WHITE PAPER

The Advantages of Dry Filtration for Plasma Cutting

The dust and fumes generated during plasma cutting can pose health risks to workers and cause damage to machinery and electronics if they are not properly captured. Two types of systems are used for plasma cutting: those that utilise water tables and those that use downdraft tables with dry media filtration. This white paper will discuss some of the safety and operational problems inherent in "wet" systems, the advantages of "dry" filtration, and how to arrive at an informed purchasing decision.

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The Advantages of Dry Filtration for Plasma Cutting

The plasma cutting processes used to cut mild steel, stainless steel and other metals generate fine particulate dust and fumes that can be harmful to workers, machinery and electronics if not properly controlled. The work tables used during plasma cutting fall into two general categories: wet and dry. Water tables fully or partially submerge the metal in water to contain the dust and fumes generated during cutting. Dry downdraft tables, by contrast, use an integrated high efficiency cartridge dust and fume collector and built-in ducts that convey contaminants to the collector where they are captured and removed.

Because water tables do not require a fume collector and ductwork, they typically offer the advantage of lower initial cost, making them the system of choice for many buyers. However, water tables can actually cost more over time due to increased maintenance requirements, operational issues and lower productivity. Even more important, employee health and safety may be compromised with wet systems. The intent of this white paper is to inform fabricators of the potential pitfalls to avoid when making a purchasing decision and summarise both the short- and long-term advantages of a dry table.

Top photo shows poor air quality during a dry plasma cutting operation, before filtration has been applied. Bottom photo shows the same shop after a high efficiency dust collector has been activated to capture smoke and fumes.

Worker Health Risks

Improved facility air quality is the number one advantage of a dry filtration system over a water table. It's true that a water table in which the part and the torch are completely underwater can effectively contain some harmful contaminants. In actual practice, however, the great majority of water tables include high precision cutting technologies in which the part sits inches above the water. In these instances, the water table might capture the majority of the dust and fumes – but a significant amount can escape into the work area.

By contrast, a dry table with a properly engineered dust collection system will continuously pull fumes down and away into the collector. Using long-life cartridge filters with high efficiency nano fiber media, dry collectors can achieve removal efficiencies as high as 99.9% on very tiny particles of 0.5 microns and larger by weight.

To understand why this level of filtration efficiency is so critical, it is necessary to review some of the health risks associated with plasma cutting fumes. Whether you are working with mild steel, stainless steel, aluminium, galvanised or another material, the Material Safety Data Sheet (MSDS) is a good starting point for identifying health risks. Most local health and safety authorities have established permissible exposure limits (PELs) based on 8-hour Time Weighted Average (TWA) for hundreds of dusts, including the numerous metal dusts generated in plasma cutting.

Example of a wet plasma cutting table designed to contain the majority of dust and fumes as parts are cut in the water.

The worst culprits are:

- **Hexavalent chromium** or hex chrome is a carcinogenic substance that results from cutting of stainless steel and other metals that contain chromium. Hex chrome overexposure can result in short-term upper respiratory symptoms, eye or skin irritations. Long-term, the greatest health danger associated with hex chrome exposure is lung cancer. Other major health effects include damage to the upper respiratory system, and allergic and irritant contact dermatitis. Respiratory tract problems can include inhalation damage to mucus membranes, perforation of septum tissue between the nostrils of the nose, and damage to the lungs. In addition, there may be injury to the eyes, skin, liver and kidneys. Once in the body, hex chrome typically targets some of the body's organs. A worker exposed to hex chrome may also experience symptoms such as sinus irritation, nosebleeds, stomach and nose ulcers, skin rash, chest tightness, wheezing and shortness of breath. A common PEL for hex chrome is extremely stringent, at 5.0 µg/m^3. When cutting stainless steel, HEPA filtration is required to stay below this threshold limit. As a result, cutting stainless steel on wet systems is often not recommended. If a water table must be used, some type of air filtering device (such as a capture hood with a HEPA filtration system) will be needed to capture any fumes that rise up from the table. But a hood limits the use of overhead lifting equipment and may not be possible to use.

- **Zinc oxide** is a pollutant generated by hot work on galvanised steel. Exposure can result in a condition known as "metal fume fever", a short-term illness in which severe flu-like symptoms occur after a break from work, such as after a weekend or during a vacation. Due to the delayed reaction, it is often confused with regular influenza and many cases go undiagnosed.

