

Understanding and Controlling Thermal Cutting Fumes

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Fabricators have invested heavily in automated cutting solutions over the past decade as manufacturers have been driven to improve product quality, increase throughput, and provide flexibility to satisfy market demands. Many companies have invested in CNC metal-cutting equipment, including thermal cutting tables, to fulfill these needs. As the technology development and cutting speeds of these machines have increased, so has the need for effective air pollution control systems capable of capturing the associated smoke and fumes. This article focuses on the key elements of providing an effective and safe fume extraction system for today's thermal cutting machines.

Thermal cutting of metals is an industry that has been around for decades, but it has experienced a significant expansion as technology advancements and industry requirements have pushed companies to operate faster and more economically. Several common types of thermal cutting processes exist, including oxy-fuel, plasma, and laser, with most modern machines utilizing plasma or laser technology. Market conditions and customer demand have driven increased throughput from the industry, while innovations and equipment improvements have added capabilities, improved reliability, and expanded the types of materials that can be thermally cut. These changes have increased performance expectations and spurred the challenge to design a successful fume control system.

Process Description

Designing the appropriate air pollution control solution begins with a thorough review of the process. The three primary processes used in thermal cutting are oxy-fuel (oxyacetylene), plasma, and laser cutting. Oxy-fuel cutting is the oldest, and perhaps most common, technology deployed in metal cutting, but it is gradually being replaced by plasma and laser technologies, which offer increased performance capabilities.

Plasma cutting utilizes a high-velocity plasma gas jet formed by an arc and inert gas flow to create extremely high temperatures (up to 50,000°F), which melts the targeted material. The gas jet also forces the molten metal through the backside of the material being cut. Laser cutting utilizes a high intensity light beam to melt or vaporize materials and may incorporate a gas jet, which blows away the molten material. (See Figure 1)

Figure 1

An example of the laser metal-cutting process. Laser and plasma technologies offer increased performance capabilities but still generate fumes.

Fume is generated at the point of cut, as well as by the molten metal slag resulting from the cut. In some cases, a three- to six-inch water basin sits directly below the cutting process to capture and immediately quench the molten material and reduce the generated smoke and resulting fume.

Fume Characteristics

Fume generation rates from thermal metal cutting vary with the process parameters, such as cut rates, total cutting time, and material thickness. The fume consists primarily of metal oxides resulting from the base metal being cut. Additionally, the cutting consumables, surface coatings, and any other contaminants present within the atmosphere also will be part of the fume make-up. Many of these contaminants are hazardous and have permissible exposure limits (PEL) set by the Occupational Safety & Health Administration (OSHA)[1]. Fumes generated while cutting materials such as stainless steel, galvanized steel, aluminum, or metals with high manganese content are particularly hazardous. (See Figure 2)

Thermally generated fumes have a broad particle size distribution, but a large portion are submicron (less than 1 μm), with as many as 60 percent being less than 0.4 μm. Particulate within this size range is highly respirable for humans and poses a significant risk to the health of those exposed. The small particle size distribution also makes these fumes particularly challenging to effectively collect.

Fume generation rates can be reduced by cleaning any oil, dust, or dirt from the base metal prior to cutting. Oils present on the surface prior to cutting will be atomized, creating hydrocarbons that will inhibit the performance of the dust collector, resulting in additional equipment and operational costs. Cutting coated metals that have been galvanized, lead-plated, or cadmium-plated also will result in higher toxic fume generation rates.

Figure 2

Common Thermal Cutting Contaminants with Associated OSHA Permissible Exposure Limits (PELs).

Common Contaminants of Thermal Cutting	OSHA PEL Time Weighted Average (mg/ m^3)
Aluminum Oxide	10
Iron Oxide	5
Chromium (III)	0.1
Copper (fume)	0.2
Magnesium Oxide Fume	10
Manganese	0.2
Nickel (elemental)	1.5
Silica (fume)	2

Capturing the Fume

Capturing thermally generated fumes at their source is the best way to control and collect them. This, however, can prove challenging because of cross drafts or other factory air currents, the fume's thermal rise resuling from high cutting temperatures, or the varying design of cutting tables. On some units, the cutter is stationary and the metal moves, while on others, the cutter is mobile and the material is stationary. The size of the base material, as well as the speed at which it or the cutter moves, further complicates source capture. All of these factors make source capture an impractical solution for cutting tables in most applications.

Since the gas jet used in both plasma and laser cutting pushes the slag and much of the generated fumes to the backside of the material being cut, enclosing the volume immediately below the material is essential to controlling and capturing these fumes. Once this volume is enclosed, extraction point(s) are positioned — as necessary and where possible — along the longest side of the table.

Calculating the required air volume to capture fumes for a particular table requires knowing the typical amount of open area of the working surface and the target velocity. In many cases, the sheet size will be less than the working surface, which leaves space for the fume to escape. Overcoming this requires an average velocity of 150–200 feet per minute across the typical open area. A general rule is to assume that 50 percent of the material could be open at one time.

