | 167 | 756 | 158 | 895 |

## CHART OF SPEED - CURRENT - ALUMINIUM VALUES

| | | 105 | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.06 | 156 | 18000 | 145 | 18000 |
| 2 | | | 0.1 | 156 | 18000 | 145 | 18000 |
| 3 | | | 0.14 | 157 | 14454 | 146 | 17200 |
| 4 | | | 0.18 | 158 | 10834 | 147 | 12912 |
| 5 | | | 0.22 | 158 | 8669 | 147 | 10321 |
| 6 | | | 0.26 | 159 | 7573 | 148 | 8855 |
| 7 | | | 0.31 | 159 | 6240 | 148 | 7178 |
| 8 | | | 0.36 | 160 | 4929 | 151 | 5521 |
| 9 | | | 0.41 | 160 | 4130 | 151 | 4643 |
| 10 | | | 0.46 | 161 | 3325 | 152 | 3763 |
| 11 | | | 0.52 | 161 | 2902 | 152 | 3354 |
| 12 | | | 0.58 | 162 | 2480 | 153 | 2969 |
| 13 | | 7 | 0.72 | 163 | 2149 | 154 | 2582 |
| 14 | | | 0.77 | 164 | 1781 | 155 | 2196 |
| 15 | | | 0.85 | 165 | 1437 | 156 | 1797 |
| 16 | | | 0.93 | 165 | 1386 | 156 | 1735 |
| 17 | | | 1.01 | 166 | 1332 | 157 | 1627 |
| 18 | | | 1.09 | 166 | 1271 | 157 | 1523 |
| 19 | | | 1.17 | 167 | 1219 | 158 | 1423 |
| 20 | | | 1.25 | 167 | 1164 | 158 | 1311 |

## 7.5 Cutting chart 125A

**CHART OF SPEED - CURRENT - IRON VALUES**

| | | 125A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.05 | 155 | 18000 | 153 | 18000 |
| 2 | | | 0.09 | 156 | 17868 | 154 | 18000 |
| 3 | | | 0.13 | 156 | 11912 | 154 | 14706 |
| 4 | | | 0.17 | 157 | 8934 | 155 | 11029 |
| 5 | | | 0.21 | 158 | 7147 | 156 | 8824 |
| 6 | | | 0.26 | 158 | 6161 | 156 | 7569 |
| 7 | | | 0.31 | 159 | 5176 | 157 | 6315 |
| 8 | | | 0.36 | 160 | 4190 | 158 | 5060 |
| 9 | | | 0.41 | 160 | 3870 | 158 | 4430 |
| 10 | | | 0.46 | 161 | 3550 | 159 | 3800 |
| 11 | | | 0.52 | 162 | 3156 | 160 | 3412 |
| 12 | | | 0.6 | 162 | 2762 | 160 | 3024 |
| 13 | | 7 | 0.87 | 163 | 2368 | 161 | 2636 |
| 14 | | | 0.95 | 164 | 1974 | 162 | 2248 |
| 15 | | | 1.06 | 164 | 1580 | 162 | 1860 |
| 16 | | | 1.16 | 165 | 1476 | 163 | 1736 |
| 17 | | | 1.27 | 166 | 1372 | 164 | 1612 |
| 18 | | | 1.41 | 166 | 1268 | 164 | 1488 |
| 19 | | | 1.56 | 167 | 1164 | 165 | 1364 |
| 20 | | | 1.7 | 168 | 1060 | 166 | 1240 |
| 21 | | | 1.85 | 168 | 988 | 166 | 1154 |
| 22 | | | 2 | 169 | 916 | 167 | 1068 |
| 23 | | | 2.17 | 170 | 844 | 168 | 982 |
| 24 | | | 2.35 | 170 | 772 | 168 | 896 |
| 25 | | | 2.55 | 171 | 700 | 169 | 810 |

