

Verbleiben

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Fume hood, exhaust system design

duced behind the sash (i.e., directly into the hood), the ~~face velocity through the sash is drastically reduced~~, and the hood will not be able to prevent leakage of fumes back into the room. For this reason, ~~auxiliary air should never be introduced directly into the hood~~. Other problems with auxiliary air systems will be discussed in greater detail below.

Another special type of hood is the **perchloric acid hood**, shown in Fig. 5. This is a special adaptation of the standard or the balanced air hood for particular use with perchloric acid or other dangerous oxidants. Such hoods are equipped with water sprays along the entire length of the exhaust duct and in the space between the back baffle and the back wall. The sprays are

periodically turned on to wash down acid crystals and organic matter that may have accumulated, and drains are provided to receive the wash water. The inside surface of the hood is usually hosed down or washed by hand. If left in the hood and in the exhaust ductwork, accumulations of organic matter and perchloric acid crystals can produce unexpected and violent explosions.

Radioactive hoods are variations of standard and balanced air hoods, specially constructed to permit easy cleaning. They are usually equipped with HEPA filters in the exhaust ducts on top of the hoods to collect radioactive particulate matter. Such hoods are used for isotope work or for other work where the discharge from the

hoods must be cleaned of harmful particulates.

There are other types of fume hoods also. The most important of these is the **exhaust box**, which is equipped with small hand openings similar to those provided for glove boxes used for hazardous biological work. Such exhaust boxes require much less air to be exhausted to the outdoors, but they may not provide adequate space for some experimental setups.

Another useful fume collector is the flexible duct or snorkel, which is used to draw heat, moisture, and nonhazardous fumes from a localized area.

What face velocities?

Since the basic purpose of a hood is to prevent leakage of fumes into a laboratory, the velocity of the air through the sash opening must be high enough to capture fumes around the periphery of the sash. A minimum face velocity of 100 fpm is recommended for fume hoods used in chemical research, and 75 fpm for hoods used in undergraduate teaching laboratories.

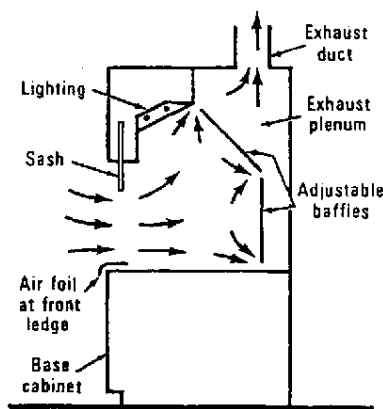
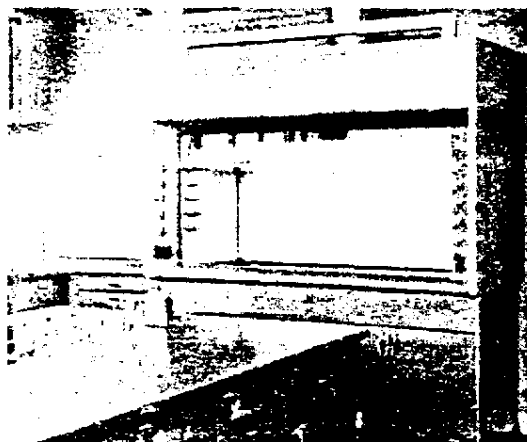
~~At a face velocity of 100 fpm, the flow of air through the sash opening is very easy to disturb. This can produce eddy currents that may reverse the air flow at the edges, thus causing the hood to leak. For example, a wake that will approach a velocity of 350 fpm. Eddy currents from such a wake can very easily disturb the smooth flow of air through the sash, usually resulting in~~

On the other hand, a velocity much over 100 fpm can interfere with tests being conducted in a hood. For example, an open flame will not burn properly at velocities over 100 fpm.

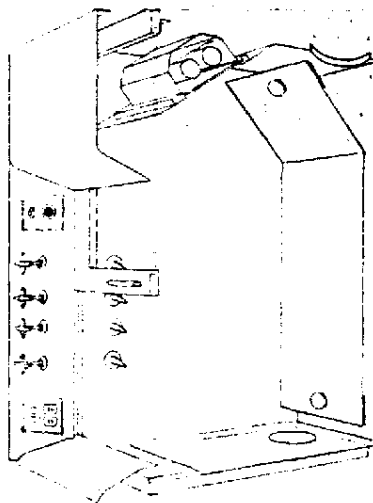
Other common causes of face velocity interferences include: location of the hood near an operable window; location near a frequently opened and closed door; or location in the path of any air motion exceeding 30 fpm, such as a nearby air conditioning diffuser or a portable fan.

Hood location, design

~~to~~ to adequate face velocity, the ~~modeling must respect the~~

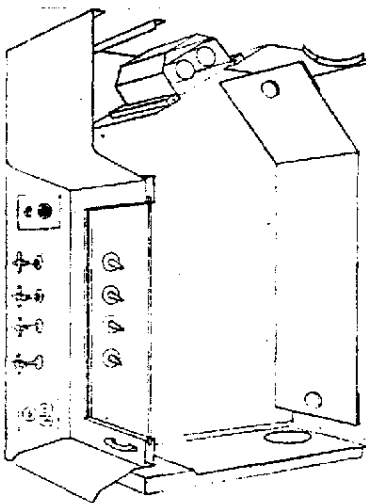


1-2 Standard fume hood.



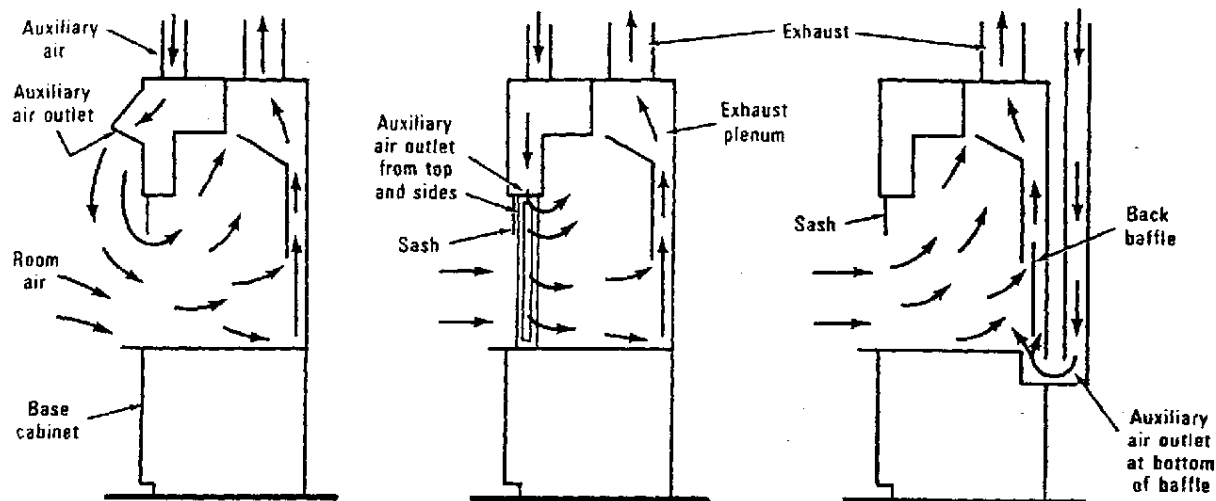
SASH UP

3 Balanced air fume hood.



SASH DOWN

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4 Auxiliary air fume hoods.

factory operation of a hood is its location. A hood located near the entrance of a laboratory will be affected by the fanning action of the door, by the inward flow of corridor makeup air, and by the eddy currents of persons passing through the door. Even worse, a hood location behind a door subjects its user to the possibility of being bumped, which could result in a serious accident.

For these reasons, it is important to locate a hood as far into the room as possible and particularly away from opening doors. Safe performance of a hood is far more important than the small increase in friction loss from slightly longer exhaust ducts. A hood should not be positioned so that its sidewall is located directly against a partition or window wall, however. This will increase the resistance of the entering air next to the wall, which will reduce the capture velocity near the wall and possibly result in concealed leaks.

A hood should be constructed to avoid center posts and sharp edged corner posts. Instead, all leading edges (where the air enters the hood at the sash) should be streamlined to prevent eddy currents that may cause the hood to leak. Also, the inside wall surfaces of the hood should be smooth and free of recesses or sharp edges that could disturb the smooth laminar flow through the hood.

Of special importance is the

leading edge of the hood work surface. In addition to being streamlined, it should have a raised air foil installed (Figs. 2 and 3) to assure a continuous smooth flow of air across the work surface when the sash is fully closed. Such a flow of air will prevent leakage of vapors that are heavier than air, and the raised surface will defeat the tendency of operators to set experimental apparatus too close to the sash opening, thereby disturbing the laminar flow and creating eddy currents.

Problems with auxiliary air

In an earlier paragraph, auxiliary air hoods were briefly described, and the point was made that auxiliary air should never be introduced into a hood behind the sash. There are other serious problems with auxiliary air hoods and auxiliary air supply systems.

Although auxiliary air introduced outside a hood and in front of the sash is streamlined, it has the serious disadvantage of interfering with the laminar flow through the sash opening. This is particularly true of hoods that have auxiliary air introduced around the periphery of the sash opening immediately in front of the sash and at right angles to the inward air flow. If, for example, the total air volume exhausted from such a hood should become diminished because of a reversed fan motor, a dirty exhaust system, or a faulty damp-

ary air across the reduced laminar flow entering the hood will disrupt smooth flow, producing severe eddy currents and leaks. (By way of comparison, if the auxiliary air is introduced inside the sash and the exhaust air volume is reduced, the auxiliary air will almost certainly be drawn into the hood). This is another reason why auxiliary air should never be introduced inside a hood).

Even if air inflow interference does not materialize, heated air delivered overhead and outside the hood in winter can be extremely uncomfortable to the hood user and can cause condensation or fog within the hood. Moreover, unless the auxiliary air is precooled and dehumidified in summer, it may add to the room air conditioning load through partial dispersion of the untreated air into the room.

Finally, it should be remembered that an entire auxiliary air supply system is very expensive and is especially difficult and costly to maintain. Consequently, for most localities, it is likely to be cheaper and certainly more satisfactory to condition all of the makeup air using the central air conditioning system than to install and maintain a number of auxiliary air systems.

If an auxiliary air system is being considered for a laboratory building, it is especially important to make a complete analysis of

Fume hood, exhaust system design

costs (operating and maintenance costs as well as first costs) to determine whether the system will really result in economies. Moreover, if an auxiliary system is decided on, special attention is needed in the selection of an acceptable hood. ~~Most discerning designers believe that auxiliary air systems should be avoided~~ and that all makeup air should be conditioned by the central system.

How about economy cycle?

Economizer systems have frequently been proposed for use with laboratory buildings in con-

junction with fume hood exhaust systems. The purpose of these systems is to ~~remove heat from the discharging exhaust air~~ in winter and ~~reintroduce the heat back into the makeup air~~ for the building. The process is reversed in summer. Such a system may include a large, slowly rotating wheel filled with porous material of a heat absorbing type; or it may consist of a run-around heat cycle incorporating heat exchange coils, piping, and pumps, or similar equipment.

Economizer systems are ~~believed to be impractical for fume exhaust systems~~ because the kinds of chemicals and vapors being exhausted are both unpredictable and potentially damaging to the economizer equipment. Moreover, as will be discussed later in greater detail, the building air intake for a laboratory building should always be located as far away from the fume discharge terminals as possible. If this is done, transfer of heat becomes impractical. Also, since there are likely to be many individual fume exhaust systems on the roof of the building, it may not be economical to recover heat from such a large number of small discharge ducts.

Locating the exhaust fan

Fifty years ago, fume hoods were usually exhausted by gravity or stack effect; that is, fumes were removed by the difference in weight between the warm inside air and the cool outside air. But this did not work well in warm

weather. So mechanical exhaust fans were installed, usually located overhead above the hoods.

