排风柜的实验安全防护效率

Erlab China GM Dominique Laloux☆

摘要 实验员在实验过程中吸入的化学气体将导致健康危害。排风柜作为实验室基础防护设备,远比想象的复杂。主要帮助实验员了解传统外排式排风柜和无风管自净型排风柜在安全防护方面应达到的标准。

关键词 外排式排风柜 安全标准 无风管自净型排风柜

How safe are chemical fume hoods for the chemists?

By Dominique Laloux★

Abstract The long term danger of inhaling chemicals in a chemistry laboratory is widely undermined, and the safety of fume hoods, supposed to protect against the inhalation of chemicals is much more complex than users think. Intends to help chemists understanding what safety level they should expect from a ducted fume hood and from ductless filtering fume hoods recirculating air into the laboratory room.

Keywords ducted fume hood, safety level, ductless filtering fume hood

★ Erlab China GM, Kunshan, Jiangsu Province, China

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Understanding the safety of fume hoods is not an easy task. But this is a critical issue, since this is the health of the chemists who are at stake and unfortunately most of them don't receive the right information from manufacturers and health officers.

Basically chemists think that fume hoods are safe when they deal with chemicals inside. They see the fume hood as a simple vented box with a vertical movable sash, where chemical vapors generated by the experiments are simply exhausted to outside and totally removed from them.

But is that so simple?

There are actually three essential questions to consider when working with a fume hood, which are:

Which level of safety should I obtain?

How a fume hood works?

How fume hoods can provide the required safety level?

1 Which level of safety should I obtain?

Fortunately, but little known, there are official concentration values of chemicals that a chemist should not exceed to inhale. They are called PEV (permissible exposure values) in UK, TWA (time weight average) or TLV (threshold limit values) in USA, TWA (time weight average) in China. For a specific chemical the TWA expresses the concentration that a chemist (or in general a worker) shouldn't exceed to inhale 8 hours per day, during a working life. The TWA values are determined by medical experts who study the long term influence of chemicals on the workers who are regularly exposed to those chemicals. When regularly inhaling more than the TWA values, those workers may suffer over the years very serious illnesses, such as cancers, pulmonary edema. The TWAs are specific to each chemical and may be reviewed by the Safety Authorities over the time if the medical research shows that they are more dangerous than expected. To take an example, acetone has a TWA of 300 mg/m^3 when nitric acid has a TWA of only 5 mg/m^3. Basically nitric acid is 60 times more dangerous than acetone! The lower the TWA, the more dangerous the chemical!

Every chemist should know the TWAs of the chemicals that they handled. It is the best way to make them aware on the long term danger of

①☆ Dominique Laloux,总经理,欧洲实验室设备委员会技术委员会 CEN/TC 332 实验室排风柜 WG4 工作组专家成员
E-mail:dlaloux@erlab.com.cn
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chemicals and create essential security reflexes. An old study made by the OSHA (Occupational Safety & Health Administration, 29 CFR Part 1910) in USA in 1990 has shown that the life expectancy of a chemist would be at least 10 years shorter than average. Since a wide variety of chemicals are manipulated in the lab, chemists should manage to inhale concentrations of chemicals much below the TWAs, since the accumulation of the TWAs of various chemicals might be even more dangerous. Today's researches show that mix of chemicals can be even more dangerous than each chemical individually. This is called the "cocktail" effect. For those reasons it is recommended actually that chemists manage not to inhale more than 1% of the TWAs of chemicals.

Another factor shall be considered when working with chemicals. It is important to make the difference between molecules (chemical gas) and visible particles (powders). A chemical molecule is extremely small, in the range of less than 1 Angstrom (or less than 10^{-10} meters), when visible particles are in the range of 50 to 400 Angstrom. In gaseous form, chemical molecules move extremely fast. In a fraction of a second, gaseous molecules of chemicals evaporated from an experiment will disperse far away from their source, unlike visible particles, such as chemical powders which travel comparatively much slower. Therefore it is essential that liquid chemicals shall be manipulated in an enclosure, capable to stop the fast moving molecules and avoid them to spread in the lab room. It should be clearly mentioned here that the use of canopy hoods, not equipped with enclosures, are definitely not appropriate for the handling of chemicals in liquid form, since a large portion of the chemical emission will disperse in the room. Those canopy hoods, although very popular because cheap to install, deliver a fake sense of safety to the chemists, which is the worse situation for them.

2 How a fume hood works?

Traditional fume hoods are vented cabinets with ducting to the building roof and blower generally located on the roof exhausting typically between 800 m^3/h until 3 000 m^3/h of air to outside. This air enters the fume hood through the front sash opening of the cabinet and takes the chemicals vapors to outside through the long tubing.