**CHART OF SPEED - CURRENT - STAINLESS STEEL VALUES**

| | | 125A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.05 | 155 | 18000 | 153 | 18000 |
| 2 | | | 0.09 | 156 | 18000 | 154 | 18000 |
| 3 | | | 0.13 | 156 | 14011 | 154 | 17337 |
| 4 | | | 0.17 | 157 | 10502 | 155 | 13009 |
| 5 | | | 0.21 | 158 | 8405 | 156 | 10401 |
| 6 | | | 0.26 | 158 | 7250 | 156 | 8921 |
| 7 | | | 0.31 | 159 | 5920 | 157 | 7189 |
| 8 | | | 0.36 | 160 | 4623 | 158 | 5500 |
| 9 | | | 0.41 | 160 | 4087 | 158 | 4576 |
| 10 | | | 0.46 | 161 | 3818 | 159 | 3818 |
| 11 | | | 0.52 | 162 | 3055 | 160 | 3185 |
| 12 | | | 0.6 | 162 | 2535 | 160 | 2730 |
| 13 | | 7 | 0.87 | 163 | 2103 | 161 | 2335 |
| 14 | | | 0.95 | 164 | 1742 | 162 | 1954 |
| 15 | | | 1.06 | 164 | 1402 | 162 | 1576 |
| 16 | | | 1.16 | 165 | 1317 | 163 | 1428 |
| 17 | | | 1.27 | 166 | 1220 | 164 | 1336 |
| 18 | | | 1.41 | 166 | 1112 | 164 | 1244 |
| 19 | | | 1.56 | 167 | 1004 | 165 | 1152 |
| 20 | | | 1.7 | 168 | 895 | 166 | 1071 |
| 21 | | | 1.85 | 168 | 829 | 166 | 1007 |
| 22 | | | 2 | 169 | 763 | 167 | 938 |
| 23 | | | 2.17 | 170 | 692 | 168 | 870 |
| 24 | | | 2.35 | 170 | 626 | 168 | 807 |
| 25 | | | 2.55 | 171 | 560 | 169 | 738 |

## CHART OF SPEED - CURRENT - ALUMINIUM VALUES

| | | 125A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.05 | 155 | 18000 | 153 | 18000 |
| 2 | | | 0.09 | 156 | 18000 | 154 | 18000 |
| 3 | | | 0.13 | 156 | 17204 | 154 | 18000 |
| 4 | | | 0.17 | 157 | 12911 | 155 | 15370 |
| 5 | | | 0.21 | 158 | 10326 | 156 | 12291 |
| 6 | | | 0.26 | 158 | 8900 | 156 | 10539 |
| 7 | | | 0.31 | 159 | 7222 | 157 | 8534 |
| 8 | | | 0.36 | 160 | 5562 | 158 | 6564 |
| 9 | | | 0.41 | 160 | 4883 | 158 | 5523 |
| 10 | | | 0.46 | 161 | 4220 | 159 | 4463 |
| 11 | | | 0.52 | 162 | 3408 | 160 | 4032 |
| 12 | | | 0.6 | 162 | 3122 | 160 | 3589 |
| 13 | | 7 | 0.87 | 163 | 2720 | 161 | 3168 |
| 14 | | | 0.95 | 164 | 2288 | 162 | 2734 |
| 15 | | | 1.06 | 164 | 1873 | 162 | 2309 |
| 16 | | | 1.16 | 165 | 1795 | 163 | 2197 |
| 17 | | | 1.27 | 166 | 1699 | 164 | 2042 |
| 18 | | | 1.41 | 166 | 1591 | 164 | 1888 |
| 19 | | | 1.56 | 167 | 1495 | 165 | 1722 |
| 20 | | | 1.7 | 168 | 1378 | 166 | 1578 |
| 21 | | | 1.85 | 168 | 1270 | 166 | 1482 |
| 22 | | | 2 | 169 | 1168 | 167 | 1383 |
| 23 | | | 2.17 | 170 | 1055 | 168 | 1283 |
| 24 | | | 2.35 | 170 | 947 | 168 | 1191 |
| 25 | | | 2.55 | 171 | 840 | 169 | 1104 |

