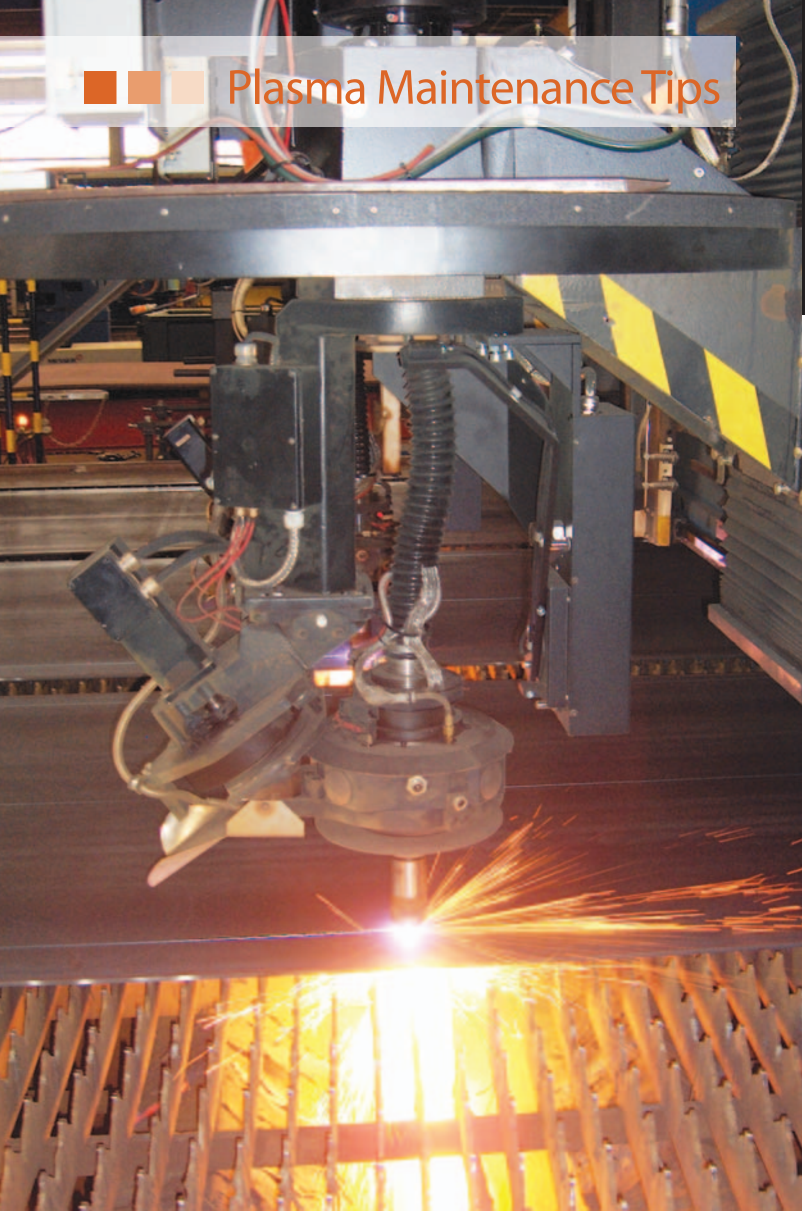

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Cleaner consumables, cleaner cuts, better production

Regular maintenance and effective troubleshooting lower operating costs

By Jim Colt

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For years mechanized plasma cutting has been a cost-effective way to cut carbon steel from thin-gauge to 1¼ in. thick. To maintain the highest performance, however, you must regularly inspect and maintain consumable parts in the torch body. This includes the electrode, swirl ring, nozzle, inner retaining cap, shield, and outer retaining cap (see **Figure 1**).

FIGURE 1 *All torch components should be regularly inspected, including (from left to right) the outer retaining cap, shield, inner retaining cap, nozzle, swirl ring, and electrode.*

The final word on maintenance, of course, should lie with the torch and plasma system manufacturer. Regardless, to know what to look for requires some basic knowledge about what each consumable component does, how each contributes to productivity, and how lack of preventive maintenance can hinder that productivity.

The Electrode

Features. Connected to the negative output from the power supply, the electrode powers the plasma arc. It also conducts high-voltage (also known as high-frequency) energy during the starting sequence. This energy ionizes the cutting gas, allowing the plasma arc to start (see **Figure 2**).

