

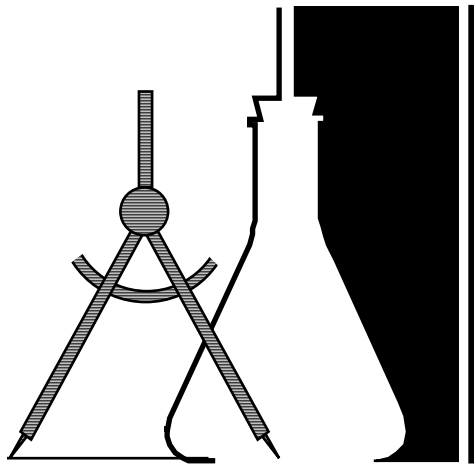
Fume Hood Scrubbers - Part I To Scrub, Or Not To Scrub?

by

Dale T. Hitchings, PE, CIH

Mr. Hitchings is President of SAFELAB Corporation of Indianapolis, Indiana, a consulting firm specializing in laboratory planning, safety and design consulting, indoor air quality and industrial ventilation consulting, and laboratory fume hood testing and training. He served as the first chairman of ASHRAE technical Committee 9.10 on Laboratory Systems. He is a Registered Professional Engineer and a Certified Industrial Hygienist. He may be contacted for questions regarding this topic or other laboratory related issues at 317-872-6600.

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LABORATORY BUILDING DESIGN UPDATE

INTRODUCTION

Concern for the environment, environmental health, and increasing government regulations are causing more laboratory designers and facility operators to consider some type of scrubber for some of their fume hoods. This is the first in a series of articles written to familiarize the reader with the aspects of fume hood scrubbers. In this part, we will be taking a classical industrial Hygiene or industrial ventilation approach to this problem by discussing source reduction or elimination in the fume hood before the contaminant is released into the airstream.

These alternatives should be evaluated *before* committing to install a scrubber. The types of scrubbers available, and their application will be the subject of future articles in this series.

ELIMINATION:

Most industrial hygienists know that engineering controls, like fume hood scrubbers, are a last resort and will attempt to avoid using them altogether if it is at all possible.

Assuming that the contaminant of concern has already been identified, the first step is to see if this hazard can simply be eliminated.

Normally, this is dead end, but if one time out of a hundred you can simply remove the contaminant from the process and not adversely affect the product then you can eliminate a capital expenditure as well as a process waste. Sometimes all it takes is someone willing to ask the researcher, "Why do we need this?" and demand a valid answer. Sometimes the answer is, "I don't know."

Enclosing the procedure to prevent the escape of a hazardous substance can also reduce or eliminate exposure, reduce waste and eliminate an air pollution source. Modifying existing equipment or procedures can also prevent the release or reduce the amount of hazardous material that is released into the airstream.

SUBSTITUTION:

If the source cannot be eliminated altogether, then it may be possible to substitute a non-

hazardous or less hazardous material for the agent of concern. This may involve some product research but the results may be well worth the effort. Any substitution resulting in a reduced hazard in the lab will also benefit those in production and application of the product as well.

CONDENSATION/TRAPPING:

The next best alternative is to condense or trap the hazard before it is released into the fume hood. Depending on the substance and its vapor pressure, this may involve simple water-cooled condensers or dry ice/acetone cold traps. Small amounts of high-concentration materials may also be removed or reduced using adsorbents like activated charcoal. In this case the material condensed, trapped or adsorbed will have to be disposed of according to proper procedures for handling hazardous laboratory waste, but the quantity will be 100 to 1000 times smaller than disposing of the liquor from a scrubber or carbon filters in the exhaust airstream.

NEUTRALIZATION/ REACTION:

It is always more efficient to treat a low-volume/high-concentration source right in the hood than treat a high-volume/low-concentration exhaust stream. Sometimes an acidic or basic contaminant can be neutralized or a toxic substance converted into another, less hazardous species before being released into the fume hood. In the case of toxic monomers like acrylonitrile, an initiator may be used to polymerize it. Polymerization will increase the molecular weight of the monomer many hundreds of times and convert it to a solid or gel with a very low vapor pressure. This process effectively eliminates the vapor component of the hazard. For many other hazardous liquids, reagents can be used to form less hazardous products before opening the process vessels and disposing of the contents and/or allowing the vapors to escape into the hood.

COMING NEXT:

If none of these ideas are appropriate for your application then scrubbing may be the best alternative for you. In Part II of this article, we will cover packed bed fume hood scrubbers and their operation.