### 7.6 Cutting chart 160A

**CHART OF SPEED - CURRENT - IRON VALUES**

| Material thickness | cutting distance | piercing distance (160A) | piercing delay (160A) | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
|---|---|---|---|---|---|---|---|
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.03 | 161 | 18000 | 157 | 18000 |
| 2 | | | 0.07 | 161 | 18000 | 157 | 18000 |
| 3 | | | 0.11 | 161 | 15724 | 157 | 18000 |
| 4 | | | 0.15 | 162 | 11793 | 158 | 14559 |
| 5 | | | 0.19 | 162 | 9434 | 158 | 11647 |
| 6 | | | 0.24 | 163 | 7989 | 159 | 9638 |
| 7 | | | 0.29 | 163 | 6545 | 159 | 7629 |
| 8 | | | 0.34 | 164 | 5100 | 160 | 5620 |
| 9 | | | 0.39 | 164 | 4550 | 160 | 4985 |
| 10 | | | 0.45 | 165 | 4000 | 161 | 4350 |
| 11 | | | 0.51 | 165 | 3620 | 161 | 3970 |
| 12 | | | 0.58 | 166 | 3240 | 162 | 3590 |
| 13 | | | 0.65 | 166 | 2860 | 162 | 3210 |
| 14 | | | 0.74 | 167 | 2480 | 163 | 2830 |
| 15 | | | 0.83 | 167 | 2100 | 163 | 2450 |
| 16 | | 7 | 1 | 168 | 1936 | 164 | 2250 |
| 17 | | | 1.11 | 169 | 1772 | 165 | 2050 |
| 18 | | | 1.22 | 170 | 1608 | 166 | 1850 |
| 19 | | | 1.34 | 170 | 1444 | 166 | 1650 |
| 20 | | | 1.46 | 171 | 1280 | 167 | 1450 |
| 21 | | | 1.58 | 171 | 1200 | 167 | 1360 |
| 22 | | | 1.73 | 172 | 1120 | 168 | 1270 |
| 23 | | | 1.88 | 172 | 1040 | 168 | 1180 |
| 24 | | | 2.03 | 173 | 960 | 169 | 1090 |
| 25 | | | 2.18 | 173 | 880 | 169 | 1000 |
| 26 | | 8 | 2.4 | 174 | 832 | 170 | 940 |
| 27 | | | 2.52 | 175 | 784 | 171 | 880 |
| 28 | | | 2.64 | 176 | 736 | 172 | 820 |
| 29 | | | 2.76 | 176 | 688 | 172 | 760 |
| 30 | | | 2.9 | 177 | 640 | 173 | 700 |

## CHART OF SPEED - CURRENT - STAINLESS STEEL VALUES

| | | 160A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.03 | 161 | 18000 | 157 | 18000 |
| 2 | | | 0.07 | 161 | 18000 | 157 | 18000 |
| 3 | | | 0.11 | 161 | 18000 | 157 | 18000 |
| 4 | | | 0.15 | 162 | 13862 | 158 | 17171 |
| 5 | | | 0.19 | 162 | 11095 | 158 | 13729 |
| 6 | | | 0.24 | 163 | 9401 | 159 | 11360 |
| 7 | | | 0.29 | 163 | 7486 | 159 | 8685 |
| 8 | | | 0.34 | 164 | 5627 | 160 | 6109 |
| 9 | | | 0.39 | 164 | 4805 | 160 | 5150 |
| 10 | | | 0.45 | 165 | 4302 | 161 | 4302 |
| 11 | | | 0.51 | 165 | 3504 | 161 | 3706 |
| 12 | | | 0.58 | 166 | 2974 | 162 | 3241 |
| 13 | | | 0.65 | 166 | 2541 | 162 | 2844 |
| 14 | | | 0.74 | 167 | 2188 | 163 | 2460 |
| 15 | | | 0.83 | 167 | 1864 | 163 | 2075 |
| 16 | | 7 | 1 | 168 | 1727 | 164 | 1851 |
| 17 | | | 1.11 | 169 | 1575 | 165 | 1699 |
| 18 | | | 1.22 | 170 | 1411 | 166 | 1546 |
| 19 | | | 1.34 | 170 | 1246 | 166 | 1393 |
| 20 | | | 1.46 | 171 | 1081 | 167 | 1252 |
| 21 | | | 1.58 | 171 | 1007 | 167 | 1187 |
| 22 | | | 1.73 | 172 | 933 | 168 | 1116 |
| 23 | | | 1.88 | 172 | 852 | 168 | 1046 |
| 24 | | | 2.03 | 173 | 778 | 169 | 982 |
| 25 | | | 2.18 | 173 | 704 | 169 | 911 |
| 26 | | 8 | 2.4 | 174 | 681 | 170 | 854 |
| 27 | | | 2.52 | 175 | 651 | 171 | 796 |
| 28 | | | 2.64 | 176 | 620 | 172 | 733 |
| 29 | | | 2.76 | 176 | 589 | 172 | 677 |
| 30 | | | 2.9 | 177 | 557 | 173 | 615 |

