Laboratory Hoods and Ventilation Enclosures
Problems and Pitfalls

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Abstract

Ventilation is the first line of defense used to protect workers in chemistry laboratories. This discussion provides insight on the design and operation of laboratory hoods, and specialized ventilated enclosures. Emphasis is on the do's and don't for proper control and containment of the potentially hazardous materials present in chemistry laboratories. Included is a discussion of basic hood and ventilation design, where hoods should be located, and how they should be operated to optimize containment. Routine testing, monitoring and preventive maintenance is discussed. Specialized vented enclosures such as, balance enclosures, microscope enclosures, and enclosures for high-throughput, automated equipment and other equipment is also discussed. The complicated engineering control known as a laboratory chemical hood is discussed in clear, easy-to-understand language so that everyone from the beginner to those familiar with the dynamics of airflow will be enriched from the discussion.

Introduction

The key to safe handling of chemicals is the use of properly designed, installed and functioning engineering controls, i.e., laboratory ventilation, laboratory chemical hoods, and vented enclosures. The two most important references for anyone seriously involved with laboratory ventilation and hoods are the most recent versions of the first two references cited at the end of this paper (1,2). The references also list several easy-to-read, hard copy references on laboratory hoods and ventilation (3-8). In addition, there are several workbooks available by Jeff Burton (9). Finally, several Internet sites are also listed in the references (10-24). Because of the constantly changing nature of the internet and the websites, it is always advisable to check for new sites by using a search engine like google (25) and searching under fume hoods, laboratory chemical hoods, etc. Note much of the Internet information is not a primary or secondary reference source and particular attention should be given to validity of the information.

Laboratory operations that involve or give off potentially hazardous chemicals (e.g., toxic, flammable, explosive, odiferous) should be performed in a properly functioning hood or vented enclosure. By definition a hood is any opening that exhausts air. A laboratory chemical hood is different from a biological safety cabinet, laminar flow hood, glove box, or vented enclosure. This Manual only addresses laboratory chemical hoods and vented enclosures.

Laboratory Ventilation and Design

The first step is to be sure the general laboratory ventilation system is working correctly. Each laboratory is different and has unique needs. The architects and engineers that design and build such facilities should be experienced in laboratory ventilation. Testing and evaluation should be conducted by professionals/organizations who are familiar with the safety and the engineering aspects of the system and who understand the requirements of the laboratory users. All hoods and vented enclosures should be certified, as described below, when they are installed, and commissioned before they are used.

There are a few basic rules to remember about ventilation design. Incoming, (i.e., supply, or makeup) air must be sufficient to replace and compensate for the air exhausted, otherwise hood containment will be compromised and contaminants will escape. Exhaust fans should be outside the building to ensure that hood ductwork is under negative pressure. This is done so that if a leak develops in the ductwork the exhaust will not escape back into the building.

Exhaust fans should be outside and as far as possible and downwind from all air intakes. Hood exhaust air should not be recirculated. Also limit the horizontal runs of ductwork and make it as short as possible. Hoods should not be piggybacked into other hood ducts without increasing the fan capacity.

Hood Location and Selection

Hoods should not be located in a major traffic flow aisle, near open windows, doorways, next to desks, near air conditioner ducts or other sources of cross-drafts. Locate hoods as far to the rear as possible in a laboratory to assure emergency escape routes. Where possible locate hoods at the dead end of aisles to minimize traffic flow in front of the hood.

Careful selection, installation, maintenance, and evaluation of laboratory chemical hoods and vented enclosures are imperative. Laboratory chemical hoods are incorrectly called fume hoods, because they control other aerosols besides just fumes (e.g., gases, vapors, mists, fogs, particulates). Always consult a qualified, and trained safety professional with specific experience whenever hoods are selected, installed and used.

Hazardous chemicals should be weighed and handled only where there is adequate ventilation, such as in a hood or vented enclosure. Many chemicals present hazards of various types. Hazardous chemicals should be weighed or used in a hood or vented enclosure and not on the open bench where dispersion into the laboratory air is possible. Appropriate protective equipment, specific to the particular hazard, should always be used. Always consult your Chemical Hygiene Officer or Safety Office and read the Material Safety Data Sheet (MSDS) before weighing and handling any hazardous chemical.

Engineering Controls

Workers should never be exposed to hazardous chemicals. Adequate ventilation is defined as ventilation that is sufficient to prevent worker exposure. Chemical concentrations should always be below the OSHA Permissible Exposure Limit (PEL), NIOSH Recommended Exposure Limit (REL), ACGIH Threshold Limit Value (TLV), or AIHA Worker Environmental Exposure Level (WEEL) for those chemicals for which these values have been established. Exposure should always be kept to a minimum. Remember smell has little to do with dose. Just because you cant smell it doesnt mean youre not being exposed. The vapors of many chemicals can be at a hazardous concentration level without any noticeable odor. The same applies to dusts, mists and fumes. The body can sometimes breakdown chemicals by metabolism into hazardous metabolites. Similarly, by-products of chemical reactions can be extremely hazardous. Planning for the handling and control of these toxic metabolites and by-products should be part of the experimental procedure. Hence, always enclose as much of the work being performed as possible in a hood or vented enclosure.