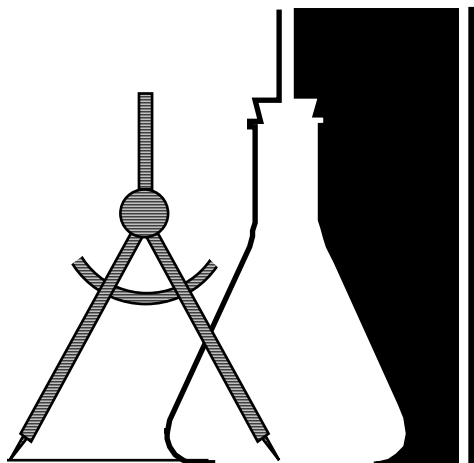
Fume Hood Scrubbers - Part II

What Are Scrubbers and How Do They Work?

by
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LABORATORY BUILDING DESIGN UPDATE

INTRODUCTION

Many laboratory designers and facility operators are beginning to consider some type of scrubber for their fume hoods. This is due, in part to concern for the environment, environmental health, and increasing government regulations.

This is the second in a series of articles written to familiarize the reader with the aspects of laboratory fume hood scrubbers. In this article we will discuss how fume hood scrubbers operate and the types of scrubbers that are commercially available. In the

previous article, "To Scrub or Not to Scrub?" (see Sept./Oct. issue of *LABORATORY BUILDING DESIGN UPDATE*) a classical industrial hygiene/industrial ventilation approach was used to decide whether source reduction or elimination in the fume hood before the contaminant is released into the airstream could be used to eliminate the hazard and if a scrubber is necessary.

HOW THEY WORK

For those familiar with industrial air pollution controls, a fume hood scrubber may appear to be a lab scale version of a typical packed bed liquid scrubber used in many chemical plants and other industries. Figure 1 shows a schematic of a typical fume hood scrubber.

Contaminated air from the fume hood enters the unit and passes through a packed bed then through the liquid spray section, a mist eliminator and then into the exhaust system for release outside the building. The scrubbing liquor is recirculated from the sump and back to the top of the system using

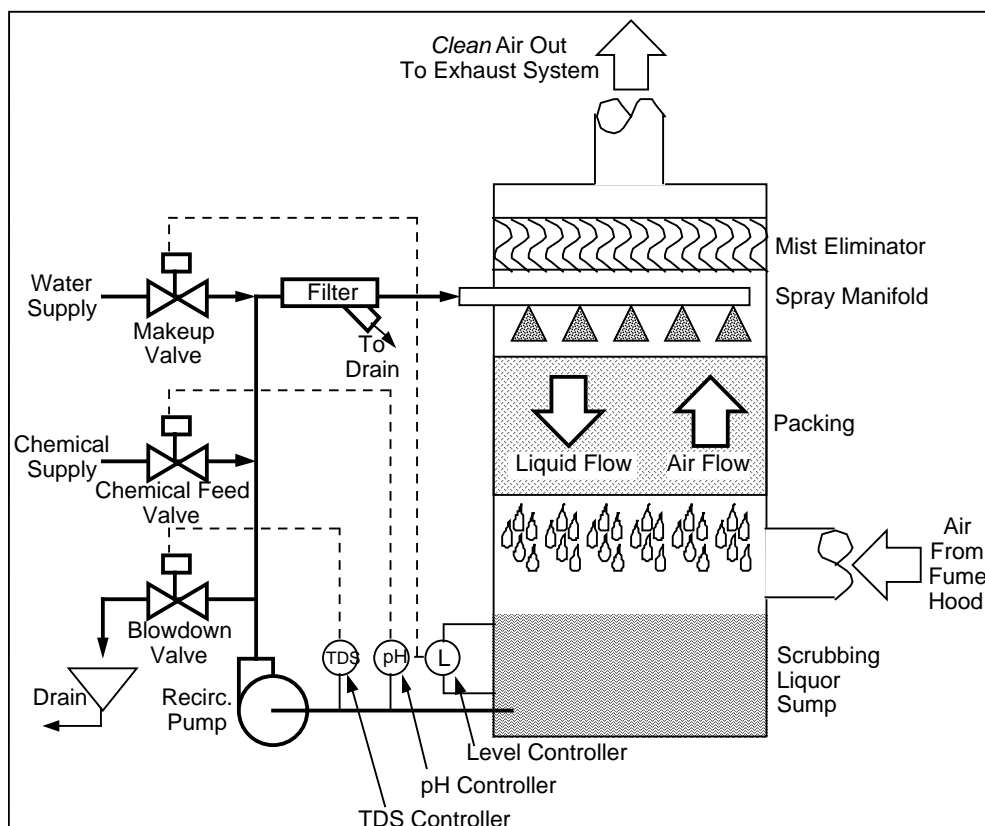


FIG.1: TYPICAL FUME HOOD SCRUBBER SCHEMATIC

a pump. The air and the scrubbing liquor pass in a countercurrent fashion for efficient gas/liquid contact. Water soluble gases, vapors and aerosols are dissolved into the scrubbing liquor. Removal efficiencies for most water soluble acid and base laden airstreams is 95-98%. Particulates are also captured quite effectively by this type of scrubber.