## CHART OF SPEED - CURRENT - ALUMINIUM VALUES

| | | 160A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | cutting distance | piercing distance | piercing delay | Quality cut voltage | Quality Speed | Maximum speed cutting voltage | Maximum Speed |
| mm | mm | mm | sec. | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.03 | 161 | 18000 | 157 | 18000 |
| 2 | | | 0.07 | 161 | 18000 | 157 | 18000 |
| 3 | | | 0.11 | 161 | 18000 | 157 | 18000 |
| 4 | | | 0.15 | 162 | 17042 | 158 | 18000 |
| 5 | | | 0.19 | 162 | 13630 | 158 | 16224 |
| 6 | | | 0.24 | 163 | 11540 | 159 | 13419 |
| 7 | | | 0.29 | 163 | 9132 | 159 | 10311 |
| 8 | | | 0.34 | 164 | 6770 | 160 | 7290 |
| 9 | | | 0.39 | 164 | 5741 | 160 | 6215 |
| 10 | | | 0.45 | 165 | 4755 | 161 | 5110 |
| 11 | | | 0.51 | 165 | 3910 | 161 | 4692 |
| 12 | | | 0.58 | 166 | 3663 | 162 | 4261 |
| 13 | | | 0.65 | 166 | 3286 | 162 | 3858 |
| 14 | | | 0.74 | 167 | 2874 | 163 | 3442 |
| 15 | | | 0.83 | 167 | 2489 | 163 | 3041 |
| 16 | | 7 | 1 | 168 | 2354 | 164 | 2848 |
| 17 | | | 1.11 | 169 | 2194 | 165 | 2597 |
| 18 | | | 1.22 | 170 | 2017 | 166 | 2347 |
| 19 | | | 1.34 | 170 | 1855 | 166 | 2083 |
| 20 | | | 1.46 | 171 | 1664 | 167 | 1845 |
| 21 | | | 1.58 | 171 | 1543 | 167 | 1747 |
| 22 | | | 1.73 | 172 | 1429 | 168 | 1644 |
| 23 | | | 1.88 | 172 | 1300 | 168 | 1542 |
| 24 | | | 2.03 | 173 | 1178 | 169 | 1449 |
| 25 | | | 2.18 | 173 | 1056 | 169 | 1363 |
| 26 | | 8 | 2.4 | 174 | 997 | 170 | 1278 |
| 27 | | | 2.52 | 175 | 932 | 171 | 1208 |
| 28 | | | 2.64 | 176 | 872 | 172 | 1128 |
| 29 | | | 2.76 | 176 | 807 | 172 | 1057 |
| 30 | | | 2.9 | 177 | 742 | 173 | 971 |