Where is this air coming from? Take for example a lab room with a dimension of 100 m^2, a height of 3.2 m, i. e. a volume of 320 m^3. And suppose that this lab is equipped with one fume hood which works with a blower delivering 1 500 m^3/h. After only 12 minutes the entire volume of the room has been "swallowed" through the fume hood. If no new air is introduced in the room, no air anymore will penetrate the hood and the chemical vapors won't be elevated through the tubing, and will spread into the lab room through the front sash opening. Therefore new air shall be introduced into the room to keep the fume hood running. Opening the windows is certainly not a solution since a chemistry lab is a place where temperature shall be kept at a steady temperature of 22 - 24 ℃ all the year round. It is then necessary to install an "auxiliary air system" introducing fresh air from outside just for keeping the fume hood running. Such a system consists in installing another piping equipped with a blower taking air from the roof to the lab room, at a flow rate identical to the flow rate exhausted by the fume—typically in our example 1 500 m^3/h. In most cases this air shall be cleaned with filters and air-conditioned, so as to penetrate the room at 22-24 ℃, and a few second later, this expensive air to produce is rejected to outside through the fume hood.

In summary a conventional ducted fume hood is a complex system (see Fig. 1) consisting of a cabinet, a tubing, an exhaust blower on the roof, another blower and another tubing to inject air into the room, filters, air conditioning and an electronic command system which shall coordinate the function of the two ventilation systems. When the fume hood is turned on, the auxiliary air system shall be turned on, when the fume hood is turned off, the auxiliary system shall be turned off at the same time. A chemistry lab shall never be under positive pressure to avoid the possible pollution of the lab to spread into other rooms of the building. It shall also not be put under strong negative pressure when doors can't be opened anymore!

3 How a fume hood can provide the required safety level?

There are two main types of fume hoods: the

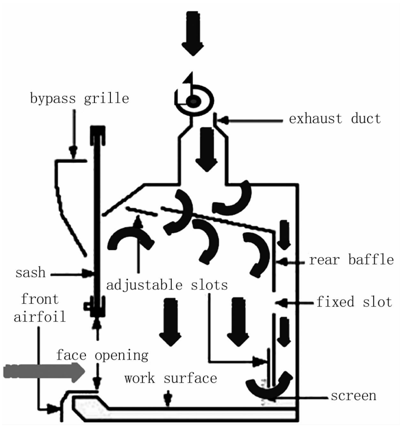

Figure 1 Ducted fume hood working principle

vented ducted fume hoods, which exhaust to outside the chemicals through ventilation, and the vented ductless filtration fume hoods (see Fig. 2), which take the chemicals to a filter through ventilation and after filtration return the purified air into the room.

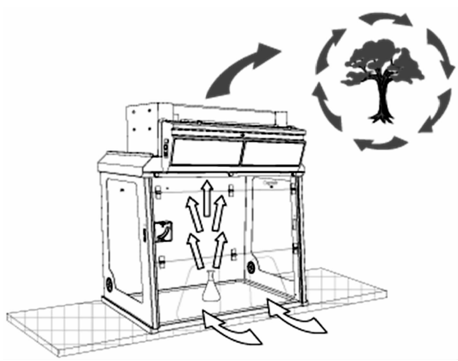
Figure 2 Ductless fume hood working principle

For ducted fume hood, the issue of safety of the user is at the level of the front sash opening. This is where the chemical vapors or powders may escape. To prevent this possible escape, the safety standards determine two main conditions: an appropriate face velocity of the air entering the working enclosure at any sash position and the capacity of the working enclosure to contain the chemical vapors or powders before they will be eliminated. The face velocity issue is relatively well known, at least by safety officers, but the containment issue is very little known, by safety officers and users, although this is an essential safety criterion of the fume hood. Since 1985, when the containment problem was discovered in USA, all the world safety standards specify the safety containment criteria, such as the ASHRAE 110:2012, the ANSI Z9.5:2011 in USA, the EN 14175 in Europe, the JB/T 6412-1999 in China.

For ductless fume hoods, the issue of safety of the user is also at the level of the front sash opening, same as for ducted fume hoods, but also at the level of the filters, since no harmful concentration of chemicals shall be returned into the room.

In any case, the result to obtain should be that the chemist shouldn't inhale more than 1% of the TWA of the chemicals he is handling in the enclosure, as explained above.