It was soon discovered, however, that the exhaust ducts readily became corroded, thus permitting the fumes (under pressure on the discharge side of the fan) to leak into the laboratory and into other parts of the building along the route of the ducts. Today, all fume hood exhaust fans are installed on roofs, usually exposed to weather. Sometimes fume exhaust fans are installed in pent-houses, but this practice is discouraged because of the danger to maintenance personnel.

Utility cores

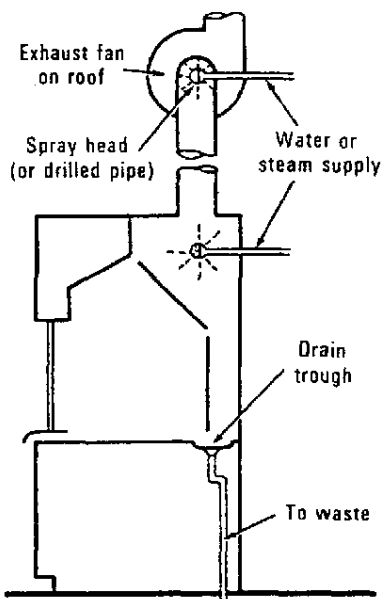
In most modern research laboratories, accessible mechanical service cores are provided for the installation of piping, electrical lines, and ducts. Most such cores are vertical shafts (see Fig. 6) large enough to accommodate a workman; others consist of vertical service closets next to corridors, with access doors at each floor. Fume exhaust ducts should always be installed in accessible service shafts so that they may be readily inspected, repaired, or replaced.

Exhaust system configuration

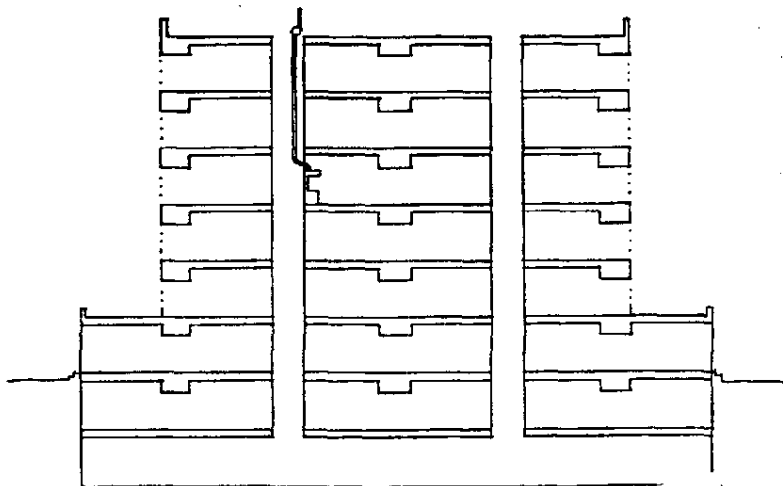
Wherever possible, ~~each fume hood should be exhausted by its own fan and duct system~~ (see Fig. 6). If this is done, only isolated hoods will go out of service when equipment fails or a system is cleaned or repaired. Also, individual exhaust fans may be turned off when a fume hood is not in use, except, of course, for those needed to remove ventilation air from the building, and when more than one hood are installed in a room or in a contiguous suite of rooms. (The latter problem will be discussed in a subsequent paragraph on safety features.)

In large chemistry research buildings particularly, there are often more fume hoods installed than are needed for the relief of ventilation makeup air. If hoods are individually controlled, selected fume hood systems may be shut off to save the cost of heating or cooling the makeup air.

On the other hand, in high rise research buildings, the large number of individual exhaust ducts required may occupy more space



5 Perchloric acid fume hood.



6 Building utility cores.

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than is available in the service cores, especially at the upper floors. By combining some of the hoods, one can reach an optimum compromise between individual hood control and reasonable service core size.

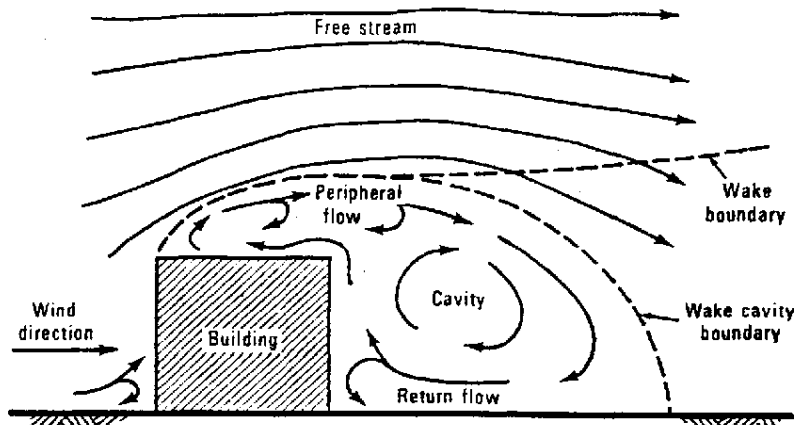
When fume exhaust systems are combined, it is important to combine only those systems handling compatible fumes and managed from a single department. Hoods serving a suite of rooms under a single research program, for example, may be combined. It is very important, however, to isolate all hoods that are likely to be used for hazardous materials such as perchloric acids, radioactive chemicals, or pathogens. In general, such hoods should be operating continuously.

Exhaust duct materials

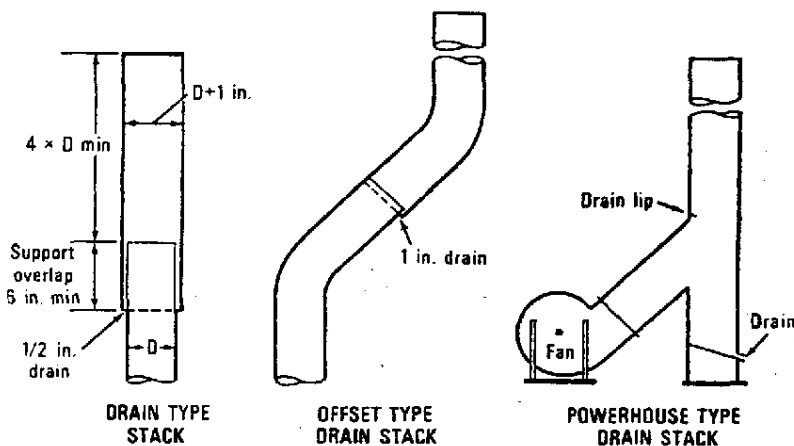
Because fume ducts are exposed to a variety of corrosive gases and vapors and because these gases may vary as research programs are changed, it is not usually practical to select a duct material that will satisfy all services. Since most ducts will corrode in time, it is important to inspect the ducts periodically and to test them regularly for air-tightness. If excessive leakage of air into the exhaust duct does occur, the effective exhaust volume at the hood may be seriously diminished.

Although aluminum, galvanized steel, and black steel have been used for fume ducts, they have only limited resistance to common chemicals. Glazed ceramic piping is usually satisfactory, but it is rarely used because of high installation costs. Materials such as cement-asbestos are inclined to absorb moisture; also, they break easily and are attacked by some chemicals. Stainless steel and Monel are satisfactory if they are used only for chemicals that do not attack them, but there is never any assurance that other chemicals will not be handled at a future date.

Reinforced plastics are selected by some designers, but a choice is made more difficult because of the great variety of materials available and their varied reactions to chemicals and especially to attack by fire. Epoxy coated steels were quite popular in recent years, but fabrication of such ducts near building sites, to reduce shipping costs, involved reliability problems.



7 Air flow patterns around a building.



8 Stack drain arrangements that eliminate need for rain caps.

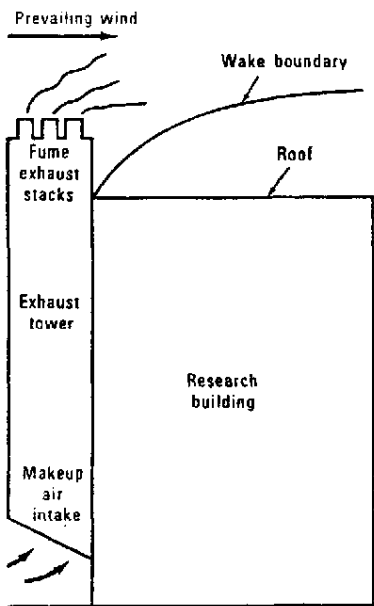
In conclusion, it should be remembered that ~~the design of the exhaust system must be such that it will provide acceptable flow characteristics~~ that may be encountered. Consequently, compromises will have to be made, with the understanding that failures may occur. For this reason, it is important to set up a routine of regular inspections and maintenance if safe and satisfactory operation is to be achieved.

Fume discharge

Each individual exhaust fan on the roof should have its own discharge duct to convey the fumes vertically upward at a high velocity as far above the topmost roof (usually penthouse) as possible. Failure in this will result in potential recirculation of fumes into building air intakes and will be particularly hazardous to personnel who use the roof for maintenance, research, or relaxation.

As the wind blows over the leading edge of a roof parapet, as shown in Fig. 7, a disturbance is created that sweeps from the edge of the parapet up over the top of the building. Above the boundary of this disturbance, wind flow is undisturbed. Below the boundary, the influence of the sharp edge of the building creates eddy currents that tend to pocket fumes released at the roof. This is called the wake cavity. Unless ~~fumes are discharged into the wake cavity~~ ~~stream above the boundary~~, where they can be carried away, they will remain relatively undiluted on the roof and in the lee of the building, where they can enter building air intakes either on the roof or at the ground. When this happens, all the care taken in designing a good fume exhaust system may be nullified. And with the present concern over air pollution, failure to disperse the fumes may give rise

Fume hood, exhaust system design



9 Exhaust tower, architecturally integrated with building.

to legal action against the building owner.

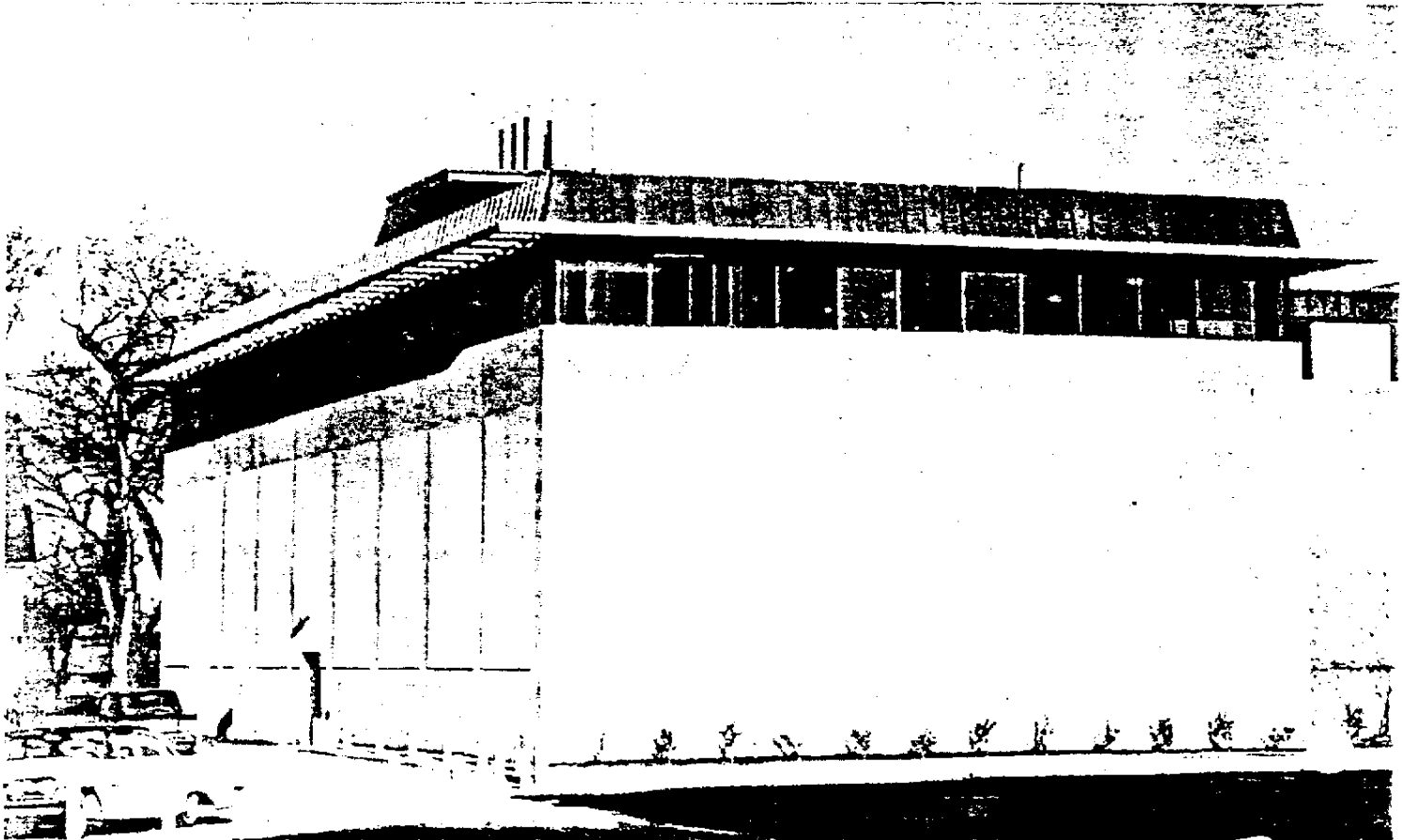
Fume absorbers such as charcoal have been proposed to relieve the fume disposal problem; so have air washers and catalysts. These devices have not been used because the kinds and amounts of fumes released are constantly changing in research and are therefore unpredictable.