LIQUOR CONTROL

The scrubbing liquor is usually water and contains dissolved contaminants from the airstream, other dissolved minerals from the makeup water which are concentrated as the water evaporates into the airstream, and optionally, some neutralizing solution which is usually a weak acid or base depending on the contaminant to be neutralized.

Maintaining the scrubbing liquor involves three controllers. As the system operates, the air entering the scrubber absorbs water from the liquid stream and becomes saturated. The water consumed in this process needs to be replaced or the scrubber will run dry. This is accomplished using a level controller that opens and closes a water makeup valve to maintain the liquid level in the scrubber.

As mentioned earlier, as water evaporates from the system, minerals from the makeup water stream are concentrated. Acid/Base neutralization reactions also produce salts that become concentrated in the scrubbing liquor. The concentration of these minerals and salts are called Total Dissolved Solids or TDS. Most TDS compounds are strongly ionic and can be measured using a conductivity meter or TDS controller. To control TDS, scrubbing liquor is drained from the system

using a blowdown valve. When this occurs, the makeup system replaces the blowdown with fresh water thereby maintaining a stable liquid and TDS level.

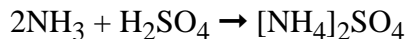
The liquor pH may also be controlled in a similar way using blowdown or by using a neutralizing chemical feed as shown in Figure 1. For example, if the airstream contains acid, a base may be used. The amount of basic solution fed into the system is controlled by a pH controller.

Since the scrubber is so effective at capturing particulates, a filter is necessary to remove them from the system. The filter may be a cleanable or disposable type. To reduce maintenance, a fine mesh strainer can be used in place of the filter. A differential pressure switch connected across the strainer is then used to actuate a blowdown valve to automatically flush the strainer.

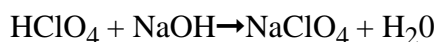
REMAINING NEUTRAL

Water soluble acids and bases are easily scrubbed and neutralized by this type of system.

An airstream containing a basic component such as Ammonia may be neutralized using a mild sulfuric acid solution. The chemical reaction is:

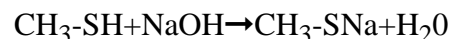


Most acids in the airstream may be neutralized using a mild sodium hydroxide or *caustic* solution. In the case of perchloric acid the chemical reaction is:



Certain water soluble organic compounds such as mercaptans may also be "neutralized" using a

mild caustic solution. In the case of Methyl Mercaptan the chemical reaction is:



UNIT LOCATION

Typically, these units are configured vertically and are located next to the fume hood in a similar configuration as Figure 1. They may handle up to approximately three hoods. Another form is the top mount version which has the packing, spray manifold and mist eliminator sections located on top of the hood and the sump and liquid handling portion underneath of the hood for a compact arrangement taking up no more space than the hood itself. These units may also be remotely located. However, the closer you can place the scrubber to the fume hood, the better off you will be when considering corrosion of the ductwork between the hood and scrubber.

CONCLUSION

Fume hood scrubbers can effectively reduce concentrations of certain water soluble acid, base and organic contaminants exhausted from a fume hood. If you are concerned about duct corrosion, hazardous stack emissions or other environmental factors associated with a fume hood you may want to consider a scrubber.

COMING NEXT:

The subject of the next and final article in this series will cover gas-phase and particulate filters for laboratory fume hoods. Their theory of operation, advantages and disadvantages will be discussed in detail.