All engineering controls are not created equal. Many hoods have specific functions. For example, canopy hoods (like those over a kitchen stove) should only be used when the effluents from the operation are forced (e.g., by heating) upward toward the hood. Otherwise the exhaust is drawn across worker and his/her breathing zone no matter how careful the work practices. Slot hoods at the back of laboratory benches are of very limited usefulness. The effective capture range of a 1 to 2 inch slot hood is only 8 to 12 inches regardless of the length of the slot. Even doubling the airflow will not substantially increase the capture range. The same is true of a simple elephant trunk type opening. As a rule of thumb, the effective capture range is about one duct diameter, i.e., a 6 duct effectively captures effluents only within 6 from the opening, beyond that the effluents are dispersed into the room.

Containment

Laboratory chemical hoods are deceptively simple in design. Just because the motor can be heard or a tissue moves at the hood face does not mean the device is containing properly. Hood exhaust volume (cfm), and face velocity (fpm), are just two parameters that can be measured. A specific value for either does not mean the enclosure is working properly. The key is whether the hood contains the hazardous material, i.e., chemical containment. Containment should be as close to the source as possible, however, working in closed systems like a glove box is usually not feasible, desired, or practical. The next best thing is to control the hazard along the path, before the hazard reaches the receiver, i.e., the worker. This means partially enclosing the source using a laboratory chemical hood, or vented enclosure where there is a front opening for access. Reliance should not be on personal protective equipment like respirators. If respirators are needed this means the enclosure is not containing the hazard. In addition, respirators provide a false sense of security, and OSHA requires a respirator fit program, which requires a lot of time, resources, and stringent documentation.

Energy Concerns

There are several reasons face velocity and exhaust rate alone should not be used to determine performance. These parameters are influenced dramatically by the room air supply, cross-drafts caused by operator movements, laboratory traffic flow, location of room doors, the nature of the equipment and processes being enclosed, and the location and type of room supply and exhaust air diffusers. In addition, use of higher exhaust rates than necessary is expensive. A single 6-foot laboratory chemical hood operating 24/7 at 100 fpm costs about $5,000/year to operate. Remember active hoods should always be left running, even after hours. Otherwise the materials used in the hood will diffuse back into the work area. Airflows that are too high can also cause turbulence at the face and compromise containment.

Vented Enclosure

Vented enclosures are intended as alternatives and complements to traditional laboratory chemical hoods. Vented enclosures are less expensive to buy, install and maintain than traditional hoods. Because they use less air they are cheaper to operate. Traditional laboratory chemical hoods are expensive to operate, but a 3 ft. vented enclosures can be operated 24/7 for only about $500/yr. Hence, vented enclosures often enable a lot more bench space and operations to be ventilated. Vented enclosures can be custom designed for specific operations (e.g., balance enclosures, microscopes, high-throughput robotic and automatic equipment enclosures, histopathology operations). When properly designed they have demonstrated excellent containment (14). In addition, they usually can be installed or removed in a matter of hours; an important advantage in todays rapidly changing corporate world. In such cases alarmed and monitored HEPA filters remove the contaminated effluents so the exhaust can be recirculated.

If the material used in the hood or vented enclosure is ***non-volatile*** and capable of being removed by a HEPA (high efficiency particulate air) filter is may be acceptable to recirculate the exhaust air back into the laboratory. There are some important restrictions however. For example, vented enclosures used for particulates should be alarmed at the face so that when the face velocity drops below a set point an alarm will sound indicating that the HEPA filter is becoming loaded. Alternatively, the pressure drop across the HEPA filter can be measured, continually monitored and alarmed. An increase in pressure means the filter is becoming loaded and should be replaced.

If trace amounts of known, specific, volatile chemical are used it also may be possible to use bagout charcoal filters to remove the effluents and recirculate the exhaust. If this is done the charcoal filter should be equipped with chemical-specific detectors and alarms to indicate when breakthrough occurs. Charcoal filters should not be used for anything more than trace amounts of volatile chemicals or where several different chemicals are used. Input from a safety professional is crucial.

Testing and Validation

Its advisable to require proof of containment by the hood manufacturer before purchase. Hood containment should also be tested again after installation and before actual use. This provides a baseline for the hood performance that is valuable in future hood evaluations. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has a specific test for containment (ASHRAE 110-1992, Fume Hoods, Methods of Testing Performance of Laboratories, 25,12,13). ASHRAE 110-1992 is specific for laboratory chemical hoods, but reputable manufacturers of vented closures will always provide similar proof of containment for their products (15).