Despite the number of warnings in the literature, ~~rain caps~~ cone shaped covers or hoods fastened to the tops of vertical stacks—are still being used to prevent rain from entering exhaust stacks. It is ~~very important that their use be avoided completely~~. The presence of a rain cap or a modern mushroom type roof exhauster will invariably result in the release of fumes laterally across the roof and completely negate the high vertical velocity needed to carry fumes above the cavity boundary and into the undisturbed air

stream above the building. There are several simple stack drain arrangements that will prevent entry of rain into exhaust stacks when fans are not operating. These are illustrated in Fig. 8.

Building air intakes

In high rise research buildings, mechanical equipment is frequently installed both in the penthouse and in the basement. To reduce air intake resistance, outdoor makeup air is often taken from both the roof and the ground floor. Because of the possibility of recirculating fumes released near the roof, every effort should be made to ~~locate building air intakes at the second floor level on the prevailing windward side of the building~~ and away from fume exhausts. A second floor location on the prevailing windward side, shown in Fig. 9, has the added advantage of avoiding most of the dust, odors, and airborne debris



10 Exhaust stacks are clustered on this research building.

that may be present at the ground floor level.

Assistance in determining the prevailing wind direction at the building site may be obtained from the local weather bureau. Some universities have meteorology departments that maintain records of wind speeds and directions. Such information is usually made available in the form of a wind rose giving the number of days during which the wind is expected to blow from various directions during the year.

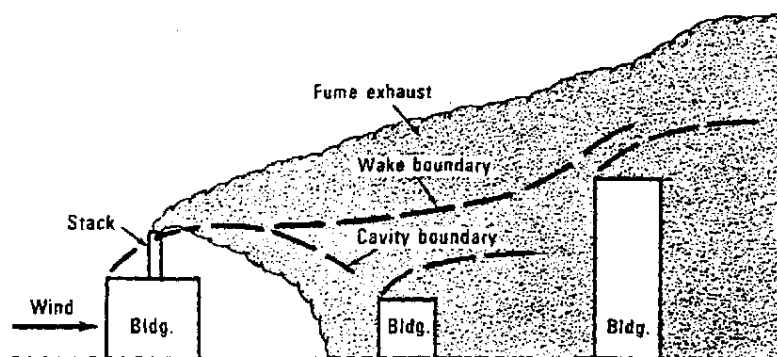
Architectural appearance

The greatest objection to high vertical discharge of fumes usually comes from the architect, who dislikes having the profile of his building disfigured with a forest of stacks. To overcome this, some architects specify screens to surround groups of stacks. Unless a screen permits easy passage of the wind, however, it will simply act as another higher wall with a sharp edge parapet, requiring additional height for the exhaust stacks.

To overcome esthetic objections, it is important for the architect to plan for the release of fumes at the outset of his design by incorporating a feature such as an exhaust tower or clusters of exhaust stacks as an architectural element of the building. Fig. 9, for example, illustrates an exhaust tower located on the prevailing windward side of the building. It discharges fumes vertically upward at high velocity, well above the cavity boundary created by the prevailing wind and at the same time high enough to eject the fumes above most cavity boundaries resulting from winds blowing from other directions. The location of the tower on the prevailing windward side of the building also provides a convenient makeup air intake for the building at the second floor level, as discussed in an earlier paragraph.

Another possible solution to the esthetics problem is to gather the individual fume exhaust stacks over the building service cores as shown in Fig. 10. Bunching of the stacks in this manner also has the advantage of creating a mass of exhaust gases, which is much less readily deflected from upward vertical flow by wind gusts.

Some designers combine the discharges from many fume exhaust



11 Fume dispersion as affected by adjacent buildings.

fans into one or more totally enclosed stacks that discharge the fumes high above the building. If a closed stack is used, it is important to oversize the stack so that it offers negligible resistance to the flow of fumes. Otherwise, the backpressure will force the fumes to flow back through an exhaust system that happens to be turned off.

Consider adjoining buildings

Because fumes are being released into the air stream above a research building, the designer should consider the possibility of fumes being carried to nearby buildings. Since the behavior of air in and around a complex of buildings, trees, and other obstacles is complicated, it is very difficult to predict the degree of contamination at an adjoining building. There are a few simple rules to observe, however.

When the wind is blowing in the direction of adjoining buildings, as shown in Fig. 11, fumes released above the roof must be directed vertically upward to a level that will assure release above the combined wake boundary created by the building complex. Thus, if the proposed research building lies entirely within the turbulent cavity behind a taller building, an exhaust stack from the shorter building should be raised to discharge above the boundary created by the taller building to avoid contamination of the lower building. If the lower building is located in front of a higher building, the exhaust stack from the shorter building must be raised nearly to the roof line of the taller building to avoid contamination of the taller building.

The distance between buildings, of course, will influence the amount of dilution occurring between buildings. The greater the distance, the greater will be the dilution and the less the need for high stacks.

Where the building relationships are particularly complicated or the contaminating effects are uncertain, it is best to conduct wind tunnel investigations using simple models of the buildings, trees, and other obstacles involved to determine the location and height at which an exhaust stack should release its contaminants. There is information in the literature that outlines methods for calculating the degree of contamination (the bibliography entry marked with a *, for example); but it may be easier to consult a specialist who is experienced in such matters. In any event, a predesign study will pay off handsomely in avoiding potential lawsuits and costly corrections.

Safety features

• *Interconnection of hoods*—If two or more hoods independently serve a single room or an interconnected suite of rooms, all the hoods in these rooms should be electrically interconnected so that the operation of one will require the operation of all. Otherwise, there is a possibility that fumes will be drawn from a hood that is not in operation by the makeup air demands of those that are in operation.

• *Alarm for hood malfunction*—All hoods, especially those handling highly toxic or dangerous materials, should be equipped with safety devices such as a sail switch, which will warn the hood user and

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the building management that the air volume exhausted from the hood has dropped to a point where it will not provide sufficient capture velocity for further safe operation.

• **Fire dampers**—Although most building codes require fire dampers in all ducts that pass through fireproof walls or floors, it is important not to install them in fume exhaust systems. If a fire should occur in a hood, or if heat from a fire near such a damper in a fume exhaust duct should cause the damper to close, the occupants in the laboratory and adjoining spaces might become casualties before anyone realized why the hood had ceased to function. Fire dampers are intended to prevent transmission of fire from one part of a building to another

through a closed circuit of ductwork. Fume exhaust systems are not closed systems, however. They deliver air only to the outdoors in an upward direction, and they are therefore essentially chimneys. For this reason, fire dampers are not needed, and their presence is extremely hazardous.

• **100 percent exhaust from laboratories**—If materials being handled in a laboratory are hazardous enough to require the installation of a fume hood, the presence of these materials within the laboratory should also require 100 percent exhaust of the air from that laboratory. Otherwise, an accidental spillage or accidental release of materials at a bench can result in fume recirculation throughout the building. Accidental recirculation is a serious hazard to other

ongoing experiments and to personnel elsewhere in the building. In the past, it has required emergency evacuation in a number of cases.

Cost of extra hoods

Because research has become more complex and because the presence of a fume hood in a laboratory seems to have become a matter of prestige, there appears to be a tendency for research organizations to specify more fume hoods than may actually be needed for the research programs involved. Additional fume hoods are very expensive, and it becomes the duty of the designer to warn the owner regarding the high costs of excessive hoods. In estimating such costs for the owner, the designer should include the following:

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First costs—

- The total installation cost for each incremental fume hood.
- The total installation cost for each incremental fume exhaust system required.
- The pro rata portion of the installation cost for the additional heating and cooling capacity needed to condition the makeup air required by each hood.
- The pro rata portion of the cost for constructing the space occupied by the hood.

Annual costs—

- The annual cost for maintaining each additional hood.
- The annual cost for operating and maintaining each additional fume exhaust system.
- The pro rata share of the annual cost for operating and maintaining the additional heating and

cooling capacity needed.

- The pro rata share of the annual cost for operating and maintaining the space occupied by the hood.

Cost of investment—

- The annual cost for the total investment for each hood.

Before discussing these costs with the owner, the designer should make allowance for the makeup air required for ventilating the building. Since some of the hoods obviously can be used to exhaust the ventilation air, the operating costs for such hoods should not be included when totaling the cost of hoods that might otherwise be considered nonessential to the total project.

Although costs vary considerably with locality, quality of construction, and current rates of in-

flation, an estimate of costs is given in Table 1 as an example. It is assumed that the typical incremental hood is a 5 ft unit with a 10 sq ft sash opening (4 ft wide by 2½ ft high) to be operated at 100 fpm face velocity, requiring 1000 cfm of air exhausted from the laboratory.

The tabulated costs are very rough estimates and are not to be used for budgeting costs for a particular job at a particular locality. The costs are intended only to focus attention on the importance of giving full consideration to the high costs of owning and operating fume hoods, especially those hoods that may not really be needed.

Before presenting such an estimate of costs to the owner, the designer should be prepared to

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Fume hood, exhaust system design

suggest alternatives for the additional hoods originally desired. One of these is the exhaust box or glovebox type enclosure described earlier, which requires much less makeup air than a fume hood. Another possibility is to provide double or triple horizontal sliding sashes in place of a single vertical sash, thus limiting the maximum air flow through the sash opening.

Another possibility, not recommended, is to provide auxiliary air for noncritical hoods as discussed earlier. An economic analysis must first be made, however, to determine whether a genuine saving can be realized with such a system (bearing in mind especially that auxiliary air hoods require the installation of individual tempered air supplies in addition to the items of costs mentioned above). Since most alternatives are costly and not at all satisfactory, simply not installing unneeded hoods is definitely the best solution.

Maintenance all-important

Since hood performance may be greatly affected by the cleanliness of the exhaust system and the direction of rotation of the exhaust fan, it is important to provide an enforced schedule of inspections and performance tests during the year to make sure that the fume hoods are operating safely and satisfactorily.

If filters are used to remove particulate matter from the exhaust air, they must be periodically inspected and replaced. Also, special attention should be given to possible corrosion of ducts and damper mechanisms and to the collection of debris along the duct. As mentioned earlier, excessive corrosion may cause air leakage into the ducts or failure of balancing dampers, thereby reducing the already critical capture velocity. It is especially important to remember that ~~wrong maintenance of the exhaust fan is likely to be the most common cause of poor hood performance.~~

Performance tests

All hoods should be periodically tested for satisfactory operation whether they are new or have been in use for many years. **Two tests** are usually performed, one for **fume leakage** and the other for **face velocity**. The test for fume leakage consists of releasing

Table 1—Investment cost and annual owning and operating cost are tabulated on a per hood basis to illustrate what items should be considered in an economic analysis of an exhaust hood system and give an idea of the magnitude of the costs involved. Costs will vary for particular installations depending on such factors as system design, hours of operation, local energy costs, accounting method used to determine annual charges on investment, and applicable insurance premium and/or property taxes.