Fume Hood Scrubbers - Part III

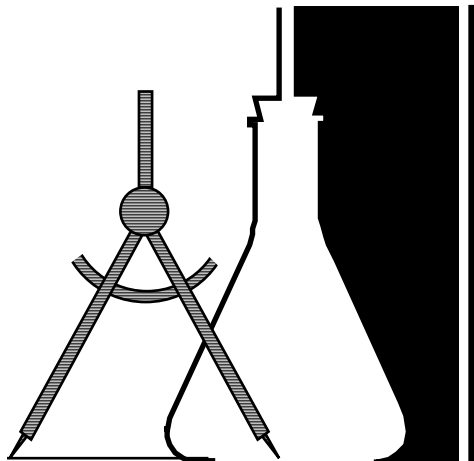
Gas-Phase and Particulate Filtration Systems

by

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LABORATORY BUILDING DESIGN UPDATE

INTRODUCTION:

Environmental restrictions on fume hood effluent in states like Delaware, NRC/DOE regulations and increasing EPA regulations are forcing the use of different types of air-pollution controls for fume hoods such as liquid scrubbers, and gas-phase and particulate filters.

In this final article in a three-part series, gas-phase and particulate filtration systems will be discussed as well as some design hints, cautions and application information for these devices. Liquid scrubbers were the topic of part II of this series, see UPDATE Nov./Dec., 1993 issue for a detailed explanation of this technology.

GAS-PHASE FILTRATION:

Besides liquid scrubbers, there are two other basic types of gas-phase filtration schemes for fume hoods. These are "inert" adsorbents and chemically active adsorbents. The "inert" variety includes activated carbon, activated alumina, and molecular sieves. These substances typically come in bulk forms for use in a deep bed, as well as cartridges, and panels for use in housings similar to particulate filter housings. They are usually manufactured in the form of beads but they may take many forms. The beads

are porous and have extremely large surface areas with sites onto which gas and vapor molecules are trapped or *adsorbed* as they pass through. For this discussion "gas" means gases and vapors. Adsorbents will handle hundreds of different compounds including most VOC's but also have an affinity for harmless species such as water vapor. These adsorbents are also used in process gas and compressed air dryers for this reason.

Their theory of operation appears simple at first: they act like a sponge to remove target gases. This is where the simplicity ends, however. The problems associated with using these devices are typically caused by their lesser-known characteristics that are rarely discussed in vendor literature.

As the air passes through the adsorbent bed, gases are removed in a section of the bed called the mass transfer zone (MTZ). At the leading (upstream) edge of the MTZ the adsorbent is saturated, at the trailing (downstream) edge of the MTZ the adsorbent is "clean." As the bed loads up with gases, this MTZ propagates through the bed in the direction of flow. If the adsorbent is not regenerated or replaced, eventually the MTZ reaches the end of the bed. This

is called *breakthrough*. After breakthrough occurs, gases will pass through the bed at higher and higher concentrations until the upstream and downstream levels are almost identical -- that is, for a steady-state/concentration airstream. This is rarely the case with laboratory fume hoods. To prevent breakthrough the adsorbent must be either changed or regenerated. Regeneration involves passing a clean airstream through the bed, usually at an elevated temperature to drive off the adsorbed vapors. And, what happens to these gases after they are driven back out of the adsorbent? They must be condensed, oxidized or dealt with in some other expensive fashion.

An undesirable characteristic of adsorbents is that once the target gas has been adsorbed, it can also be released or *desorbed* under normal operating conditions. For example, high concentrations of the target gas are adsorbed onto a scrubber bed during an operation in a fume hood. This will create a "dirty" layer in the bed. If the hood continues to operate "clean," then as the clean air passes through the bed the gases start to desorb at the leading edge of the bed, they are carried to the end of the MTZ and hopefully re-adsorbed there. Given enough time, the saturated portion of the bed and the

MTZ are pushed forward and out of the bed. So much for pollution control. This is why ductless "fume hoods" are considered by many to be unsafe. The "filters" in them simply retain the contaminants for later release into the laboratory, or if already saturated, allow contaminants to pass through relatively unaffected. To prevent this, monitoring of downstream concentrations of the target gas is necessary.

This desorption process has been used successfully in the past when the actual amount of target gas released to the atmosphere was not an issue, but the concentration was. There is a midwestern chemical plant where research was done using a Mercaptan—one of the smelly chemicals used as the warning odor in natural gas. This family of chemicals is not significantly toxic, but has an incredibly low odor threshold on the order of parts per *billion*. The lab management was concerned about the possible public relations nightmare that would occur if even a few grams of this liquid were spilled in a fume hood. The location of the building was near the fence line of the plant and calculations revealed that even with a well-designed stack of reasonable height and reasonable discharge velocity that the odor outside the fence line would be quite objectionable for some distance. Since this compound smells like natural gas, the local gas utility would probably be called to investigate. Eventually they would discover the source of the odor and blame it on the chemical company. The answer to the problem was to install a carbon bed scrubber that was designed to catch the vapors from a spill and then release them over a long period of time and at a low enough concentration to avoid a public relations problem.