Hood Types

There are several types of laboratory chemical hoods, e.g., conventional, by-pass, auxiliary air, vertical sash, horizontal sash, combination horizontal/vertical sash (i.e., HOPEC), radioisotope, perchloric acid, floor mounted (improperly known as walk-in), bench level, constant volume, and variable air volume hoods. For a full discussion of each type and purpose of these hoods consult one of the references cited above in the beginning of this Section. It should be noted that auxiliary air hoods are no longer recommended. These hoods were for were originally designed for energy savings, but this design is not practical since the auxiliary air had to be conditioned before it was used; thus negating any energy savings.

Hazard Evaluation, Risk Assessment, and Hazardous Chemicals (26)

A hazard is the danger that can result when an unwanted event occurs. Hazards are evaluated according to their potential to cause harm, based on an analysis of their properties and their conditions of use. Risk is a measure of the probability and the consequences of the hazards resulting from an activity or condition. Risk assessment is an evaluation of the probability, extent, and impact that an undesirable event could have on the health and welfare of humans and the environment.

Chemicals often present biological, chemical, environmental, or physical hazards. A hazardous chemical or chemical mixture is one that can fit into one of three categories. 1. It has undesirable biological effects, either acutely or chronically, with reasonable regard to size and duration of dose, type of exposure and the physical state of the material needed to produce such effects. 2. Its toxicity information is not available, but is highly suspect because of its structural or functional similarity to known toxic agents. 3. It is combustible, flammable, explosive, caustic, corrosive or highly reactive (e.g. an oxidizers). OSHA, NFPA, EPA, DOT, CPSC, and other organizations have specific definitions for specific hazardous chemicals, classes and substances. Hazardous chemicals should always be weighed or used in a hood or vented enclosure and not on the open bench where dispersion into the laboratory air is possible. Appropriate protective equipment, specific to the particular hazard, should always be used. Always consult your Chemical Hygiene Officer or Safety Office and read the Material Safety Data Sheet (MSDS) before weighing and handling any hazardous chemical.

Hood Use

Once a hood is installed the responsibility shifts to the users. A periodic and routine maintenance and inspection schedule should be established. This includes inspection of motors, fans, pulleys, belts and routine lubrication. Always have an emergency plan for hood or electrical failure. The safety department or Chemical Hygiene Officer should establish a routine hood monitoring and evaluation program. Safety personnel should use separate velometers or anemometers that are calibrated each year and visually inspect and evaluate every hoods at least annually. Each hood should be marked with a date of inspection, face velocity and the proper operating sash height.

All hood users should receive proper training before they ever use a hood. Except for gloved hands and protected arms no part of the workers body should ever enter a hood, especially the head. This is why the term walk-in hood is no longer used. Always wear proper personal protective clothing including appropriate eye protection. Always lower the sash whenever the hands-on operation is completed. Keep the sash fully closed when the hood is unattended. Never shut off a hood unless the hood is clean and decontaminated. Hoods should not be overcrowded and should not be used to store unwanted or unused chemicals, materials or equipment. Avoid clutter in hoods. Keep light fixtures clean, ground electrical outlets and keep them free from corrosion and in proper working order. Inspect baffles to ensure they have not slipped shut. Malfunctioning sashes and broken glass should be repaired before the hood is used. All work in a hood should be carried out at least 15 cm (6 in) from the sash edge of the hood. A yellow line 15 cm from the edge can serve to indicate the limit of usage. Adequate airflow and the absence of excessive turbulence are necessary for safe operation. Ensure that equipment does not block the hood baffles. It may be necessary to place large equipment on 2 blocks to permit adequate and uniform airflow.

When feasible apparatus used in hoods should be fitted with condensers, traps or scrubbers to contain or collect hazardous effluents. The hood should never be used as a means for disposing of chemicals (e.g., by evaporation). The effective operation of a hood depends on many factors including face velocity, the overall ventilation pattern of the room, the adequacy of room air supply, and the methods of working at the hood. Before each use, be sure that the hood exhaust system is working properly. Routinely inspect the hood immediately before it is used.

Always keep your head outside of the hood face. Specialized vented enclosures and workstations are now commercially available for many operations like weighing, microscopy, pipetting, and use of automated equipment. Flexible ductwork or "elephant trunk" hoods should be used over the exit ports of equipment like gas chromatographs and atomic absorption spectrometers to remove toxic effluent from the laboratory environment. Remember that in the event of an accident or fire every item in the hood may be involved, including those stored in the hood.

Conclusion

The Americans With Disabilities Act resulted in new commercially available hood designs, and new advances in laboratory design for access by disabled persons. Hood standards like those of ANSI, ASHRAE, NFPA (27), and SEFA (28) are continually being revised. Laboratory chemical hoods, and vented enclosures and workstations are continuing to evolve and represent an exciting and dynamic aspect of chemical health and safety.

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