Investment cost (installed) per hood	
• Cost of hood and bench (5 ft hood length at \$280 per lin ft)	\$ 1,400
• Cost of hood utilities, including 20 ft of piping (water, \$125; gas, \$100; air, \$75; electricity, \$80; drain, \$70)	450
• Cost of hood exhaust system (fan, \$400; roof opening, \$100; wiring, \$300; 75 ft of duct at \$10 per ft)	1,550
• Pro rata cost of heating and air conditioning equipment (6 tons for 1000 cfm of outside air at \$1500 per ton)	9,000
• Pro rata cost of space occupied by hood (5 by 3 ft floor space at \$80 per sq ft)	1,200
Total investment cost	\$13,600
Annual owning and operating cost per hood	
• Cost to maintain and test hood	25
• Cost to maintain and test exhaust system	40
• Pro rata cost to maintain heating and air conditioning system (6 tons times \$4000 per year maintenance contract for 200 ton system)	120
• Pro rata cost to maintain building (5 by 3 ft floor space at \$3 per sq ft per yr)	45
• Cost to operate 1000 cfm exhaust system (1 KW per hp per hr for 1 hp times 24 hr per day times 365 days per yr at \$0.015 per KWH)	130
• Pro rata cost to operate cooling system (6 tons for 1000 cfm of outside air at 1.25 KW per ton times 1200 hr per yr at \$0.015 per KWH)	135
• Pro rata cost to operate heating system (110 Btu/h per cfm times 1500 hr per yr at \$0.10 per therm)	165
• Pro rata cost to operate building air supply fan for 1000 cfm makeup air (assume same costs as for exhaust fan)	130
Total operating cost	\$ 790
• 5 percent per yr for \$13,600 investment	680
Annual owning and operating cost	\$ 1,470

odorous fumes such as ammonia or hydrogen sulfide within the hood. If fumes are detected outside the hood, especially around the face opening, the capture velocity at the sash opening may be inadequate, or there may be an interfering air disturbance. Cleaning the exhaust system, adjusting the air flow damper, or increasing the fan speed may improve the performance if low face velocity seems to be the problem.

If, on the other hand, the leakage seems to be caused by interference from a stream of auxiliary air supply or other air velocity near the sash, the nature of the interference may be investigated by placing liquid titanium tetrachloride on masking tape placed around the periphery of the sash opening and on lengths of string strung as a series of grid traverses over the entire sash opening. Observation can then be made of the path of visible fumes to determine where there is spillage into the room. Smoke bombs have also been used to determine air flow patterns at sash openings and identify interferences.

A ~~hot wire anemometer~~ is usu-

ally used to measure actual face velocity. This is done as a traverse over the entire sash opening, including especially all edges and corners. The overall average face velocity is obtained by averaging the velocity readings at prescribed positions of the traverse.

Since the tests described above depend on subjective observation and on testing procedures that are difficult to standardize, they are considered to be unadaptable and inadequate. For this reason, ASHRAE has set up a research project for developing fume hood performance criteria and new test procedures. Although ASHRAE has approached fume hood users and manufacturers for support, no funds have been made available so far. Because of national concern over air pollution, however, and the trend toward suing equipment manufacturers and building owners because of unsafe equipment designs or unsafe working conditions, the need for criteria and test procedures is becoming urgent, and special efforts are again being made to find a way to develop the much needed performance criteria and suitable test procedures.

ventilation

E. L. WALLS

W. P. METZNER

FUME HOODS—SAFETY VS. COSTS

Size, air velocity, total flow, and economy are compatible

The two requirements for fume hood operation—safety and economy—seem almost incompatible in the light of increasing safety requirements and the ever increasing costs of building and operation.

Little question can be raised regarding the need for fume hoods. They exist for the sole purpose of protecting the user from the toxic or noxious effects of the chemicals or other contaminants with which he works. The extent and manner in which it is done, however, is probably the most controversial subject one can choose in the design of today's research, works, and teaching laboratories. Countless articles and books have been written on the subject, but few of these, if any, have really come to grips with the problem of providing a safe fume hood which is economical in both capital and operating costs.

Face velocity—air moving from the operator across the contaminating source—determines whether the hood is safe or not. Regardless of how much total air a fume hood has moving through it, if it doesn't have sufficient face velocity it isn't safe. The source of this air (the working air) is from the room, which in most of today's laboratories is conditioned air. This is the major cost item. Thus, the crux of good fume hood design is providing maximum face velocity at minimum total air movement.

The rule-of-thumb correlation between fume-hood exhaust and air conditioning refrigeration is that each 200 cubic feet per minute (c.f.m.) of air exhausted equals 1 ton of refrigeration, or in terms of cost, equals approximately \$1000 in capital investment. Thus a conventional 6-foot wide fume hood, ranging in cost from \$900 to \$1400, having a face opening of 16.5 square feet with a face velocity of 100 feet per minute (f.p.m.) would require an investment in an air conditioning system of approximately \$8200, to say nothing of what it would cost to operate the system. Also, the requirement of

1650 c.f.m. would severely limit the number of fume hoods that could be located in a laboratory room.

Building costs are constantly increasing. In addition, during the last decade advancing technology and use of new and unknown materials have raised the commonly accepted safe face velocity of chemical fume hoods from 50 to 100 f.p.m. (7). This is still going up. Some materials are already considered hazardous enough to require face velocities in excess of 200 f.p.m. The matter of face velocity recommendations is well covered in the

WHY AVAILABLE FUME HOODS DID NOT MEASURE UP

The conventional fume hood was obviously not acceptable. A very high volume of air (up to 1600 c.f.m.) is required to produce safe face velocity when the hood is open far enough to permit freedom of work.

The auxiliary-air hood with internally supplied air was dismissed because it accomplishes absolutely nothing toward reducing the air required from the room to assure a safe face velocity. In fact, our experience with this type of hood was that it tended to "bounce" air out of the hood. None of these hoods with an auxiliary air fan is used at Monsanto today.

The auxiliary-air hood with supplementary air supplied just outside and pulled through the face of the hood, is a satisfactory choice from the safety standpoint. Again, large quantities of air must be handled. Also, the auxiliary air, although tempered, passing over the head of the user is not too desirable.

Both of the auxiliary air hoods must be provided with a bypass to take air from the room when the sash is closed, or the system will be hard to balance. Such a system is also expensive because it requires three ductwork systems—two for supply and one for exhaust.

article (3), "An Approach to a Rational Method of

Recommending Face Velocities for Laboratory Hoods."

The problem that had to be faced in the design of

Monsanto Chemical Co.'s new Research Center at

Creve Coeur, Mo., was

- To provide a 6-foot wide fume hood for each man
- To provide for four men to each laboratory module
- To recognize the need for a high face velocity
- To maintain reasonable capital and operating costs
- To design a system for the building of 80 laboratory modules

Safety would not be compromised. Since either re-

ducing size or number of hoods would be detrimental to

the research effort, a new approach had to be found to

provide both—economically.

In its final form, the hood designed was safe. A face

velocity of 100 f.p.m. was provided, with only 550 c.f.m.

hood with similar performance.

As for cost, this fume hood costs little more than con-

ventional equipment—between \$1100 and \$1300 per

unit. But it requires only 50 to 60% of the investment

in air conditioning equipment needed for a conventional

hood with similar performance.

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ventional equipment—between \$1100 and \$1300 per

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hood with similar performance.

Use of a horizontal sliding sash instead of the conventional

rising sash

—Taking the air flow through the hood at all times

Air is introduced through simple baffles at the sides and floor of

the hood

Two major innovations made such performance possible:

conditioning system can be easily balanced.

and easy maintenance were built into the unit. The air

areas easily accessible. Maximum human efficiency

equipment. A 6-foot opening was provided, with all

of air flow, even when the hood area was filled with

equipment.

These new fume hoods provide safe operation at minimum cost. The

bench-model hood yields a face velocity of 120 f.p.m. in the one-third

open position and 55 f.p.m. in the two-thirds open position at a total

air discharge of 550 c.f.m. The walk-in hood uses 650 to 700 c.f.m.

and will accommodate 10-foot tall apparatus. It is accessible throughout

its height by upper and lower sliding glass sections. The lower

section can be completely removed, including the track, to facilitate

installation and removal of large apparatus. With slight modifications,

two hoods can be installed back to back to form a walk-through hood



UTILITY VALVE HANDLES

AIR INTAKE LOUVERS

STORAGE

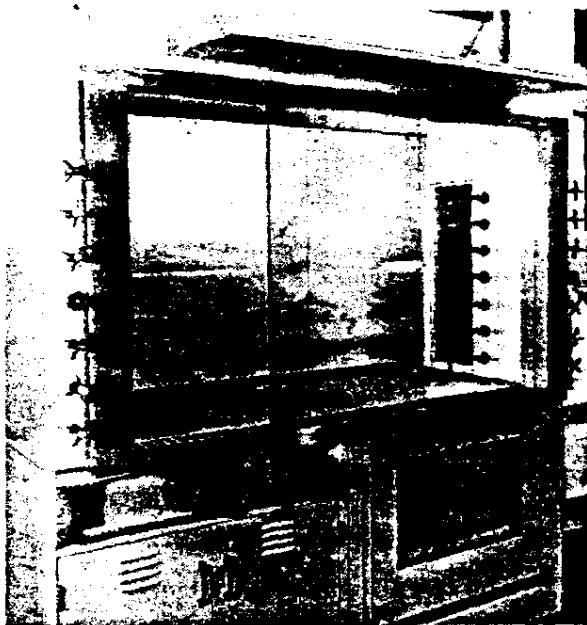


Figure 1. The original prototype hood. Immediately above the sash opening is a hinged blow-out panel held in place by magnets. The panel is designed to relieve pressure within the hood in the event of an accident and to reduce the chances of the glass sash blowing completely out of the frame. (The glass is Saflex safety plate). The deep well provided at the side of the hood permits the use of tall apparatus. Power is taken into the hood through openings at each of the front corners.



Figure 2. Smoke tests assure air movement away from the hood face.

In the final hood, static pressure variation cannot be measured with ordinary instruments with the hood open or closed. This, coupled with the building's double duct high velocity air conditioning system, makes balancing of the total system quite easy. The hood has eye appeal with clean, easily maintained lines.

Acknowledgment. The authors wish to acknowledge the contributions of W. A. Clenay, J. R. Kendall, C. C. Wirts, and the many chemists of Monsanto Chemical Co. who made the design of these hoods possible.

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Figure 3. Prefabricated piping and electrical systems are seen in place on the hood prior to connection to the main service distribution system. All services except the drain are in the superstructure, so that the hood is quite easily moved.



Figure 4. The second prototype included many changes suggested by testing. The redesigned bottom grill was a major improvement.

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SPECIFICATIONS

The fume hood must satisfy the size requirements for conducting experiments in all branches of chemical research except radiological chemistry.

It must provide safe face velocities for the work being performed.

It should use no more than 550 c.f.m. of room air, due to the room size and occupancy (22 X 30 feet with 4 men). An excess of 2200 c.f.m. of air movement in the room would result in high discomfort to the occupants.

It must be easily balanced as a part of the total air conditioning system. No air from the laboratory rooms is to be recirculated in order to reduce the danger of experiment contamination.

It must be easily movable.

It must be easily maintained and aesthetically acceptable.

Although listed and discussed separately, these specifications are interrelated, and they must be considered simultaneously in the design.

Basic Hood Design

The first three; namely, size, velocity and total air flow were the key factors which determined the over-all type of fume hood. They seemed so incompatible that the job at first seemed impossible. How could a hood 6 feet wide be used freely while maintaining a face velocity of 100 f.p.m., or better, with only 550 c.f.m. of total air available? Every portion of the hood space should be readily and easily accessible to the user. Yet the hood opening must not exceed 5.5 square feet. The only way these criteria could be satisfied was the use of horizontal sliding sash in lieu of the conventional rising sash. For the 6-foot wide hood, a three-sectioned sash was chosen which, when one third open, yielded 100 f.p.m. velocity with a 550 c.f.m. air movement. Thus, three of the requirements were satisfied.

