WHITE PAPER

The Basics of Laser Fume Extraction

Airborne dust and fumes generated during laser cutting processes can harm both workers and equipment if they are not properly controlled. Today's laser cutting machinery is typically designed to allow "plug and play" installation of fume collection equipment. Selecting the right collection system, however, is a multi-faceted decision. This white paper will help facilitate the decisionmaking process by examining five key areas of concern: health risks, fire and explosion hazards, equipment design considerations, maintenance and operational factors, and the benefits of air recirculation downstream of the fume collector.

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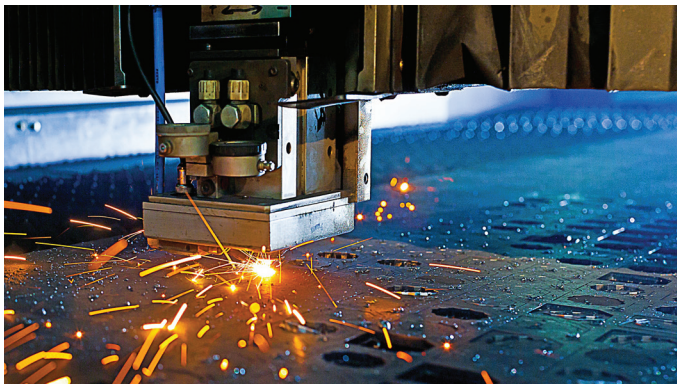
The Basics of Laser Fume Extraction

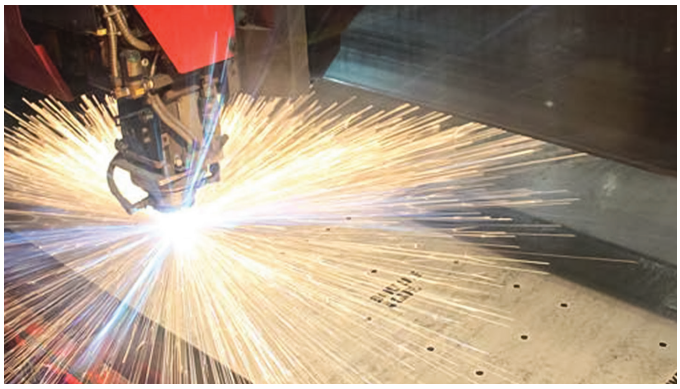
The airborne “smoke” generated during the laser cutting process is actually a fume cloud comprised of very fine dust particles of less than 1 µm that can be absorbed into the lungs and can harm workers’ health. They can also infiltrate machinery and electronics, causing other costly problems. These particulate contaminants can be properly controlled through high efficiency dust and fume collection systems.

Fortunately, today’s laser cutting machinery is typically designed to allow “plug and play” installation of fume collection equipment. A good fume collector should be as reliable as the lighting in your facility: You should be able to turn it on and not have to think about it, allowing you to concentrate instead on people, processes and production schedules.

Selecting the right fume collection equipment is an important and multi-faceted decision. This white paper examines five key areas of concern.



Sheet metal part fabrication on a laser table.



A Camfil APC promotional part is produced on a 4 KW laser table.

1. Health Risks

A wide range of health risks have been associated with laser cutting fumes, and the nature and severity of the hazard will vary with the type of material being cut. Whether you are working with mild steel, aluminium, galvanised or another material, the Material Safety Data Sheet (MSDS) is a good starting point for identifying health risks.

OSHA (www.osha.org) has established permissible exposure limits (PELs) based on 8-hour time weighted average (TWA) for hundreds of dusts, including the numerous metal dusts generated in laser cutting. Among 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.

  A worker exposed to hex chrome may experience symptoms such as sinus irritation, nosebleeds, stomach and nose ulcers, skin rash, chest tightness, wheezing and shortness of breath. The current OSHA PEL for hex chrome is extremely stringent, at 5.0 µg/ m^3.