- **Manganese**, which is present in some steel alloys, can cause workers to feel exhausted, apathetic, weak or headachy. Chronic overexposure to fumes containing manganese leads to a condition known as "manganism", which is characterised by neurological and neurobehavioral health problems. Manganese discharges are now specifically regulated in most countries by the national health and safety authorities.

Example of a dry downdraft table: Contaminants are exhausted to an outdoor dry media dust collector that captures dust and fumes.

It is imperative to know and follow local exposure guidelines for these and other metals, particularly where workers are at risk for long-term health effects. But sometimes people simply get sick and miss work, experiencing headaches, upper respiratory symptoms or general discomfort even when a facility is in compliance with local health and safety regulations. When this happens, it may be necessary to set even lower exposure limits compared to the limits set by the local health and safety authorities.

A well-designed plasma downdraft table with a cartridge fume collector will properly filter hazardous contaminants, making indoor environments safer and healthier. Cartridge collectors will control respirable particulate at the point of generation, ensuring that it will not spread and be inhaled by workers in other areas of the plant.

Safety and Explosion Concerns

In addition to health problems from airborne fumes, water table plasma cutting systems carry other inherent safety risks:

Slip hazards: Water tables are prone to leakage, which can cause slip and fall hazards. Even if the table itself is watertight, routine handling of parts in and out of the table creates spillage, with the same results. For example, when a skeleton is pulled off after cutting, the underside of the metal will be wet and likely to drip onto the shop floor. Accumulated oil in the water ends up on the floor and does not evaporate.

Allergic skin reactions: If small metal parts fall between the slats and disappear into the dirty water, it will be necessary to reach in to fish them out. The worker risks exposure to resident bacteria and algae, which have been known to cause severe skin rashes. The water also contains chemicals that are used as stabilisers and anti-corrosion agents. These may cause adverse reactions as well. Additionally, in the case of smaller water tables, or large jobs with a lot of thick cutting, the water can reach temperatures that can scald or burn.

Plasma cutting on a water table creates a dirty, high-maintenance environment.

Hydrogen gas explosions: Aluminium and water can react to produce hydrogen gas which poses an extreme explosion hazard. When a machine is shut down between shifts, hydrogen pockets can form underneath the plate being cut and from waste in the water. When the plasma arc is reactivated, it can trigger an explosion powerful enough to dislodge the gantry from the rails. One mitigation technique to prevent hydrogen pockets from forming is to keep the water bubbling constantly with an aeration system. Still, due to the intrinsic danger, some manufacturers take a hard stand and state that aluminium should not be cut in water.

Explosive dusts: It is important to note that aluminium dust can itself be explosive, so even with a dry system it is important to take the proper steps to equip it with the right explosion protection. Whatever type of metal you are cutting, there are situations in which a combustible dust hazard may be present. The only way to know for sure is to test your dust for explosibility and document a dust hazard analysis for the plasma cutting operation.

If your dust is found to be an explosion hazard, there are very specific and limiting requirements for your dust and fume collection system. The end user needs to determine the hazards associated with the dust and which standards apply as per the EU directive 99/92/EC and related standards. A first preliminary investigation can be done using the GESTIS-EX database, where a reference might be found. This database contains a huge number of tests that have been performed over the years.

The directive requires any company operating with explosion risk to have an explosion protection plan and a zoning map. The zoning for dust explosions is supported by the standard EN 60079-10-2, where you can find relevant support. If you are unable to perform this risk assesment by yourself, it´s recommended to contact an appropriate and competent consultant.

The type of dust collector, explosion protection and duct isolation required for each application will vary, depending on dust parameters and installtion conditions. An engineer knowledgeable of the process should perform the assessment with support from the dust collector and protection suppliers.

Quality and Productivity Issues

Shop operators who have experience with both wet and dry tables report a number of differences between the technologies in regard to cutting quality and speed, consumable life and productivity.