The next factor, air balance, was not quite so simple. Air flow formulas were of little value and the design had to be empirical. To reduce the total building space requirement, a decision was made to use a single exhaust fan for the four hoods within the laboratory module. If the air conditioning system was to be balanced it was mandatory that each hood, regardless of sash position, maintain as near constant static pressure drop as possible. The "by-pass" damper system used on many hoods having a rising sash was not practical with the horizontal sliding sash. The answer to this problem was to make the air flow through the hood at all times. Air was introduced into the hood at the sides with a simple baffling system sufficient to prevent splash-outs. Severe tur-

bulence caused by the side-entering air was effectively eliminated by introducing air at the bottom of the sash through a grill placed level with and between the front edge of the bench top and the sash frame (Figure 1). A stainless steel trough was designed to run under the full length of the grill to catch liquid spills. This trough doubles as a cup sink for draining off condenser water, etc.

Prototype Testing

A prototype hood was built and installed in a full size laboratory mock-up at Monsanto's Dayton, Ohio, Laboratory. This approach to testing cannot be over-emphasized. Any fume hood is subject to the conditions of its environment and it is rather common for a hood to perform satisfactorily in one place and fail completely in another. Some of the factors affecting the performance of a fume hood are location within the space relative to traffic patterns, proximity to doors and heat-yielding sources, room air currents, and temperatures. Smoke tests (Figure 2) were used to establish flow patterns.

Tests of the first prototype are a subject within themselves (2). This hood when empty, was safe—i.e., it had no negative flow through a one third open position, with only 300 c.f.m. total air exhaust. Introduction of equipment into the hood, however, required raising the total air to 410 c.f.m. With the sash closed completely, air entering the bottom opening rose so rapidly across the sash that the Venturi effect caused aspiration of air toward the front. Thus, when the hood was opened, there was a tendency for light vapors to be swept into the room. Although this boil-out was immediately swept back into the hood, it definitely crossed beyond the face of the sash and was highly undesirable.

Figure 4 shows the second prototype. The bottom grill was redesigned with smaller openings to eliminate the Venturi effect at the sash opening. Several changes were made for more efficient use. The bottom grill was hinged longitudinally to permit easy cleaning of the trough and to permit easy passage of electric cords into the hood across the entire face. The electric service was incorporated into the frame of the sash and portable variable transformers were placed on a shelf immediately under the trough. The side baffles (which were "knuckle knockers") were changed to louvers in the face of the sides with the valve handle extensions passing through the louver. The lights were installed in an inverted drawer accessible by opening the blow-out panel, which permitted use of the space above the hood for storage.

Tests of the second prototype resulted in placement of guiding vanes on the lower side of the bottom grill and addition of slots in the back baffle to produce a more laminar flow of air across the hood floor; reduction in the size of the side louvers to reduce the air flow; and a reduction in the height of the sash opening which increased the face velocity without impairing visibility. These changes were incorporated into the final hood design.

AUTHORS. E. L. Walls is a Laboratory Design Consultant and a Registered Professional Engineer in St. Louis, Mo. He was Project Architect for Monsanto's Research Center in St. Louis and designed the fume hoods described here. W. P. Metzner is Director of the Monsanto Research Center.

Ventilation

ESSO RESEARCH AND ENGINEERING COMPANY

(FORMERLY STANDARD OIL DEVELOPMENT COMPANY)

P. O. BOX 45, LINDEN, N. J.

MEDICAL RESEARCH DIVISION

TELEPHONE: WABASH 5-1600

July 24, 1962

Mr. F. S. Venable
Humble Oil & Refining Company
Manufacturing Division
Baton Rouge Refinery
P. O. Box 551
Baton Rouge 1, Louisiana

Dear Fred:

Attached is a draft of some material which we have put together on laboratory hoods, and you requested this in light of your current interest in hood installations. Please treat this in a confidential manner as it is being considered for publication and will be subject to some changes.

Very truly yours,

N. V.

N. V. HENDRICKS

NVH:WK

Att. - R.D. on "Chemical Type Laboratory
Hoods" - 7/1962 NVH

SAL 000045385

CHEMICAL TYPE LABORATORY HOODS

1. CONTINUED INTEREST IN HOODS

Fume hoods have long been a standard fixture in chemical laboratories where, until recently, little attention has been given to actual hood performance. The requirements of new laboratories, especially research facilities have introduced new concepts both in design and operation of chemical hoods. Several factors have become important and each has a bearing on the requirements for design and operation.

In many new laboratories, hood installations are much more extensive than in older facilities. Some laboratories may treat an entire wall length as a hood, giving a considerable area of hood face with corresponding large air flow requirements. Along with this is the acceptance of higher hood face velocities that are required for adequate control of highly toxic materials.

A different problem is seen in many older laboratories where original hood design and related appurtenances have been established. In these situations, the initial design called for lower air movement than

is acceptable today, and an often complicating factor is the addition of other hoods to a fixed system or in some cases other ventilation systems actually competing for the available air in the rooms. Obviously, this results in lowering the efficiency of an already questionable arrangement.

Laboratory architects frequently use chemical hoods to exhaust the supply air to the laboratory building. Thus, the total exhaust from the hoods is balanced against air input. This arrangement becomes critical in terms of building heating and air conditioning when total hood operation calls for large volumes of air. Depending on actual hood requirements, this may even rule out air conditioning for some laboratories, as well as imposing unusual heating problems for others.

These engineering and architectural problems related to hoods certainly justify serious consideration as to what can be done to make maximum use of older hood installations, and further, what can be done with the design of new installations to minimize these problems. There is a great need for sound criteria for the design and operation of chemical hoods.

2. MEDICAL RESEARCH DIVISION INTEREST IN HOODS

In the course of industrial hygiene studies in a number of locations, the Medical Research Division of Esso Research and Engineering Company has made around several hundred chemical hoods under a wide variety of conditions and at many locations. These have covered velocity and air flow measurements as well as atmospheric sampling for contaminants around hood areas. These studies clearly demonstrated need for and value of criteria for uniform hood operations.

In 1958 the Medical Research Division suggested a classification schedule for laboratory hoods in order to take advantage of lower air flow requirements where work does not involve highly toxic materials. This schedule relates air flow requirements to toxicity of materials handled. These principles proposed at this time are considered valid today.

As interest in hood design and operation increased, further study was given to this area in 1960 and recommendations on laboratory fume hood installations were prepared. This material was broader than the schedule suggested in 1958, and included a number of design features. It was prepared

after visits to a number of locations where studies on hood design and operation had been made. The present discussion brings together the features of these earlier reports and also includes new material developed since 1960.

CHEMICAL TYPE LABORATORY HOODS

3. HOOD OBJECTIVES AND USAGE

When air is moved through a hood, there should be only one primary objective and this is the capture and removal of any material which is emitted inside of the hood. Air movement for any other purpose in the laboratory can be done in a much more economical and efficient manner by other means.

The needed volume of air to effect capture and removal not only depends on the physical characteristics of the hood and its location, but also on hood objectives and usage. Depending on the toxicity of the material being handled, the effectiveness of capture and removal can vary over a wide range from complete removal for highly toxic materials to lower orders of removal efficiency for less toxic substances. For example,

if only water vapor is being emitted, the effectiveness needs only to be sufficient to control humidity conditions in the laboratory. If, however, a material such as nickel carbonyl is involved, the removal efficiency needs to be complete.

Hoods may serve purposes in addition to removal of emitted materials from either continuous or periodic operations, particularly where more than one hood per laboratory is available. Invariably, the hoods are interconnected with the building exhaust system and, often as not, this requirement becomes the primary function during design stages. Hoods are sometimes used as a safety enclosure of an operation which does not emit any material unless an untoward event occurs. Designing for a sufficient volume of air movement to contain an explosion is generally unwarranted. Hoods are also used only for heat removal from hot operations or for hazardous chemical storage. All of these factors must be considered when deciding on the volume of air movement needed.

4. SOME FACTORS AFFECTING HOOD OPERATION

There are a number of characteristics related to materials used

in a hood that can influence hood operation. In addition, there are physical factors associated with activities in the laboratory that may become important. Some of the more important ones are listed below.

A. Characteristics of Materials Handled

- Liquids - vapor pressure, temperature, molecular weight, latent heat vaporization and toxicity.
- Solids - particle concentration and size distribution in the air and toxicity.
- Gases - concentration, specific gravity, toxicity.

B. Condition of Hood Usage

- Contaminant emission rate.
- Contaminant emission velocity.
- Location and direction of emission.

C. Disturbing Effects

- Traffic past hood.
- Room air currents.
- Heat rate in hood.

- Movement of equipment in hood.
- Obstruction of air pattern by equipment in hood.

These items suggest that careful consideration must be given to a number of factors when arriving at the theoretical design of a hood system. Some of these components can be expressed in a quantitative fashion, while others, though important, are difficult to describe in a quantitative fashion and are even more elusive in terms of inclusion in actual hood design.

Another item is the cost of hood installation and operation. System design begins with the hood, and once these characteristics are worked out, it automatically establishes the design of the rest of the system, such as volume of air, duct work and air movers. It becomes evident that in order to keep these items at the lowest level consistent with satisfactory operation, considerable effort can be justified in evaluation of hood factors and actual design.

Two other major factors are involved, not only in the capital investment, but also in operating expense. These are any air conditioning or heating load that may be occasioned by removal of air from the laboratory.

The extent of these factors are, of course, largely dependent on local climatic conditions.

5. IMPORTANT DESIGN AND USE CRITERIA

The following list of recommendations will provide guide lines for judgment on hood and air supply location, hood design and hood operation.

A. Location-

1. The hood should not be located near an open window, adjoining heavy traffic aisles or doorways. The presence of room turbulence caused by these factors, and poorly located room air supply outlets, may negate the usefulness of the laboratory hood.
2. Air supply to the laboratory is best accomplished by use of a perforated ceiling as the supply plenum. High velocity, supply grills are not desirable because of created air turbulence which may necessitate higher face velocities for adequate hood control. Supply plenums in the ceiling, on the other hand, have been shown to have tremendous air flow capacity with low turbulence and may be more economical in use for this reason.

3. Spot local exhausters that can be moved to the point of contaminant release, using adjustable blast gates on flexible ducts, can be utilized to advantage. Such units are highly desirable in areas where emission-creating laboratory work may be conducted outside of the hood.
4. Additional exhaust grills in laboratories (other than hoods) can be provided to withdraw supplied conditioned air when the hoods are not operating.
5. The use of an ~~auxiliary~~ supply to conserve on air-conditioned air exhausted by hoods can be justified only if the auxiliary air is treated, primarily to prevent condensation problems. It is recommended that this air be brought to near room temperature and outside ambient humidity, if it is used.
6. Auxiliary air, if used, should be supplied outside of the hood proper through either a perforated ceiling or a low velocity grill. Auxiliary air supplied inside the hood disturbs the patterns of room air entry into the hood, and makes fume escape highly probable.

B. Design Features

1. The edges of the hood should be shaped to give a smooth air foil entrance. Such a shape is particularly necessary at the bottom edge where the optimum design would be a ~~quarter ellipse~~. A clearance should be provided between the bottom air foil and the bench-top to allow air flow under the foil at all times. This action provides a constant flow of air into the hood, clearing it even when the doors are closed. The side edges of the hood are not as critical as the bottom edge. ~~Expanding the sides~~ so they are at a 45 degree angle with the hood is an acceptable substitute for an elliptical section. The tapered sides should be at least 6 in. wide and have the edges rounded.
2. The back baffle in the hood should have at least three openings, one at the intersection of the baffle and the bench-top, and the second, at the intersection of the baffle and the hood face or top, and the third between these two. These openings should run the full length of the hood, and each should have a minimum open area equal

to the outlet duct area. Adjustable slides may be used in conjunction with these baffle openings to establish the desired uniformity at the face after installation.