FIGURE 2 *The electrode powers the plasma arc and helps ionize the cutting gas, allowing the plasma arc to start.*

As the main contact point for the plasma arc, the electrode gets very hot. An oxygen electrode's end emitter, made of hafnium, can exceed 3,000 degrees F during operation. For this reason, most plasma cutting electrodes carrying more than 100 amps of cutting current are liquid-cooled, as opposed to gas-cooled electrodes in smaller mechanized and hand-held plasma systems.

The floating coolant tube, a key component of both the electrode and torch design, is loosely installed in the torch. When the electrode is installed, the coolant tube self-aligns to the electrode's internal features. Coolant enters the top of the tube at relatively high pressure and is forced through a tight fit around the hollow mill of the electrode. This squeeze increases the coolant velocity, which effectively causes the coolant to strip away the steam buildup around the hot hafnium, making heat removal efficient.

Troubleshooting and inspection. Ensure the electrode matches up with other consumable parts. Use only parts recommended by the manufacturer; any substitution may cause problems such as poor cut quality, slowed cutting speed, and shortened electrode life.

Gas delivery system leaks can also be an issue. Even a minor leak caused by a loose hose fitting or a split or kinked hose can reduce cut quality and consumable life. Changes to the predesigned gas pressures and flows will change the plasma arc characteristics. Every day check the inlet pressure for the plasma and shield gases, and ensure that compressed air (when supplied from a local compressor) is clean, dry, and free of oil.

Handle the electrode and other consumable parts with clean hands. When installed in the plasma torch, dirty or greasy electrodes can cause stray electrical tracking that eventually can lead to torch failure.

Also, do not overtighten the electrode. Having an O-ring seal, the electrode is installed properly when you feel the locating shoulder bottom in the torch. Excessive tightening can cause tolerance problems within the torch.

Inspect the end of the coolant tube for nicks and notches, especially if you had a catastrophic electrode failure. A damaged coolant tube produces uneven coolant flow and shortens electrode life. If the end is damaged, replace the tube.

To inspect electrode wear, look at the hafnium emitter at the tip. A new electrode has a dimple machined in the hafnium to force the arc attachment point to a dead-center position. A used electrode will have a small pit caused by evaporation of the hafnium during starting and steady-state cutting (see **Figure 3**). A new electrode wears rapidly for about the first and last 10 percent of its life. In the middle of its life cycle, the electrode wear is slow and predictable. Operations using longer cuts require fewer starts and so help extend electrode life.

Besides causing cut problems like dross and angularity, electrodes with pits between 0.045 and 0.050 in. can cause catastrophic failure that can damage the nozzle, shield, and possibly the coolant tube. Consult your plasma system supplier for recommended electrode changeouts. In general, though, a standard oxygen electrode should be changed when the pit depth, as compared with a new electrode, has reached around 0.040 in.

Measure the electrode's pit depth with a dial indicator. First, use a new electrode with the same part number as the partially used electrode you need to measure. (Electrodes with different part numbers appear very similar, but have a different overall length.) Position the pointed tip of the indicator in the center of the hafnium emitter's dimple. Then adjust the dial to 0. With the indicator zeroed to a new electrode, perform the same measurement with the partially used electrode (see **Figure 4**).

It is common to see black marks that start at the hex and swirl around the perimeter of the electrode body toward the hafnium emitter. These are usually caused by dirt left inside the torch during a consumable changeout. But if those marks become prominent, etched into the copper electrode body, it could indicate badly contaminated plasma gas.

The electrode's copper body should remain clean and shiny, even at the end of its life. Any signs of grayish heat discoloration could indicate a torch cooling issue. When inspecting a used electrode, carefully view the position of the hafnium pit. An off-center pit could indicate a gas flow problem that may be related to an incorrect or damaged swirl ring or incorrect gas flow settings.

Cutting machine operators generally learn to notice changes in cut quality in the workpiece or in sound from the plasma system. Many, of course, are under pressure to get the longest life out of their consumable parts to lower operating costs. In most cases, however, changing the electrode before it fails allows the nozzle and the shield to last longer, effectively lowering operating costs while maintaining high cut quality levels.

▲**FIGURE 3** *The electrode on the right has a pit 0.023 in. deeper than the new electrode on the left. The pit was caused by hafnium evaporation during starting and steady-state cutting.*

▲**FIGURE 4** *Use a dial indicator to measure pit depth of partially used electrodes.*

▲**FIGURE 5** *The nozzle's primary function is to constrict the plasma gas to increase energy density and velocity.*

The Nozzle

Features. Nozzle design hinges on the physics related to high-temperature gas flows, and fundamentally it has to last a reasonable amount of time under very high temperatures (see **Figure 5**). Its primary function is to constrict the plasma gas to increase energy density and velocity. The nozzle is also instrumental in the electrical process that ionizes the plasma gas before the actual cutting arc starts. Inside certain nozzles, the gas actually swirls around the electrode, creating a centrifugal effect that creates a cool layer of un-ionized gas between the arc and the copper nozzle. This, among other methods, is how a 25,000-degree-F energized arc can exit through a copper nozzle and not instantly melt the copper.