To summarise these findings:

- Water decreases the accuracy of the cut by grounding the plasma arc. As a result, high-definition and small-hole plasma cutting are done above water, increasing fume exposure.
- Water may also compromise the cut edge quality by inducing ripples known as “striation”. Turbulence in water agitation will almost always affect bottom edge quality, perpendicularity of cut, and concentricity of holes.
- Excess dross is created if the space between the plate and the water is not held to exact specifications. If the dross is quenched too quickly by water, it hardens and sticks to the back of the part, making it very difficult to clean off and adding labor cost.
- The quenching effect of water on cut parts can affect the hardness of mild steel material. This can make it difficult to perform any additional machining operations. It can also cause product to be out of compliance with customer specifications – for example, in construction of bridges and other structures where strict tolerances must be maintained. If a part is completely submerged, it is true that the water actually reduces the heat-affected zone around the area being cut, but it will still be very hard to do any additional machining.
- Steam and moisture can clog the torch head, causing it to overheat.
- Part marking cannot be performed under water. It is necessary to raise the parts up for this operation, which will result in some fumes being released into the atmosphere.
- Cutting in a dry system is faster than cutting under water. Users estimate that a dry system will be 10-15 percent faster depending on whether the torch and metal are submerged or just above water.
- Plasma in a dry system maintains a clean column and can extend the life of consumable parts within the system. Dry systems are associated with better cut quality and a smoother cut edge.
- With dry systems, bevel cuts can be made to the edge of the plate without increasing table size. When beveling with water tables, however, the table size must be increased to allow for sidewall cutting head clearance. This must be considered when sizing a water table and will likely add to the initial cost.

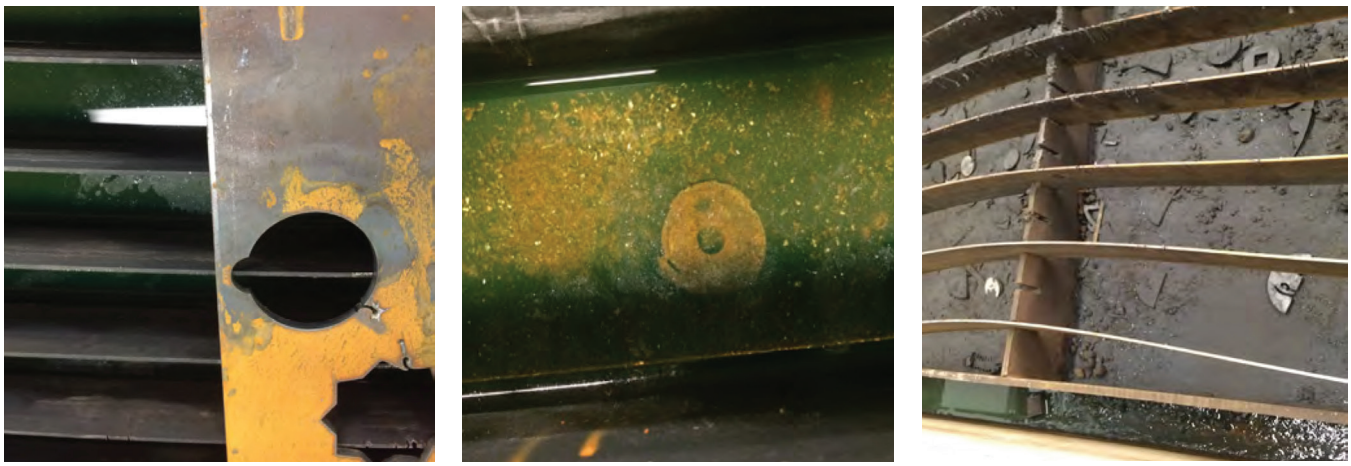
Maintenance and Operational Requirements of Water Tables vs. Dry Systems

Water Table Maintenance

There are a number of maintenance and operational issues associated with water tables, most of them related in some way to coping with water.

Chemicals: Chemical stabilisers must be added to keep the water as clean as possible, and rust inhibitors must be used to reduce corroding of parts. Even with these treatments, bacteria and algae may still form in the water, creating a sanitation issue and unpleasant odors; and the anti-corrosion agents will reduce but not eliminate rusting. As noted earlier, workers may also suffer ill effects when reaching into the dirty water to retrieve small parts.

Climate conditions: Some shops that do plasma cutting are not climate-controlled. In very warm environments, mosquitoes or other insects have been known to take up residence in water tables. In cold climates, water in the table or in a fill line or drain may freeze overnight or over a weekend. If freezing causes a component to rupture, it will create a maintenance headache and a major expense.



A few of the common problems with water tables are revealed in these close-up views: (Left:) Metal has rusted from the wet environment in dirty water with chemical treatment below; (Middle:) A small part coated in film has fallen into the water; (Right:) Sludge and small parts remain after a table is drained down.

Humidity: The standing water in the table and steam generated during cutting will add humidity to the factory environment. Steam and moisture can clog the torch head and cause it to overheat, resulting in unwanted downtime. If the humidity level becomes too high, it can impact the reliability of other equipment in the area and further increase maintenance costs.