3. Each hood should have its own fan exhausting to an individual stack.

In critical situations, fan speed and size can then be changed easily to meet changing requirements. Plenums and the use of fans to exhaust many hoods are considered to be undesirable mainly because of the inflexibility of the system and its wasteful exhaust capacity. For an existing building using a plenum exhaust system, additional hoods might be accommodated even at limited exhaust and supply capacity if the hoods are placed on an on-off operations using electrically controlled dampers. The dampers would open into the plenum system only when the hood is turned on. Hood use factors as low as 55 per cent have been noted in some laboratories. Advantages may be taken of this fact in some cases where careful study has been done and controlled hood use can be effected.

4. The fans should be controllable near the hood face with an on-off

switch. Two-speed fan operation, if desired, can be accomplished by a two-speed motor for most fans or, at lower cost, by a reversing switch for forward-curve, centrifugal fans.

5. The exhaust stacks should not have weather protection that requires the air to change its direction upon discharge. No weather protection, or else a butterfly damper cover on the top of the stack should be used. New style weather exhausts have been developed and good results are reported with them.
6. Where open face velocities exceed 125 feet per minute, the installation of an atmospheric damper is suggested to prevent excessive velocities when the open face area is reduced upon closing the sash.

C. Hood Operation

1. Equipment placed within the hood should be so located that the points of contaminant release are ~~at least 6 inches back from the hood face.~~ Tests have shown that even at very high face velocity, contaminants located near the face of the hood can escape into the room by "follow-out" when an individual walks past the hood face. This point is of

paramount importance. Laboratory acceptance of the principle of working back in the hood can be implemented by placing a 1/4 in. thick edging, 6 in. wide on the bench-top near the hood face. Any similar device to attain a "defense in depth" is warranted.

2. The lower hood baffle opening should not be obstructed with large objects or many small ones. Bottles or chemicals that require some ventilation should be placed in a ventilated storage area or on separate shelves provided in the hood proper.
3. Concentrated heat loads within the hood exceeding about 5,000 watts or 1,000 watts per foot of hood length create thermal vectors that require higher face velocities for adequate control.

6. CLASSIFICATION SCHEDULE

For maximum flexibility in the use of hoods, and also for maximum health protection, the ideal situation would be to provide universal hoods with an air flow which would insure complete capture of all materials released within the hood. However, a reduction in investment can be effected by an alternate procedure. This would involve classifying hoods for different

services. This assumes that only normal laboratory work would be done and that no unusually large quantities of materials would be involved or released. Although the advantage of a reduction in investment has been pointed out, there is the disadvantage of lowering the flexibility of hood use and the further disadvantage of offering no overall modification of ventilation rates once an installation of this type has been made.

In establishing categories of hoods, the following classes are suggested.

- A. Class S hoods are recommended for handling highly toxic materials where complete control is required. For work falling into this category, hoods should operate at a face velocity of 125 ft./minute. Such hoods should have special design characteristics depending on each individual situation. Materials handled in these hoods would include tetraethyl lead, radioactive materials, beryllium compounds, carbonyls, and materials having a similar high order of toxicity.

4 As a guide, Class S hoods would be used to handle materials

with a maximum allowable concentration (MAC²⁶) of <.1 ppm for gas and vapors or <.1 mg/cu.m. for dusts, fumes and mists.

B. Class A Hoods would operate at a face velocity of 80 ft/minute.

These could be used for any operation with the exception of those offering potentially severe hazards due to a high order of toxicity of materials to be handled. Basically these hoods would be used for materials having from a moderate to a high order of toxicity.

For reference, Class A hoods could be specified for materials whose MAC's are in the range $\geq .1$ to < 100 ppm for gas and vapors, $\geq .1$ to < 15 mg/cu.m. for dusts, fumes and mists, and ≥ 5 M.P.P.C.F. for mineral dusts.

C. ~~Class B Hoods~~ would operate at a face velocity of 50 ft./minute.

These could be used for all operations where the hazard is not unusual due to a moderate or low order of toxicity of materials to be handled. This would include essentially all hydrocarbons

and most likely would represent a great portion of the work required under a hood in most petroleum laboratories.

Class B hoods could be utilized when the contained materials have the following MAC's: ≥ 100 ppm for vapors and gases, ≥ 15 mg/cu.m. for dusts, fumes and mists, and > 5 M.P.P.C.F. for mineral dusts.

where: ppm - Parts of vapor or gas per million parts of air by volume.

mg/cu.m. - Milligrams of dust, fume, or mist per cubic meter of air.

M.P.P.C.F. - Millions of particles per cubic foot of air.

These hood classifications are suggested for installations where more than one hood is to be provided. For situations where one hood only is installed, a Class B hood is suggested.

It is suggested that where the toxicity of a material is unknown, but because of certain characteristics, it is suspected of possessing a high order of toxicity, the material be handled under a Class S hood. It is further suggested that any other materials not given on the established MAC

lists be handled under Class B hoods until toxicity information is obtained.

On the basis of such information, assignment to other hood classifications might be possible.

In order to insure a reasonable uniformity of air flow across the hood face, it is suggested that ~~no area of the face should have a velocity~~ less than 80% of the average value. When a hood system is put into operation its air movement is at an initial peak, then will decrease over a period of months or years. Part of this loss is recoverable and part non-recoverable. Recovery may be accomplished by maintenance on the system, fan, duct work etc. On the other hand, little can be done about the non-recoverable portion of the loss, and this may amount to 15-20%. This point should be recognized and compensation made to cover it in the ~~initial design by allowing~~ing a 20% ~~in excess of the rated air movement.~~

While it is pointed out that the greatest flexibility and highest order of protection can be obtained by an installation of universal hoods for normal laboratory use, the schedule outlined above may offer a reasonable hood operation with considerable savings. The limitations of this type

schedule should, however, be recognized. There will be the administrative or supervisory problem of seeing that these hoods are used for the category of materials for which they were designed. Also, there is the case where only one hood is available for general laboratory work. In this situation we would suggest a Class A hood.

7. HOOD TESTING - COMPLIANCE AND PERFORMANCE

A. Instruments

Suitable instruments for measuring air velocity include most of the hot wire thermo-anemometers and the swinging ~~van~~ anemometer (velometer). Care must be exercised in selecting instruments, since many air velocity units do not accurately indicate velocity below 100 FPM. Instruments found useful by Medical Research Division include the Alnor Thermo-anemometer and the Alnor velometer.

Some mention should be made of the need for instrument calibration. This equipment is quite sensitive and handling and shipping will frequently throw an instrument off calibration.

Periodic calibration is essential.

B. Test Positions

In testing the open area of a laboratory hood, ~~linear areas~~ should be used, if possible, for the maximum open position.

With sashes in the half open position, perhaps, as many as eight areas would be appropriate. The individual doing the testing can quickly assess the number of test points needed to accurately measure the linear velocity into the hood accounting for the variations in velocity at the face. As a means of checking both the instruments and the air velocity, two tests are recommended for checking the average velocity. The first test is run with the hood open to its maximum open position; the second, run with the hood half way open. The average velocities are obtained simply by averaging the results of the multi point traverse, and in each case, the average velocity is multiplied by its corresponding open area during the testing. The same value for total volume withdrawn by the hood should be

obtained from the two tests. If not, then retesting will be necessary to be sure that turbulence factors have not changed the readings at any one location. In this regard, it is important also to test the hood for unusual air flow patterns by using smoke tubes or titanium $TiCl_4$ coated swabs.

It is best to run the hood tests under actual operating conditions, where pneumatically-operated stirrers, hot plates, burners, and the like, would be used. Such items plan an important part in the effectiveness of the hood operation as measured by the tests outlined here. Tests on an empty hood without any operation being conducted inside may not give representative results for the same hood being used with equipment such as that described.

C. Number of Tests

Depending upon hood usage, ~~tests may have to be repeated as~~ often as monthly for highly changeable toxic experimentation. For other routine operations, ~~yearly testing~~ may be perfectly

satisfactory. New hoods should be tested initially to be sure they meet design specifications. If the hood is acceptable, the data will serve as a comparison for future testing. This is, of course, true for any hood. Data recorded near the hood will serve as an operating standard for future testing. The critical point here is not the exact frequency of testing, but the necessity to retest periodically, and in the same manner. A simple chart as developed by Ketchum can be used for permanent record and comparative purposes.

D. Evaluation of Results

Uniform flow across the face is considered to be important for controlling emissions at all points in the hood. For this reason, a criteria of velocity distribution has been established. The velocity at any point should not be less than 80% of the average velocity. For variation greater than this, it is suggested that the baffle plates be adjusted to give this desired uniformity. Depending upon the operation

being conducted in the hood, the average face velocity should at least equal the average value suggested in these criteria. In comparing tests with previous results, it is important to recognize that air flow may be decreased with time because of such factors as dirt accumulation in the ducts, fan belt slippage, fan wheel corrosion and deterioration. From experience, it has been found that the decrease in air flow from initial operation may be as much as 20% after a few years of operation. Thus, in repeated testing, it would be expected that the air flow levels would decrease slightly between tests. As long as the average velocity and velocity distribution criteria are met, however, no action will be necessary. Good maintenance practices should keep laboratory hood systems working properly.

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Eyewash, Safety Shower*Continued from preceding page*

The lever, if used, should be no more than 34 in. above floor height, with an 8-in. handle and require about 10 oz of pressure to activate it.

All safety shower valves or control devices throughout the plant should be the same height, the same position, and operate at the same position relative to all features of the unit.

All controls should be located so that they are directly in front of the employee when he is in a position to be neutralized by the water spray.

The unit, once activated, should remain on until deliberately deacti-

vated.

The control device should operate in the direction of travel.

Safety showers and eyewash facilities should be marked in some manner.

It is recommended that a light be located at the shower which turns on whenever the shift is in operation.

Alarms should be installed that, when the shower is activated, sound in other areas of the plant, especially the first aid facilities.

The area around the shower or eyewash on the floor should be painted with a 3-ft circle, colored tile, or other markings (preferably high visibility yellow or green).

Special facilities should be provided where caustic soda is used based on recommendations by the firm's consulting medical practitioner.

Eyewashes and safety showers should be full-flow tested for pressure and volume at least once a month for one minute and tests recorded.

All units should be tested on a daily basis by a bump test.

Employees should be trained and tested periodically in the use of eyewash facilities and safety showers.

Written directions should be provided at the unit in large letters.

—Bill Larson, Chairman
R&D Section Training Committee

'Adequate' Fume Hood Face Velocities Pose Problems

This article was abstracted by Gordon DeWall, chairman, R&D Technical Publications Committee, from a paper presented at the Research and Development Section program at the National Safety Congress October 19, 1976.

WHAT IS an "adequate" face velocity

for a laboratory fume hood? Much has been written on this subject. Although there are some differences of opinion, the consensus is that 100 linear feet per minute (fpm) is adequate for most operations involving toxic materials and 150 fpm is required for operations involving highly toxic chemicals such as carcinogens, carbon tetrachloride, beryllium, and others.

Occupational Safety and Health Administration (OSHA) standards specify that face velocities for certain carcinogens shall be an average of 150 fpm, with a minimum of 125 fpm. However, face velocities are not specified for the balance of the chemical agents for which a threshold limit value (TLV) has been established.

The problem is further complicated by the fact that what was adequate for yesterday's research may be totally inadequate today because TLV's may have changed. A hood designed for a material with a TLV of 10-100 parts per million of air by volume (ppm) may not be adequate if the TLV is reduced to 1 ppm.

Stated as simply as possible, an adequate face velocity for a laboratory fume hood is that face velocity necessary to maintain the exposure concentration in the breathing zone below the appropriate ceiling values and/or the eight-hour time-weighted averages or TLV's. If exposures can be maintained below the appropriate action levels (normally 50 percent of the TLV), medical surveillance is not re-

quired, and air and biological monitoring requirements are greatly reduced.