- **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.
- **Metal dust particles** generated during cutting are an eye irritant and can be a leading cause of eye injuries in factories.

It is imperative to know and follow OSHA exposure guidelines for these and other metals, particularly where workers are at risk for long-term health effects. But sometimes workers will experience headaches, upper respiratory symptoms or general discomfort even when a facility is in compliance with OSHA. When this happens, it may be necessary to set even lower exposure limits to eliminate employee complaints. A well-designed cartridge fume collector will properly filter hazardous contaminants to make indoor environments safer and more healthful.

Eight-cartridge dust collector captures laser cutting fumes from an automated tube cutting application.

Cartridge collectors are the best control for respirable particulate at the point of generation, ensuring that it will not spread and be inhaled by workers in other areas of the plant. These collectors use automatic cleaning systems that allow units to run for extended periods of time between filter change-outs.

2. Fire and Explosion Hazards

Fire prevention is a big issue with lasers due to the nature of the raw material and the use of potentially flammable oil for corrosion protection of this material. Also, un-oxidised metals and their fumes can be combustible and potentially explosive. Prevention measures for a dust and fume collector should, at a minimum, include fire detection with an interlock that shuts down the fan, a sprinkler system to extinguish a fire, a spark arrestor on the ducting to the collector, and flame-retardant filter media.

The fan interlock and sprinkler system will protect the collector from fire damage and the factory from smoke damage. The spark arrestor and flame-retardant filters will reduce but not eliminate the risk of a fire. It is important to note that no spark arrestor is a 100 percent guarantee that a spark will not get into the collector, and flame-retardant media will still burn if the dust on it is combustible. Do not rely on spark arrestors and flame-retardant media as your only fire controls on processes that handle sparks and that produce combustible dusts. If your dust is determined to be explosible, more sophisticated fire protection and explosion preventions systems may be required.

Much of the dust generated in laser cutting is inert and therefore does not pose an explosion risk. However, 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.

A **dust hazard analysis** will also be needed to identify the full range of combustible dust deflagration, fire and explosion hazards specific to the application. You need to determine the hazards associated with your dust and which standards apply.

To establish if the dust is explosive or flammable its recommended to do a dust hazard analysis. It's the users responsibility to analyse their processes and materials and ensure that they work safely. If the dust is shown to be explosive there is a requirement for the company to create an explosion protection plan and a zoning document. The starting point for this is the ATEX User Directive 99/92/EC and underlying EN standards. The explosion protection plan needs to form a basis of a safe working place from this aspect. This means that any equipment used in a zoned area needs to comply to the needed safety category. Also training and routines for the operators shall be covered by the plan. And the plant will be required to not just make the plan once, it shall be a living document continuously updated when needed. Also equipment needs to be maintained and inspected to prove continued compliance during use. For example Camfil offers an annual safety inspection of all safety related equipment.

Compact dust collector QS2 from the Quantum Series, specifically designed for extraction of single laser tables. Units available in three different sizes with air volumes from 1,500 up to 5,500 m³/h.

The type of dust collector, explosion protection and duct isolation required for each application will vary, and a dust hazard analysis should be conducted to determine system requirements. An engineer knowledgeable of the process should perform the assessment with support from the dust collector and protection control suppliers.

3. Design Considerations

Proper design of any fume collection system involves what is sometimes known as the "three Cs" – **capture**, **convey** and **collect**. The system should be designed to capture dust at the source, convey the dust through ducting, and collect it safely to the hopper or storage drum.

Correct sizing is a critical step. Sometimes a fume collector will be undersized in an attempt to minimise capital investment. This is a common mistake that often increases the hazards associated with combustible dusts. If airflow and suction are compromised with an undersized collector, combustible dust can build up in the ducting. If sparks are present, they will skip from dust pile to dust pile in the duct to the collector, causing a fire. If the dust is explosible, the hazard could result in a flame front from a deflagration in the dust collector traveling back through the ducting to the process equipment. An undersized dust collector will not perform as expected and may contribute to unforeseen hazards.

