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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 desorbtion 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 adsorbers 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 CO_2 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 manufactures 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.