Investigative Study Made

In order to better define the face velocity necessary to assure, an investigative study was undertaken at Oak Ridge National Laboratory. The data in Table 1 represent workroom air samples taken in the breathing zone during actual operations being performed in laboratory hoods using the chemicals indicated. The ranges of hood face velocities and concentrations, as well as the total number of samples for each contaminant, are given. The airborne concentrations for each contaminant have been averaged. Concentrations and TLV's are expressed in ppm, except those for mercury, which are in milligrams per cubic meter of air (mg/m³).

The average concentration of each contaminant sampled was less than 50 percent of the respective TLV. Based on these data, it is apparent that a face velocity of 100 fpm is more than adequate to control breathing zone concentrations of most contaminants used in laboratory hood operations.

As an alternative to performing breathing zone sampling on every employee potentially exposed to a toxic chemical, a system was devised using carbon monoxide as the test gas. Pure carbon monoxide gas was metered in at the air foil of approximately 350 hoods at a flow rate sufficient to produce 10 TLV's of carbon monoxide (500 ppm) inside the hoods. The individual per-

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Table 1. Air Sampling Data for Operations Conducted in Hoods at ORNL

Contaminant	Average breathing zone concentration (ppm)	TLV ^a (ppm)	Range of concentrations (ppm)	No. of samples	Range of hood face Velocities (fpm)
Methyl ethyl ketone	17	200	<1-90	13	75-170
Toluene	<0.1	100	0-0.1	6	70-160
Xylene	<0.1	100	0-0.1	3	75-140
Dioxane	<1	100	<0.1-1.4	2	130
Carbon tetrachloride	2	10	<1-3	3	140
Hydrofluoric acid	<0.3	3	<0.3-0.5	3	110
Trichloroethylene	<10	100		1	120
Tetrachlorethane	<0.5	5		1	140
Tetrabromethane	<0.01	1	1	1	85
Methylene iodide	<0.1			1	85
Mercury	<0.005 (mg/m ³)	0.05		1	110
Benzene	2.6 ^b	10	0.2-13.6 ^b	42	65-170

^a Threshold Limit Values for Chemical Substances in the Workroom Environment, American Conference of Governmental Industrial Hygienists, Cincinnati (1975).

^b These operations were not totally confined to the hood.

forming the test then went through a series of motions designed to simulate actual work movements. Breathing zone concentrations were determined during these activities. Some 1,000 to 1,200 determinations for carbon monoxide in the breathing zone were made during this investigation.

The highest concentration detected was less than 5 ppm, or less than 10 percent of the TLV. (Note: 5 ppm is considered the lower limit of detection for the MSA carbon monoxide detector tube which was used.) These data confirm that face velocities of 100 fpm protect the employees from exposure to carbon monoxide at the concentration tested. Similar studies involving different test contaminants conducted at Oak Ridge also support this conclusion.

Three Observations

In the process of generating data from these specific studies, three significant observations were made regarding the practical aspects of hood design.

A research laboratory that uses a wide

variety of toxic chemicals should design and maintain special use hoods. These hoods would handle materials that either are extremely toxic or have some special property(s) requiring a higher capture velocity and/or a specific legal requirement. Such hoods should have a design face velocity of 150 fpm and should not drop below 125 fpm.

Insofar as practical, a hazardous duty laboratory hood should be dedicated to a specific operation using a specific contaminant(s). Examples of such toxic materials are beryllium, certain radionuclides, and chemical carcinogens. These hoods should be specifically labeled, when feasible, for the contaminant they were designed to handle in order to facilitate administrative control over their use.

As OSHA continues to reduce its permissible exposure levels for chemical contaminants, the advantages of special use hoods are clear, since such hoods would eliminate the need for installing new ventilation systems for intermittent operations.

It should be pointed out that there

are certain liabilities associated with face velocities as high as 150 fpm. Probably the major one results from increased air turbulence created inside the hood by high velocities.

The use of a hood air bypass should be discouraged. It has become routine practice to use either a bypass damper or the downward movement of the sash itself to regulate a duct opening for the purpose of allowing room air to bypass the hood face and be exhausted via the hood duct. Although this achieves the seemingly practical goal of a constant air velocity through the hood face, it robs the operator of optimized control, i.e., attaining enhanced velocities by merely lowering the sash. The possibility of exaggerated velocities could theoretically be obtained when the sash is lowered to a minimum opening without a bypass, but in practice this is not a serious problem. The elimination of air bypasses permits design of hoods in a manner more consistent with the economics and philosophy of industrial hygiene engineering, i.e., to make every cubic foot of air moved work to reduce exposure.

For general laboratory use, a hood with the sash set at the 40 percent open point can still be operated conveniently while improving the shielding and reducing the exposure to toxic materials. Hoods should be operated with minimum sash openings.

Despite the general applicability of the 40 percent operating position, it is imperative that the designer know the ultimate use of the hood. There will surely be instances where the normal operating sash opening must be greater than 40 percent. In these cases, the flow should be adjusted to provide 100 fpm at this operating position. The 40 percent figure presented here represents a criterion developed from practical experience that provides an appropriate design point in the absence of more definitive data.

References

Code of Federal Regulations, Title 29, Section 1910.1003-1016.

Committee on Industrial Ventilation, *Industrial Ventilation, A Manual of Recommended Practice*, 13th ed., American Conference of Governmental Industrial Hygienists, Lansing, Mich. (1974).

Building Systems Design Reference Section

Clearing the Air in Laboratories

A discussion of fume hood applications and make-up air systems used to remove contaminants from laboratories and preventing cross-contamination between rooms within a laboratory building.

SAL 000045411

by: JOHN D. CONSTANCE, P.E.
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AN IMPORTANT aspect of environmental engineering is the removal of contaminants from laboratory spaces to prevent cross-contamination between various rooms within the laboratory building. This can be most effectively accomplished with exhaust fume hoods and to a lesser degree by exhaust canopies, correctly installed at the point of origin or point of emission of the contaminants. Main purpose of this article is to review fume hood application and make-up air systems.

Laboratory work and chemical testing involves procedures that could contaminate the air inside the occupied spaces. The nature of the contaminants varies widely: high humidity from steam baths, odors from hydrogen sulphide analyses, corrosion capabilities of alkalis and acids, solubility of acetone, explosive properties of perchloric acid, health hazards of bacteriological aerosols, and poisonous properties of nickel carbonyl. Ideally, the best procedure is *not to emit*; but the next best is to remove or exhaust directly and as close to the point of origin for safety of laboratory personnel and possible damage to property.

To achieve this end, the most common and accepted method used for containment and removal of the contaminants is by restricting the contaminant producing procedures to within an enclosure or hood. And simultaneously room air is drawn across the hood face to capture and re-

move the contaminants so as to prevent them from escaping into the occupied spaces.

In the design of a fume exhaust system utilizing hoods or enclosures the following factors must be analyzed and evaluated: capture velocities (exhaust air rates), fume hood design, fume hood location and arrangement, make-up air source, make-up distribution, exhaust system, exhaust duct materials, exhaust air treatment, special systems (and considerations)

Capture Velocities

The quantities of air required for hood exhaust systems are based on several important factors, the most important of which is *capture velocities*. For most applications in the chemical and metallurgical industries, these velocities will range from 50 to 200 fpm. The lower figure is used to control contaminants released at low speed into relatively quiet air (15 to 25 fpm). The higher figure is used to control contaminants released at high rates. Under certain special conditions face velocities as low as 25 fpm have been used with induction type hoods.

The matter of face velocity selection for laboratory hoods is rather mixed. In the conceptual design of a laboratory facility this consideration is given much argument and thought, especially when air conditioning is also being included. It is worthwhile to remember at this point that ~~the~~ every 1,000 cfm of air exhausted through a hood requires 1,000 cfm of make-up air to be added to the system capacity because of make-up air requirements to "feed" the hoods. At \$1,000 per ton of refrigeration the cost of exhausting 1,000 cfm would range from \$3,000 to \$4,000. This certainly adds to the hood burden and overall costs of capital outlay.

~~Some designers~~ state emphatically that in ~~the design of a fume hood system~~ ~~the face velocity should be maintained at 100 fpm~~. Attempts have been made to relate face velocity to hood service by compromising fume hood usage together with the added responsibility of supervision by laboratory personnel to insure that the fume hoods are restricted to the type of contaminants for which face velocities were selected. To this end, Brief¹ offers a method of hood classification as a step toward economy of design and operation.

Fume hoods for highly toxic contaminants (threshold limit value of less than 0.1 ppm) are classified as Type "S" hoods and are designed for operating face velocities of 150 to 130 fpm. Type "A" hoods, for moderately toxic contaminants (threshold limit value of less than 100 ppm), can be sized for face velocities of 100 to 80 fpm. Hoods for non-toxic contaminants, Type "B" (threshold limit above 100 ppm), are sized for a face velocities from 60 to 50 fpm.

It should be emphasized that threshold limit values (TLV's) represent airborne concentrations of materials which most workers may be exposed repeatedly dur-

gineer and others to make any necessary adjustments. This allows continuous monitoring and control which should predict more exactly the final projected results of time required to finish the project, estimated profit, or loss, and similar items.

An actual project was used in the simulated situation that was tested. This project was set up into its component tasks utilizing the general model as a planning guide. "I" and "J" nodes and time durations were assigned. Work assignments were made in accordance with available manpower (in retrospect). In accordance with this specific arrangement necessary cost library of task code numbers for personnel, and comparative data for simulation purposes were developed and run through computing facilities at the University of Nebraska. Results were then analyzed. The system was shown to be feasible for use in actual design situations with no real penalties in terms of loss of time or money, but rather with an overall gain in the total costs of design. It seemed obvious that all personnel involved would benefit and the profit situation would be improved.

Overall Planning Guide

This discussion has considered only the HVAC aspects of design. Extension to all phases of the design process is desirable. It should not be difficult to set up an overall general model which would program all of the disciplines into units like black boxes which could then plug into the total system at various points. This overall planning guide could then be used for all phases: Civil, mechanical, architectural, and even construction. An owner could expect a better picture of his cost in terms of the complete system. All projects in a particular office could be arranged in somewhat the same planning procedure by using the black box concept. This should give the management team better information upon which to base long range planning, including marketing and accounting, as well as the design divisions. Forecasts of predicted costs, available manpower, etc.,

should be possible. It may even be feasible to extend this sort of system planning to selection of mechanical systems in design of the building.

The Critical Path Method is no more time-consuming or difficult than other management methods. It does, however, clearly present realistic conditions readily amendable to changes. Factual, intelligent and timely decisions at the onset of the project can be made as well as a critical evaluation in light of changing conditions.

Summary

- PHVAC engineering aspects of building design analyzed as a subsystem of total project and problems of planning, scheduling and time-resource-cost control of engineering functions, are susceptible to operations research methods.

- Techniques and procedures of CPM/PERT (Program Evaluation Review Techniques) are as applicable to analysis of engineering design projects as they are to construction and production projects. Engineering design involves definable interrelated individual tasks requiring resources allocation and time assignment in order to develop a workable schedule for execution. The logical plan of action may be shown most effectively and simply by means of a network diagram model. Time-cost limits for component tasks may be established through application of CPM/PERT algorithms.

- The CPM/PERT model of engineering design subsystem provides a dynamic and responsive management tool from the standpoints of similitude, simulation, and optimization during planning, scheduling and control phases of project organization and operation.

- As is the case for most scientific management systems, CPM/PERT policies and procedures must be developed within each firm and at all levels of management.

- Development of a generalized model, similar to the one described, would provide a stan-

dard yet highly flexible base from which optimal models can be derived for each specific application. In fact, the generalized model could be expanded into a system for optimal alternative selection for the best and most economic utilization of available resources at any time referenced to a least time-cost trade-off analysis. Beneficial effects of optimal utilization of personnel upon a company morale cannot be over-emphasized.

- The CPM/PERT system presented must be recognized as nothing more than a management tool. Each individual engineering firm must adapt techniques and methods imaginatively to best fit its structure and operational philosophies. This process requires education and training at all levels of management. Provision must be made to encourage innovation and continuing optimization. A policy of total optimization must preclude the usual ever-present problems of sub-optimization of subsystems by departments or individuals.