Sizing is dependent on several factors: the laser wattage (power) being used; the size of the laser table and whether the open area is in one section or broken into zones; the thickness and type of material being cut; speed of cutting, and hours of operation – including whether it is a "lights-out" programmable system designed to run at night. An air filtration specialist can help calculate the right size collector for your application.

Linear scales: As the gantry of a laser moves along the rails, it takes positional readings from linear scales. Typically, these scales are covered with adjustable accordion-like bellows. If dust isn't properly controlled, it can penetrate beneath the bellows and settle onto the scales, preventing the gantry from taking accurate readings. The result is unwanted downtime for operators to disassemble the bellows and clean the scales. Fume collection equipment must be properly designed to pull out the dust before it can work its way beneath the bellows.

CO_2 vs. fiber laser cutting: With CO_2 laser cutting, the lasers typically have an open top. But as the industry moves toward fiber lasers, the fully enclosed tops utilised with this technology are becoming more prevalent. The enclosed top potentially affects the air and smoke turbulence in the enclosure and the ability to capture fumes and dust. The fiber laser dust itself is different as well as the enclosure. Make sure your dust collection supplier has experience in the new technology and in the design modifications required to deal with those changes.

A Farr Gold Series® 20-cartridge collector captures fumes from three automated flat laser cutting machines.

Proper noise control must be designed into the system whenever the collector is located inside. Fan exhaust from fume collection systems can be very noisy, creating a fatiguing and hazardous environment. An exhaust silencer will reduce the noise level and can often be customised to meet varying needs.

Filter media: Laser cutting produces dust with low bulk densities and small particle sizes (i.e., below 1 µm). To effectively filter this dust, long-life nano fiber filters with flame-retardant properties are recommended. When a layer of nano fibers is applied on top of the base filter media, the nano coating promotes surface loading of fine dust, preventing the dust from penetrating deeply into the base media. This translates into better dust release during cleaning cycles and lower pressure drop readings through the life of the filter for longer service life, better energy performance and greater resistance to wear and tear.

Design function: Also, make sure the collector is being used for its designed function. Sometimes a shop will purchase a laser table to cut mild steel and then use it to cut other metals that might have different explosive or biological hazards – or even to cut wood or acrylic, which could create a fire risk or plug the filters because the fume collection system is not designed to handle those materials.

Flame-retardant filter media should always be used in fume removal equipment for laser cutting applications.

4. Maintenance and Operational Factors

A well-designed and properly sized fume collector is engineered to keep maintenance to a minimum. The only operator inputs should be occasional changing of the pulse-cleaning on-demand pressure settings as the filters wear, and eventual replacement of filters when differential pressure through the system reaches the maximum level specified by the filter manufacturer. This is very important to ensure that filters are effectively controlling dust and fumes.

Collector location: As noted earlier, most lasers have plug and play dust collection solutions to facilitate cost-efficient startup. These collectors are typically located indoors. When the collector is designed to be operated and maintained "from the face", i.e., from one surface, it can be more readily tucked into a tight corner or between columns to solve space constraints. Another solution is a structural mezzanine that bridges over the laser table. The mezzanine can hold the fume collector, laser resonator and chiller, opening up floor space and consolidating all the laser support on one clean, safe, serviceable platform. In addition to easy access, the operator should also be able to change filters quickly with no need for tools.

Though indoor collectors offer lower initial cost and easier startup, you might want to weigh the advantages of locating the collector outdoors. A high quality collector will incorporate features such as Totally Enclosed Fan Cooled (TEFC) motors and heavy-duty powder coated paint, allowing outside operation even in cold, severe environments. Though an outdoor collector will be costlier to construct, it saves on factory space and reduces noise levels, providing an excellent long-term solution.