To optimize nozzle life, pierce the metal at the recommended height and with the pierce delay time specified by the manufacturer. The delay allows the pierce to go completely through the workpiece before machine motion starts and before the pierce gas settings change to cut settings. Never operate the current at higher settings than the nozzle is designed for, and always set gas flows at manufacturer-specified levels. Also, never fire the torch in air, which overheats the front of the nozzle orifice.

Often a nozzle will last longer than an electrode if the electrode is changed before it fails. Keeping close track of electrode life, and changing it before failure, can prolong nozzle life and dramatically lower consumable costs.

Troubleshooting and Inspection. As with the electrode, trying to match the nozzle with noncompatible consumable parts can cause significant problems. Use only consumable parts recommended by the manufacturer. Any substitutions can cause cut quality problems, shorten consumable life, and damage the torch.

Focus on the orifice shape on the outside and inside of the nozzle. On the outside, ensure that the orifice bore is perfectly round with no nicks. A new nozzle will have very sharp orifice edges, and after some wear these edges will start to round out, eventually affecting cutting quality. If necessary, use a jeweler's loupe or microscope to find the defects.

Equally important is the nozzle's inner bore. Look for a perfectly round orifice with no nicks or heavy arc marks. It is normal to have a white or grayish residue in the bore, along with some black or gray swirl marks. The white material, hafnium oxide, can be cleaned out with a pencil eraser. The black or gray swirls, usually no cause for concern, are carbon tracks created during arc starting, normally from some drops of coolant from the last consumable change. Do *not* scratch the inner bore of the nozzle with a sharp tool or attempt to clean the orifice with a tip cleaner; these will both affect performance.

Swirl Ring

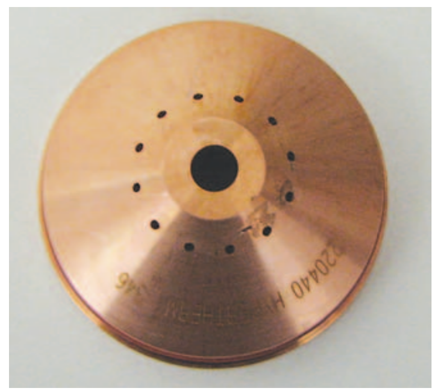
Features. The swirl ring, as the name implies, swirls the plasma gas flow around the electrode and nozzle. It controls the gas flow through the nozzle orifice in a way that improves cut-edge angularity, and it creates a centrifugal effect that slings heavier, un-ionized gas molecules to the edges of the nozzle orifice, increasing nozzle life. The ring also aligns the nozzle orifice with the electrode emitter and electrically insulates the negatively charged electrode from the positive nozzle.

The swirl ring can be made from several materials. Some companies manufacture swirl rings from composites or ceramics, designed to work in a pure oxygen atmosphere inside the torch body. Others use volcanic lava. Machined and baked for durability, the lava has excellent electrical insulating properties, and it can also endure high temperatures.

Troubleshooting and Inspection. Swirl rings are fairly fragile, so take care when inserting and removing them from the torch. Note that there is a different swirl ring for every process and power level, so make sure the swirl ring in use matches the application. Many rings look similar but their critical dimensions—including orifice size and angularity—differ. A subtle change can affect cut-edge angularity and smoothness, produce dross, and shorten consumable life.

Imperfections, such as cracks or dirt, can hinder gas flow and, hence, affect cut quality. Inspect all O-rings, especially the inner one, and look for cuts and flat spots. Carefully inspect all metering and swirl holes (see **Figure 6**) for foreign material. On the external O-ring, use a very small amount of O-ring lubricant—just enough to be shiny on your fingers. Do not lubricate the internal O-ring.

▲**FIGURE 6** *The swirl ring swirls the plasma gas flow around the electrode and nozzle, and it creates a centrifugal effect that slings heavier, un-ionized gas molecules to the edges of the nozzle orifice.*



▲**FIGURE 7** *The shield protects the nozzle from double-arcing from the workpiece.*

Swirl rings generally don't wear out if inspected and cleaned periodically. Careful use and clean hands will make them last longer. If properly maintained, a swirl ring should still operate after 50 electrode and nozzle changes.