## 7.7 Cutting chart 180A

**CHART OF SPEED - CURRENT - IRON VALUES**

| | | 180A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | Cutting distance | Piercing distance | Piercing delay | Quality settings | | Maximum productivity settings | |
| | | | | Voltage | Speed | Voltage | Speed |
| mm | mm | mm | seconds | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.02 | 166 | 18000 | 161 | 18000 |
| 2 | | | 0.06 | 166 | 18000 | 161 | 18000 |
| 3 | | | 0.1 | 166 | 18000 | 161 | 18000 |
| 4 | | | 0.14 | 166 | 13419 | 161 | 16567 |
| 5 | | | 0.18 | 167 | 10735 | 162 | 13254 |
| 6 | | | 0.22 | 167 | 9022 | 162 | 10797 |
| 7 | | | 0.26 | 167 | 7309 | 162 | 8348 |
| 8 | | | 0.3 | 168 | 5600 | 163 | 5915 |
| 9 | | | 0.34 | 168 | 4919 | 163 | 5279 |
| 10 | | | 0.39 | 169 | 4238 | 164 | 4644 |
| 11 | | | 0.44 | 169 | 3870 | 164 | 4272 |
| 12 | | | 0.49 | 170 | 3502 | 165 | 3900 |
| 13 | | | 0.54 | 170 | 3133 | 165 | 3529 |
| 14 | | | 0.59 | 171 | 2765 | 166 | 3157 |
| 15 | | | 0.66 | 171 | 2397 | 166 | 2785 |
| 16 | | 7 | 0.82 | 172 | 2197 | 167 | 2541 |
| 17 | | | 0.9 | 173 | 1998 | 168 | 2297 |
| 18 | | | 0.98 | 173 | 1799 | 168 | 2052 |
| 19 | | | 1.07 | 174 | 1600 | 169 | 1808 |
| 20 | | | 1.16 | 174 | 1400 | 169 | 1563 |
| 21 | | | 1.26 | 175 | 1316 | 170 | 1472 |
| 22 | | | 1.36 | 175 | 1232 | 170 | 1380 |
| 23 | | | 1.47 | 176 | 1148 | 171 | 1288 |
| 24 | | | 1.58 | 176 | 1064 | 171 | 1197 |
| 25 | | | 1.7 | 177 | 980 | 172 | 1105 |
| 26 | | 8 | 1.93 | 178 | 925 | 173 | 1029 |
| 27 | | | 2.02 | 178 | 871 | 173 | 953 |
| 28 | | | 2.11 | 179 | 816 | 174 | 878 |
| 29 | | | 2.2 | 179 | 761 | 174 | 802 |
| 30 | | | 2.29 | 180 | 706 | 175 | 726 |
| 31 | | | 2.39 | 180 | 687 | 175 | 705 |
| 32 | | | 2.5 | 181 | 667 | 176 | 685 |
| 33 | | | 2.61 | 181 | 647 | 176 | 664 |
| 34 | | | 2.73 | 182 | 627 | 177 | 643 |
| 35 | | | 2.85 | 182 | 608 | 177 | 623 |

## CHART OF SPEED - CURRENT - STAINLESS STEEL VALUES

| Material thickness | Cutting distance | Piercing distance | Piercing delay | Quality settings | | Maximum productivity settings | |
|---|---|---|---|---|---|---|---|
| | | 180A | | Voltage | Speed | Voltage | Speed |
| mm | mm | mm | seconds | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.02 | 166 | 18000 | 161 | 18000 |
| 2 | | | 0.06 | 166 | 18000 | 161 | 18000 |
| 3 | | | 0.1 | 166 | 18000 | 161 | 18000 |
| 4 | | | 0.14 | 166 | 15774 | 161 | 18000 |
| 5 | | | 0.18 | 167 | 12625 | 162 | 15623 |
| 6 | | | 0.22 | 167 | 10615 | 162 | 12726 |
| 7 | | | 0.26 | 167 | 8360 | 162 | 9504 |
| 8 | | | 0.3 | 168 | 6178 | 163 | 6430 |
| 9 | | | 0.34 | 168 | 5195 | 163 | 5454 |
| 10 | | | 0.39 | 169 | 4558 | 164 | 4558 |
| 11 | | | 0.44 | 169 | 3746 | 164 | 3988 |
| 12 | | | 0.49 | 170 | 3214 | 165 | 3522 |
| 13 | | | 0.54 | 170 | 2783 | 165 | 3126 |
| 14 | | | 0.59 | 171 | 2440 | 166 | 2745 |
| 15 | | | 0.66 | 171 | 2127 | 166 | 2359 |
| 16 | | 7 | 0.82 | 172 | 1960 | 167 | 2091 |
| 17 | | | 0.9 | 173 | 1776 | 168 | 1903 |
| 18 | | | 0.98 | 173 | 1578 | 168 | 1715 |
| 19 | | | 1.07 | 174 | 1380 | 169 | 1526 |
| 20 | | | 1.16 | 174 | 1183 | 169 | 1350 |
| 21 | | | 1.26 | 175 | 1105 | 170 | 1284 |
| 22 | | | 1.36 | 175 | 1027 | 170 | 1213 |
| 23 | | | 1.47 | 176 | 941 | 171 | 1142 |
| 24 | | | 1.58 | 176 | 863 | 171 | 1078 |
| 25 | | | 1.7 | 177 | 784 | 172 | 1007 |
| 26 | | 8 | 1.93 | 178 | 758 | 173 | 935 |
| 27 | | | 2.02 | 178 | 723 | 173 | 863 |
| 28 | | | 2.11 | 179 | 687 | 174 | 785 |
| 29 | | | 2.2 | 179 | 651 | 174 | 714 |
| 30 | | | 2.29 | 180 | 614 | 175 | 638 |
| 31 | | | 2.39 | 180 | 612 | 175 | 619 |
| 32 | | | 2.5 | 181 | 570 | 176 | 592 |
| 33 | | | 2.61 | 181 | 552 | 176 | 573 |
| 34 | | | 2.73 | 182 | 541 | 177 | 552 |
| 35 | | | 2.85 | 182 | 524 | 177 | 540 |