Both plasma and laser cutting result in very high temperatures, which can make the extracted air volume excessively hot. This heat can be a safety threat and require use of synthetic filter media, such as spunbond polyester or Nomex®, in the dust collection equipment. A more economical solution for dealing with high-temperature airstreams is using ambient air to dilute the hot air being drawn from the cutting table. Mixing the air to maintain an airstream temperature below 180°F will avoid any potential problems.

Identifying the Proper Dust Collection Equipment and Filter Media

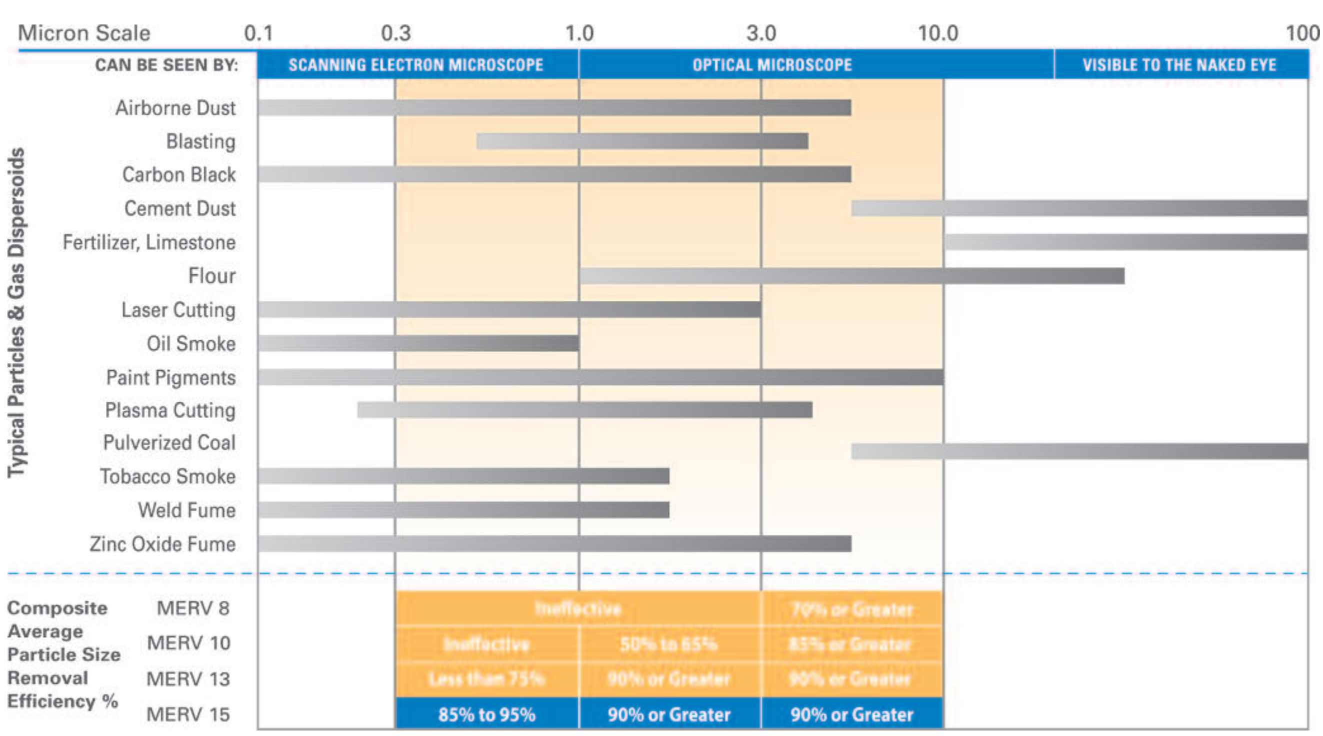
Dust collection systems utilized to capture fumes generated from thermal cutting must be capable of effectively collecting submicronic particulate (less than 1 μm), so filter media must perform accordingly. ASHRAE Minimum Efficiency Reporting Values (MERV) can be used to determine filter efficiency and capability of collecting particulate within a given size range. Figure 3 shows the particle size range of a variety of common contaminants, including plasma and laser cutting fumes, as well as the average removal efficiency for particle size ranges, which are used to establish the MERV rating. As indicated in the chart, achieving the higher efficiency necessary for effective removal of plasma and laser cutting particulate requires a filter with a higher MERV rating.

Selecting filter media with surface loading characteristics also is important for thermal applications. Small particulate has a tendency to lodge itself within the pores of a filter with thicker and less efficient depth loading media, which can block the flow of air, causing pressure drop and an increase in energy required to maintain airflow. Surface loading technology, such as nanofiber (Figure 4), provides a fine fiber barrier on the surface of a filter media substrate to collect the particulate and limit it from lodging itself within the substrate. Using nanofiber filters with this surface loading capability not only lowers the operational pressure drop and increases the dust-holding capacity, doing so also increases the effectiveness of the reverse jet pulse cleaning system incorporated on most dust collection systems. The combination of high efficiency and surface loading should result in longer lasting filters, lower operational emissions, and reduced energy consumption, leading to lower operating costs.