Shield

The shield protects the nozzle from double-arcing from the workpiece during piercing or in the event of contact during steady-state cutting. It also helps cool the nozzle and control the cut-edge squareness. For optimal cut-edge angularity, the shield's main orifice must be perfectly centered to the nozzle's main orifice (see **Figure 7**).

Troubleshooting and Inspection. Problems most often arise when the machine pierces too close to the workpiece, so be sure to follow manufacturer specifications for pierce-height settings and delay times. Shields can also fail when the electrode itself is allowed to operate until catastrophic failure. When this occurs, the electrode, nozzle, shield,

▲ **FIGURE 8** *The inner cap holds the nozzle and swirl ring in place while directing coolant flow to the nozzle exterior.*

▲ **FIGURE 9** *The outer retaining cap holds the shield in place over the inner retaining cap and directs secondary gas flow to the shield.*

▲ **FIGURE 10** *Inspect and clean the torch body at least once per shift.*

and sometimes the coolant tube need to be replaced.

The shield's main orifice must be perfectly round with sharp edges. Bleed orifices—the small holes surrounding the main center orifice—must not be plugged.

Steel may become plated around the orifice. This indicates that the system pierced too close to the workpiece. Sometimes you can pick off the steel from the copper. If the orifice is still perfectly round, it can be reused; just be sure to inspect both the shield inside and outside. To minimize spatter, it's good practice to polish the front shield face with a Scotch-Brite® pad and apply a water-based welding antispatter spray.

Inner and Outer Retaining Cap

The inner caps hold the nozzle and swirl ring in place while directing coolant flow to the nozzle exterior. Its front composite piece is designed to mount the shield concentric to the nozzle orifice and route secondary gas to the shield. The outer retaining cap holds the shield in place over the inner retaining cap and directs secondary gas flow to the shield. This cap also has a contact tab that serves as an electrical contact to the plate, as used on some torch height control systems (see **Figure 8** and **9**).

Troubleshooting and Inspection. For the inner cap, inspect the composite ring for signs of burning or cracking, and look at the ring's holes for plugging. Ensure that the nozzle hole is round and has a smooth sealing surface for the front-nozzle O-ring. If the cap has bleed holes at the base, make sure they are not plugged. Inner caps must be kept very clean, especially the composite ring, where dirt or grease can cause carbon tracking and burning. If properly maintained, the cap should last for more than 100 electrode and nozzle changeouts.

For the outer cap, inspect the integrity of the area where the shield O-ring seals. The area should be perfectly round with no nicks or arc marks. Ensure that the threads are in good shape on the composite section, and inspect and/or replace the electrical contact tab if necessary. After use, clean the spatter off the front of the cap with a Scotch-Brite pad. Use a light coat of water-based welding antispatter spray on the face of the cap and the shield. If the spatter is periodically removed from the face, the outer cap should last for more than 100 electrode and nozzle changeouts.

Torch Main Body

The torch's main body holds the consumable parts and delivers coolant to the nozzle and electrode, then returns it to the heat exchanger unit in the power supply. It also directs preflow, plasma, and shield gases toward the consumables. It creates the path for the high-voltage start circuit for gas ionization and, of course, delivers the cutting current.

While the main body technically isn't a consumable, the life of this device hinges on how well it is maintained. The key is cleanliness. Dirt and grease on the inner parts can provide a path for stray electrical discharge, which can create a carbon trace path, eventually causing internal arcing and torch failure.

Troubleshooting and Inspection. Inspect and clean the torch body at least once per shift (see **Figure 10**). First, remove the cooling tube. Then clean all interior components with a clean cotton cloth. After this, blow it out with compressed air at low pressure. Inspect the cooling tube and, finally, reinsert it.

Make sure that the retaining cap threads are clean, and check the integrity of the inner cap sealing O-rings, which should be lightly coated with O-ring lubricant. Use caution: Too much lubricant can attract dirt to the composite insulation. Blow off threads and exterior parts with low-pressure compressed air.

Finally, clean the rear torch connections, check the integrity of the O-rings on the composite posts, and blow the assembly clean.

Better Maintenance, Better Cutting

Plasma cutting is one of the most efficient ways to cut sheet and heavy plate, but that efficiency can evaporate quickly without proper consumable maintenance. The tips mentioned here are guidelines; consult your plasma system supplier for specific maintenance schedules—and follow them. Because despite the lengthy discussion here, maintaining a torch assembly can, in reality, take only a few minutes a day.

And that, of course, is much better than hours or potentially days of lost time caused by a total torch failure. ■

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