Filter "seasoning": A fume collector fan is typically designed to provide the manufacturer's recommended airflow when a filter is dirty or at the end of its life. When filters are clean, the initial startup pressure will be very low and the airflow will be higher than desired. The airflow should be restricted with a damper at startup to a minimum volume of air needed to capture the smoke. If the damper is left wide open, the fan will pull more than the design airflow. This wastes energy and may cause filters to plug prematurely. This problem can be avoided by adjusting the fan damper to reduce the airflow when filters are new or by using a VFD that manages the flow automatically.

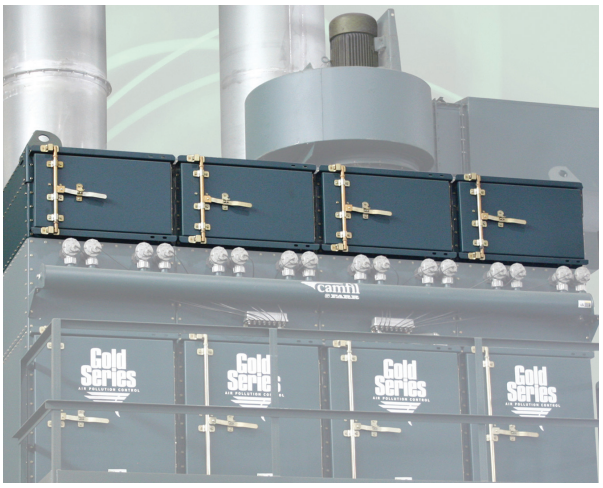
Dust removal: Cleaning out collected dust is a simple but sometimes overlooked maintenance task. If dust accumulates over the top of the storage drum, it can back up into the hopper and cause a collector malfunction. Alternately, the overflowing dust can fall out on the floor when the drum is moved, creating an unsafe mess and a possible fire hazard.

Monitoring: Remote monitoring of critical information is recommended. Many laser suppliers have central diagnostic centers where they can pull up and diagnose problems for customers. Monitoring of the fume collection equipment can be tied into this function or handled independently through new web-based diagnostic systems. These systems can electronically monitor an entire network of fume collectors and provide automatic alarming of fault conditions as soon as they occur – enabling you to stay connected to vital information whether you are in or out of the shop.

5. Air Recirculation Downstream of the Fume Collector

Air recirculation is the single best way to save energy and maximise return on investment with a fume collector. By recirculating heated or cooled air back through the building, it reduces the need for costly make-up air that's required when you vent the air outdoors after it passes through the collector. Facilities in all regions report five- to six-figure annual energy savings, with the greatest savings seen in northern climates which experience longer, colder winters.

Its important to know you local regulations for recirculation as its not allowed in all countries, if its prohibited its possible to use a heat exchanger to recover heat.



This space-saving after-filter module is integrated on top of the fume collector. It provides backup protection in a recirculating fume collection system.

When recirculating air downstream of the collector, a HEPA after-filter module is recommended and, if you're filtering hex chrome, galvanised steel or other hazardous dusts, it may be required.

In summary, a high efficiency dust and fume collector can greatly reduce or nearly eliminate employee exposure to airborne contaminants generated during laser cutting, resulting in a cleaner and greener work environment that improves comfort and morale, boosts productivity and enhances manufacturing reliability. A properly designed system will also reduce fire and combustible dust hazards. When you add air recirculation to the equation, you achieve the trifecta of compliance, health/safety and energy savings.

References

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- https://osha.europa.eu/en/themes/dangerous-substances/practical-tools-dangerous-substances/chromium-vi
- Local work environment authorities
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- GESTIS substance database: www.dguv.de/ifa/gestis-database

About the Author

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Ulf Persson is the Product Manager for dust, fume and mist extraction solutions in the EMEA region. He has more than 30 years' experience in air filtration and industrial dust collection and joined Camfil 15 years ago. In his role Ulf is developing application-specific extraction solutions, consults customers in determining the right dust collection equipment but also works as safety & containment expert.

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