Cleaning: The water table must be drained periodically for cleaning. The heavy metal sludge in the tank makes for a difficult maintenance challenge: It can take as much as 10 - 20 hours to clean an average size water table. The frequency of this task will vary greatly with the level of cutting – i.e., intermittent cutting vs. a shop cutting three shifts a day.

Disposal: Water must be added regularly to compensate for evaporation, and dirty/oily water must be disposed of properly. When cutting stainless steel, the water will contain hex chrome and is considered a hazardous waste. Wet sludge in the bottom of the table must be cleaned out periodically and is also a hazardous waste. Disposal requirements vary geographically: To find out more information, start with your contracted trash/recycling hauler and the local government agency that oversees hazardous waste. Most recyclers will not take wet material. The metal dust may have to be dry. Some shops will lay it out to dry, while others will purchase a drying oven, adding equipment and energy cost as well as processing time. Either way, this extra step of handling potentially hazardous dust adds cost and headache.

Corrosion: Corrosion is another problem related to the presence of water. As noted, rust-inhibiting additives in the water will reduce but not eliminate this problem. Mild steel components – including the gantry, rails and gear rack – are subject to rusting and premature failure. Manufacturers of wet tables recommend wiping these components dry every day to reduce rusting. Corrosion of mild steel parts processed on a wet table is accelerated. When the table itself eventually rusts and cannot be moved in one piece without falling apart, it is no longer salvageable.

Dry System Maintenance

By comparison, a dry system incorporating a downdraft table and cartridge dust/fume collector can be properly designed and engineered to keep maintenance to a minimum reducing downtime for greater productivity and lower cost per part.

This dry plasma cutting table is served by an adjacent cartridge dust and fume collector to maintain air cleanliness.

Sizing recommendations: Three of the most important factors in collector sizing are the expected amount of smoke/fume particulate being collected, the size of the downdraft table and the material being cut.

Several factors affect the amount of particulate being collected, referred to as the "loading". First is the amperage of the plasma cutter itself. A 400-amp plasma torch will cut much faster and have much higher particulate loading than a 130-amp torch. Some tables may have multiple heads operating at the same time, which will cause more particulate to be generated than a single-head system. Second is the size of the downdraft table. This affects the volume of air needed to create the appropriate capture velocity at the face of the table. Third is that different materials produce varying amounts of particulate. For instance, galvanised metals are known to produce higher levels of particulate.

An air filtration specialist can calculate the right size collector for your application and the best filter media for the job. Extended life flame retardant filters with open-pleat nano fiber media are recommended for these applications.

Cartridge mounting configuration can have a major impact on filter performance and service life. Some fume collectors are designed with horizontally-mounted cartridges that can allow dust to become embedded on the top of the filters. This condition can shorten filter life and provide a dusty surface for sparks to ignite. Vertical mounting, by contrast, reduces the load on the filters and helps improve service life while reducing fire and explosion risks.

Filter service: Cartridge collectors use automatic cleaning systems that allow units to run for extended periods of time between filter change-outs. The only operator inputs are occasional changing of the pulse-cleaning on-demand pressure settings as the filters wear, and eventual replacement of filters when they have reached the end of their life. Collected dust must also be cleaned out periodically from the storage drum.

These are important but easy tasks compared to the maintenance and disposal issues encountered with dirty water and wet sludgy dusts. The resulting differences in cost can be dramatic.

To cite an actual example from field experience: A marine manufacturer found that their plasma cutting systems were producing excess smoke which the existing water table could not properly contain. Disposal of the water and sludge, which were classified as hazardous waste, was another ongoing problem. By replacing the water table with a downdraft system and high efficiency dust collector with vertically-mounted filters, the company was able to recoup its investment in about 18 months by eliminating the previous maintenance and disposal costs. They also achieved a significant and immediate improvement in air quality, safeguarding the health of employees.

In conclusion, when choosing between a water table and a dry filtration system for plasma cutting, it is short-sighted to base the decision on a first-cost comparison. When you introduce health risks, safety and explosion concerns, product quality, productivity, maintenance and operating expenses into the equation, the cost and performance benefits of dry filtration systems over time will far outweigh any initial price disadvantage.

References

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- https://osha.europa.eu/en/themes/dangerous-substances/practical-tools-dangerous-substances/chromium-vi
- Local work environment authorities
- Directive 2019/1831 - indicative occupational exposure limit values
- GESTIS substance database: www.dguv.de/ifa/gestis-database

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