CHART OF SPEED - CURRENT - ALUMINIUM VALUES

| | | 180A | | | | | |
|---|---|---|---|---|---|---|---|
| Material thickness | Cutting distance | Piercing distance | Piercing delay | Quality settings | | Maximum productivity settings | |
| | | | | Voltage | Speed | Voltage | Speed |
| mm | mm | mm | seconds | V | mm/min | V | mm/min |
| 1 | 5 | 5 | 0.02 | 166 | 18000 | 161 | 18000 |
| 2 | | | 0.06 | 166 | 18000 | 161 | 18000 |
| 3 | | | 0.1 | 166 | 18000 | 161 | 18000 |
| 4 | | | 0.14 | 166 | 18000 | 161 | 18000 |
| 5 | | | 0.18 | 167 | 15510 | 162 | 18000 |
| 6 | | | 0.22 | 167 | 13031 | 162 | 15033 |
| 7 | | | 0.26 | 167 | 10199 | 162 | 11283 |
| 8 | | | 0.3 | 168 | 7433 | 163 | 7672 |
| 9 | | | 0.34 | 168 | 6206 | 163 | 6582 |
| 10 | | | 0.39 | 169 | 5038 | 164 | 5454 |
| 11 | | | 0.44 | 169 | 4180 | 164 | 5049 |
| 12 | | | 0.49 | 170 | 3958 | 165 | 4629 |
| 13 | | | 0.54 | 170 | 3600 | 165 | 4241 |
| 14 | | | 0.59 | 171 | 3204 | 166 | 3839 |
| 15 | | | 0.66 | 171 | 2841 | 166 | 3457 |
| 16 | | 7 | 0.82 | 172 | 2672 | 167 | 3216 |
| 17 | | | 0.9 | 173 | 2474 | 168 | 2910 |
| 18 | | | 0.98 | 173 | 2257 | 168 | 2603 |
| 19 | | | 1.07 | 174 | 2054 | 169 | 2282 |
| 20 | | | 1.16 | 174 | 1820 | 169 | 1990 |
| 21 | | | 1.26 | 175 | 1692 | 170 | 1890 |
| 22 | | | 1.36 | 175 | 1572 | 170 | 1787 |
| 23 | | | 1.47 | 176 | 1435 | 171 | 1684 |
| 24 | | | 1.58 | 176 | 1306 | 171 | 1591 |
| 25 | | | 1.7 | 177 | 1176 | 172 | 1506 |
| 26 | | 8 | 1.93 | 178 | 1109 | 173 | 1399 |
| 27 | | | 2.02 | 178 | 1035 | 173 | 1308 |
| 28 | | | 2.11 | 179 | 967 | 174 | 1207 |
| 29 | | | 2.2 | 179 | 892 | 174 | 1115 |
| 30 | | | 2.29 | 180 | 819 | 175 | 1007 |
| 31 | | | 2.39 | 180 | 731 | 175 | 959 |
| 32 | | | 2.5 | 181 | 651 | 176 | 908 |
| 33 | | | 2.61 | 181 | 630 | 176 | 874 |
| 34 | | | 2.73 | 182 | 618 | 177 | 848 |
| 35 | | | 2.85 | 182 | 587 | 177 | 822 |