Both types of fume hoods are equipped with an enclosure and a front sash which can be opened to allow the chemist to work inside. For the face velocity the safety standards specify in general 0.4 to 0.6 m/s. This is designed to create an air barrier which shall be maintained to counter the influence of air drafts in the surrounding of the fume hood, such as people walking in front of the fume hood, the opening and closing of doors, lab ventilation drafts from ceiling inlets, or even drafts from other fume hoods located nearby. If the face velocity is too low, those droughts might take air from the fume hood through the front sash. If the face velocity is too high, it will create a bottleneck in the air discharge pipe and very high air turbulences in the enclosure and such air turbulences will provoke a release of chemical vapors to the chemist through the front sash. Face velocity at the sash plane opening can be easily verified with a hot wire anemometer capable to detect low air velocities.

The second criteria, called the "containment", are actually even more important for the safety of the chemist, but, as mentioned before, very little known and complex to verify. It shall guarantee that the chemical vapors released inside the enclosure are kept inside and can't escape through the front sash. This possible escape incurs if the air inside the enclosure is too turbulent. High turbulences may disrupt the air barrier at the sash opening and take chemical vapors to the room and affect the chemist. Containment of a fume hood enclosure shall be verified with a tracer gas, generally SF_6 (Sulfuric hexafluoride) which is emitted at a high concentration in the fume hood enclosure and with a probe placed at the nose level of a dummy, simulating a chemist, placed in front of the fume hood to check if SF_6 has escaped and at which concentration. The safety standards specifications vary for the results to obtain, 100 ppb of SF_6 maximum for fume hoods "as installed" (installed at customer site) in USA, 500 ppb in China. Unfortunately those values are not related to the TWAs of chemicals. And the lower the concentration of SF_6 found at the nose level of the dummy, the better.

Containment is affected by the face velocity. If too high, it will provoke high air turbulences in the enclosure and an easy rupture of the air barrier from inside the enclosure. If too low, air drafts from the environment of the hood, will also create an easy rupture of the air barrier, but this time from outside the enclosure.

Containment of ducted fume hoods is severely affected by the exhaust pipe diameter connected to the ceiling of the fume hood and which is generally 300 to 400 mm. It represents a bottle neck for the passage of large quantities of air entering the ducted fume hood and causes very high air turbulences and a possible rupture of the air barrier at the sash level. Obtaining a good containment with a ducted fume hood is very challenging. Many ducted fume hoods installed at customer sites don't offer a sufficient safety to the chemist, releasing through the sash concentration of chemicals which might exceed the TWAs of the chemicals handled, endangering his health over the years. Containment of ducted fume hood is almost never checked, since it is not known, complex and expensive to perform. The rupture of containment is rarely identified by the chemists or safety officers when working in the fume hood, since the concentrations released, although dangerous, are not "smelly" enough to be detected by the nose of chemists.

So far, ductless filtration fume hoods offer a significant advantage to the ducted hood, since the air penetrating the enclosure is taken to large surfaces of filters, placed above the enclosure, not to a narrow duct, and is therefore not turbulent at all, offering an unparalleled protection to the chemist in the frontal area of the fume hood. Typical containment of ductless fume hoods tested with SF_6 is in the range of 0 to 50 ppb, far below the limit of 100 ppb.

The challenge of ductless filtration fume hoods is actually not at the sash level, but at the filtration level, since the air is recirculated into the room and not exhausted. According to the latest safety standard JG/T 385-2012 recently published in China, similar to other international standards, such as the European NFX 15211: 2009 or the American SEFA 9, the filters of ductless filtration fume hoods shall be capable to filter the chemicals with a very high efficiency, so that not more than 1% of the TWAs of the chemicals handled in the fume hood shall be released into the room. The filters shall stand such high filtration efficiency for a long period of time, at least six months, to justify the costs of the filters. Another benefit of the ductless filtration fume hoods is that they can be installed immediately anywhere in a lab since they are not connected to a ductwork. They can provide immediate safety to the chemists at their usual workstation and help to multiply the number of safety stations since their number is not limited as they don't consume air and don't need auxiliary air to be introduced in the lab room.

To guarantee the safety of ductless filtration fume hoods, the JG/T 385-2012 specifies tests to be performed regarding face velocity, containment and filtration capacities. Tongji University Shanghai, in its Department has the expertise the test officially the ductless filtration fume hoods to the JG/T 385-2012 and ducted fume hoods to the JB/T 6412-1999.

4 Conclusion

Fume hoods can effectively protect the chemists, provided that they are well designed, tested in their testing facilities by manufacturers according to the relevant standards, tested by third party laboratories which have the appropriate expertise, and regularly tested on site where they are installed. But this is not enough. Chemists shall be well informed on the long term risk of chemicals, the safety criteria of the types of fume hoods that they use and how to use the fume hoods safely. A yearly training of chemists for the use of fume hoods should be considered to keep updating their knowledge, increase their safety awareness and guarantee their long term health.