Sizing the dust collector appropriately needs to be done according to the total airflow requirement based on hood design and any other sources of air, e.g., bleed-in. The target filtration velocity, or the ratio of airflow volume to filter area for thermal cutting applications, ranges between one and three feet per minute. Process factors, such as base materials, cutting rates, loading conditions, and duty cycle, also will impact the final selection. Using dust collection

Figure 3

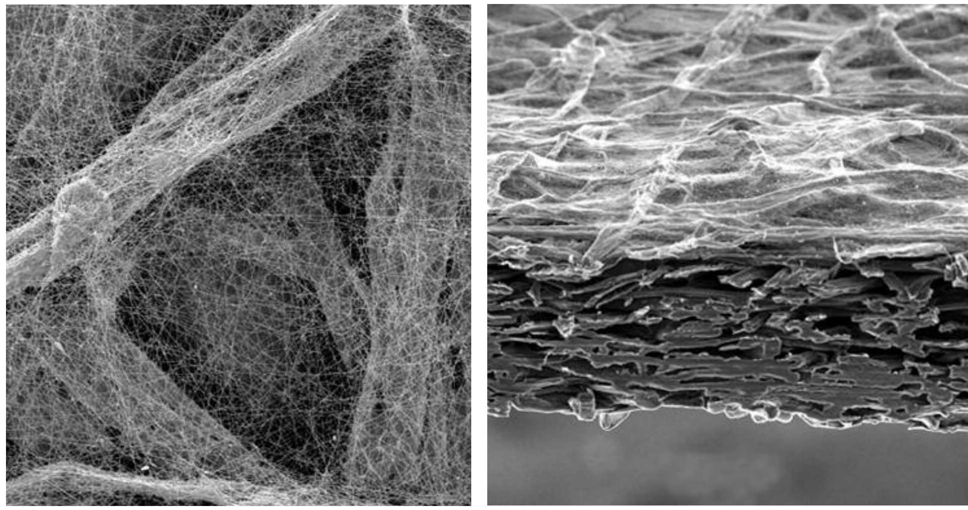
Filter Efficiency Ratings for Capture of Common Contaminants



systems in thermal metal-cutting processes has some inherent safety risks, which need to be addressed by the systems' design and configuration. Perhaps the greatest of these risks is fire. Since flammable dust is being collected in the presence of both sparks and molten metal generated from the cutting process, all the ingredients necessary for combustion — oxygen, fuel, ignition source — are present.

Figure 4

An example of ProTura® proprietary nanofiber surface loading technology at 600x magnification.



Proper ducting system design provides an important first safety step by allowing adequate transport velocity for the captured particulate. This ensures that the velocity is not too high to also transfer molten metal or large sparks and prevents dust from falling out of the airstream, collecting in the duct, and being more exposed to sparks. Incorporating spark arrestors, which are designed to separate or extinguish sparks before they enter the dust collector, also can help. Most spark arrestors utilize the momentum of the spark's mass to separate it from the airstream. Some of the more common examples are drop out boxes, centrifugal separators, cyclones, and quenchers. Spark detection and extinguishing systems, which inject an extinguishing agent into the duct system, are other options.

Certain precautions can help minimize the damage associated with a dust collector fire. Units can be equipped with sprinklers or extinguishing systems. Consult a fire expert to ensure that the extinguishing agent matches the dust being collected. Dust collectors also can be fitted with filters that feature fire retardant filter media. While this media will not prevent a fire, it is designed to deter combustion by slowing the spread of a fire if one occurs.

Besides posing a combustion risk, fumes and dusts produced during thermal cutting may present an explosion risk, as well. Whether a risk exists, or how severe it may be, depends on the base material and the application characteristics. National Fire Protection Association (NFPA) regulations provide guidance on how to safely design and maintain dust collection systems when explosion potential exists. The initial step is to analyze the collected material and determine if explosion protection is required or not. If so, the best practice is to install the dust collector outdoors, minimizing risks associated with an explosion. The unit should be equipped with a rupture panel or chemical suppression system. Also, inlet and outlet ducts should be isolated as necessary to reduce the risk of propagation and secondary explosions.

Summary

To efficiently collect fumes generated from thermal metal-cutting equipment requires optimum performance from the equipment's air pollution control system. Evaluating that system to ensure safe and proper capture, conveyance, and collection of particulate will lead to optimal performance of the dust collection equipment and a safer environment for workers. Consult a dust collection expert to review and understand the requirements of these systems and to prescribe a safe, efficient, successful solution. **APC**

References

1. www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9992

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