Another characteristic of adsorbents is that they have differing affinities for different substances. For example, an adsorbent scrubber is used with a hood in which chemical *A* is used. The

adsorbent has an average affinity for chemical *A*. Later, chemical *B* is used in this same fume hood, for which the adsorbent has a high affinity. As chemical *B* passes into the bed it displaces chemical *A* which is either re-adsorbed downstream (if you're lucky) or is forced out of the bed completely. This can also happen with ductless fume hoods which use panel or cartridge adsorbents with a very short residence time and low-capacity. The process is similar to the hemoglobin mechanism in our blood, which has a higher affinity for carbon-monoxide than oxygen.

It should be noted that adsorbents have a different removal efficiency and saturation point for each different compound and that this efficiency is not 100%. A certain concentration of gas will pass through the bed at all times. The life of the adsorbent bed depends mostly upon its volume or mass and to a lesser extent upon its shape which determines the air velocity through the bed. Airstream concentration of the target gas and concentration of other non-target gases (including water vapor) will also affect the capacity of the bed for the target gas.

Chemically active adsorbents are simply inert adsorbents impregnated with a strong oxidizer such as potassium-permanganate. Although there are other oxidizers targeted to specific compounds, the permanganates are the most popular. The adsorbent part of the bed captures the target gas and gives the oxidizer time to achieve a reasonable destruction efficiency. The media in these beds is not economically reusable because the oxidizer is consumed over time. Downstream monitoring to detect breakthrough or sampling of the media to determine the remaining capacity of the bed should be done regularly.

An advantage of the chemically active beds over the inert beds is that

actual destruction of the target compound occurs. There is still a solid waste problem, but the media contains only a fraction of the level of the target compound as an inert media would. A disadvantage of these types of scrubbers is that if high concentrations of organics or hydrocarbons are carried into the bed, as would occur if a liquid were spilled in the hood, a large exotherm will occur in the reaction zone of the bed (similar to the MTZ). This exotherm may cause a fire to occur in the scrubber. Because of this, care should be taken when locating these devices and other downstream devices like particulate filters. Fires may occur in these devices at surprisingly low temperatures due to the catalytic action of the adsorbent matrix.

Both the inert and chemically active types of adsorbent beds are used successfully in certain applications where proper precautions are taken to deal with the undesirable characteristics mentioned previously and where proper maintenance and monitoring are done. Frequent bed regeneration/replacement (or both) may be necessary in some applications. Most people have problems when these systems are forgotten and not properly maintained.

Remember that in each case, you are trading an acute air pollution problem for a chronic one, or for a solid-waste disposal problem. When spent adsorbent is reactivated, either accidentally in place, over time, or on purpose, the target gas is desorbed back out of the bed. Factories that are in the business of regenerating adsorbent media usually oxidize the desorbed material in a thermal oxidizer also known as a TOX or incinerator. This solves the pollution problem -- or does it? No. You're now trading CO₂ emissions for VOC emissions. Think about it.

PARTICULATE FILTRATION:

Air from fume hoods and biological safety cabinets in which radioactive or biologically active materials are used should be properly filtered to remove these agents so they are not released into the atmosphere. Other hazardous particulates may require this type of treatment as well. The most popular method of accomplishing this is by using a HEPA (high-efficiency particulate air) filter bank. These HEPA filters trap at least 99.97% of all particulates 0.3 microns or greater in size. The engineering aspects of these filters are relatively straightforward and will not be covered here, but the operational and maintenance aspects must be given special attention. These systems must be specified, purchased and installed so that the filters can be changed without exposing the worker or the environment to the agents trapped in the filter. Sterilizing the filter bank is prudent before changing filters that may contain etiologic agents. Unfortunately, you can't do anything to a filter contaminated with radioactive material, however. In any case a "bag-in, bag-out" method of replacement should be used. Some very clever engineers have designed methods of using special plastic bags, sleeves, tie wraps, and other devices to change contaminated filters while keeping the entire operation completely sealed. Consult your HEPA filter manufacturer for details on these procedures.

CONCLUSION:

There are many types of pollution control devices for laboratory fume hoods. These include liquid scrubbers, adsorbers, and particulate filters. Each has unique engineering and operating characteristics. Some of the characteristics of these devices are not well documented and special care should be exercised when using them. Like all aspects of laboratory facility environmental control system design, the application of these devices should be done by an experienced engineer.