- Overall aspects of this kind of systems analysis substantiates the validity of modern trends toward integration of design and construction subsystems into integrated "design-and-build" operations.

- An extension of the systems approach which CPM presents seems obvious. Investigation of feasible systems to select the optimum can become more of a reality because of the availability of more realistic time schedules. When initial estimating is being done to prepare times of alternative design schemes, various items to be designed are being formulated. It should be possible to include information as to the cost of the various types of equipment, since the type of equipment to be designed is known. Up-to-date libraries of costs could be developed. Designers could plug into the system information about alternative designs and output could be comparative costs. This sort of capability would allow truly optimal design practices. Decisions would then result only after investigating all feasible approaches. AAA

ing a normal work day of 8 hours duration during a working life-time. The values should be used with care; they should not be used as sole criteria.

Small glove compartments of cabinets are used to confine highly hazardous radiological and bacteriological procedures. Open hoods should not be used for these purposes. Usually such cabinets have relatively small exhaust requirements due to confinement of the work.

Fume hood efficiency depends on the amount of air exhausted. To assure flexibility of operation and maximum safety to laboratory personnel, a fume hood should be designed or selected for exhaust air rates ample for complete removal of all contaminants. This may be a logical step when only one hood or two are involved in a single facility. If a laboratory facility has several hoods, however, generous exhaust through all hoods can impose a heavy initial and operating cost penalty on the air conditioning and heating system.

Where a large facility has only one or two small hoods the room air supply may exceed maximum requirements for hood exhaust air. And no special consideration for satisfactory exhaust hood requirements is needed. ~~With one hood present a ventilation rate of 1 1/4 cfm per sq ft of floor area would be required to maintain uniform conditions. This figure may be used as a design guide.~~

The next factor which must be considered is the total volume of air passing through the fume hood, expressed in cubic feet per minute (cfm). This simple calculation is made by multiplying the square footage of the fume hood sash opening by the selected face velocity. Allowance must be made for overcoming the effect of static pressure. This is the loss of air or the rate of resistance or the friction incurred by the volume of air as it passes through the hood and connecting ductwork and discharge stack. ~~Most hoods are rated in this respect at 1/4" static pressure loss.~~ This allowance is also sufficient to compensate for the static resistance of 20 feet of straight ducting with one 90° el-

bow. When longer duct lengths or additional elbows are required, the allowance for static pressure must be increased.

As we have mentioned previously, exhaust requirements are a matter of great concern in the design of the overall system. Another way of measuring hood burden on air conditioning load is that it requires more than one third of a ton of cooling capacity per 1,000 cfm of outside air for each degree of wet bulb difference. In laboratories, make-up air for exhaust accounts for a major portion of the refrigeration cooling load and is also a basic factor in determining the required capacity of the air handling system. It, therefore, behooves the designer to work out carefully the required exhaust rate.

Fume hoods normally add up to be the major source of exhaust, making it desirable from the design point of view to standardize on a fume hood that exhausts a minimum quantity of room air in controlling and containing the contaminants. It is safe to say that most chemistry laboratories, no matter what their specific purpose, contain at least one hood or canopy. From actual experience with laboratory design, it is often difficult to select a one-hood design that will satisfy all users and still be adaptable to each need.

Fume Hood Designs

The function of an exhaust system is to protect the worker from exposure as we have seen. Thus, the heart of the system is the hood or canopy and the design of the system begins with the hood, which is, at best, a compromise between the ideal and the practical.

Basically, a laboratory hood is a simple box, Fig. 1. Without the necessary indraft shown for the basic ventilated hood, Fig. 2, the material inside the hood can become airborne and be emitted into the room by any one or combination of the following normal laboratory operations: Thermal action—convection currents within the box. Mechanical agitation, Aspirating action by cross currents of air outside the box. Material can escape from the basic hood only through the door

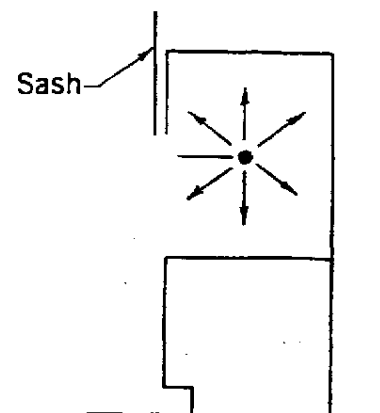


Fig. 1. Basic laboratory fume hood design.

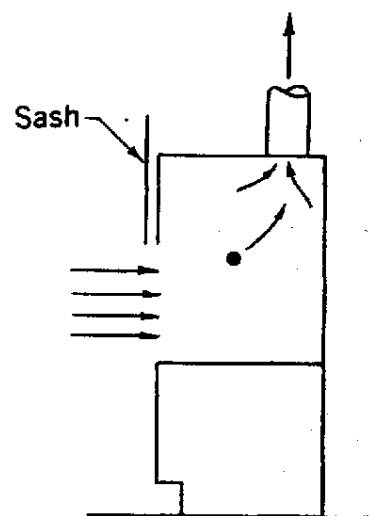


Fig. 2. Laboratory hood without necessary indraft shown.

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or opening in front. However, in the simple ventilated hood, contaminants are kept inside the hood by the action of the air flowing into the opening. To contain and keep the material from escaping, sufficient air must be exhausted from the hood to create and maintain an indraft through the face of the hood opening.

Exhaust hoods should control contaminated air so that the contaminant does not reach the breathing zone of the laboratory technician in significant quantities as pointed out earlier in hood rating. If no emission of contaminant takes place, then the air within the hood should not be contaminated at all.

Hood Location and Arrangement

For proper operation of the fume hood, there should be no disturbance or turbulence at the face of the hood. When planning the laboratory layout it should be done with thought to avoid locating the fume hoods near open windows, open doors, heavy traffic aisles, room supply and air handling units. There may be one exception, however. In the case of Type "S" hoods, the safety of laboratory personnel may require that the fume hood be near a door for easy and quick exit in case of an accident.

It is **good practice** to locate the ends of the hood at least three feet from any wall of the room. See Fig. 5. This will avoid a one-sided approach of the frontal air stream as it enters the hood. For best operation room air circulating velocity should be kept low (25 to 50 fpm) so as to present minimum disturbance to the air pattern as it approaches the face of the hood. Supply air distribution should be carefully designed to this end.

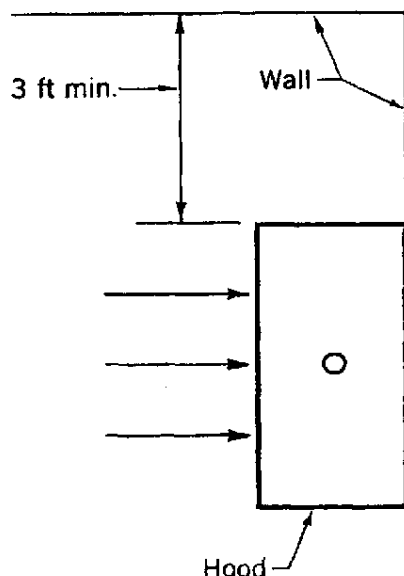


Fig. 5. Locate ends of hood at least 3 feet from any wall to avoid onesided approach of frontal air stream entering hood.

Ceiling diffusers of the aspirating type should be used for this. See Fig. 6. In other words, laminar flow design is recommended for best results. Air supply terminal units should be of the type designed for introduction of the supply air with *minimum* turbulence of room air.

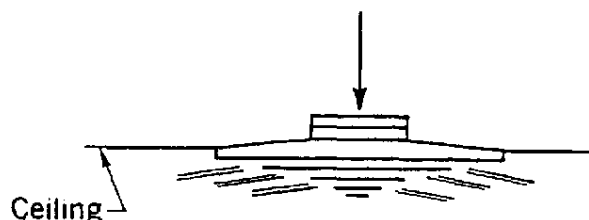


Fig. 6. Aspirating type ceiling diffusers should be used for supply air distribution.

Even at ideal conditions, a person working at a hood—or just walking by—can cause sufficient disturbance in the air flow pattern to spill some hood air from the hood by an aspirating action. Fortunately, as the face velocity does go up the chances for spillage go down. From this we can appreciate that the basis for evaluating hood performance is the average face velocity of the air flowing into the hood.

Even in a well designed hood the location and setting of the apparatus within the enclosure can make or break the operation. Among the main disrupting factors are the following:

- Large pieces of equipment located within the hood chamber will interfere with the air flow through the hood.
- Hot plates, bunsen burners and other concentrated heat loads located at one end of the hood will disturb the air flow pattern.
- If the fume hood duct stub locations are greatly offset to overcome building obstacles such as girders, the air flow at the end of the fume hood furthest from the duct stub will be less than at the end where the duct stub is located. (See Fig. 7)

Make-up Air Source

Make-up air to balance the air exhausted is the most essential design feature of any fume hood exhaust system. When a fume hood is operating poorly closer analysis will most often show inadequate make-up air supply. There is no air for the hood to "breathe" and an improperly sized make-up air supply system will starve the fume hood and restrict its intended operation.

Some designs depend on air drawn from adjoining corridors and office space. Introduction of make-up air by indirect means is a most economical approach. However, such a system can lead to balancing problems and cross-contamination between laboratory spaces. Positive introduction of air from corridors and office spaces by use of transfer fans can improve this. Such a positive approach will improve air balance but can still cause cross-contamination.

It has been found that the most reliable, flexible, and easily maintained system arrangement is that in which an adequate supply of outside conditioned make-up air is supplied to the laboratory space to balance the air being exhausted through the fume hood. It is good

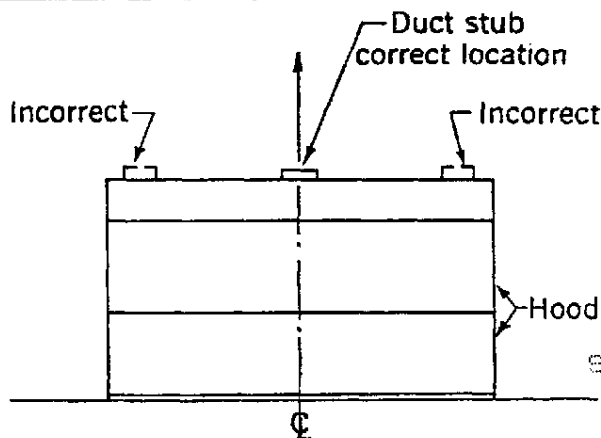


Fig. 7.

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A. J. Story, *Survey of C-710 Laboratory Fume Hoods* (Report No. KY-L-714, Union Carbide Corp. Nuclear Division, Paducah Gaseous Diffusion Plant, Paducah, Ky., Prepared for U.S. Atomic Energy Commission under U.S. government contract W-7405 eng. 26 (June 18, 1974).

Threshold Limit Values for Chemical Substances in the Workroom Environment, American Conference of Governmental Industrial Hygienists, Cincinnati (1975).

—N. E. Bolton and W. E. Porter
Industrial Hygienists
Oak Ridge National Laboratory
and J. T. Dufour, Industrial Hygienist
U.S. Energy R&D Administration
Oak Ridge Operations
Oak Ridge, Tenn.

R&D Executive Committee Meets



John N. Romine, safety director, Research and Development, Phillips Petroleum Co., addresses the Research and Development Executive Committee. Romine, who is first general chairman of the section, retires from Phillips Petroleum Co. in September.



Dr. Robert Chanaud, president, Engineering Dynamics, Denver, Colo., addresses the Research and Development Executive Committee during a luncheon meeting.

Fire Prevention Program Aids Off-the-Job Safety

THE NEEDLESS loss of life due to home fires can be substantially reduced by means of appropriate training in fire prevention and by the installation of early warning smoke detectors. Fire prevention week (October 9-15, 1977) is a good time to initiate a program which emphasizes home fire safety to employees at work and to neighbors in the community.

Two methods of presenting a program have been used successfully at an R&D facility. Both provide employees the opportunity to evaluate their fire safety needs and to order ionization-type smoke detectors, window escape ladders, and fire extinguishers. Local fire equipment suppliers and distributors were most cooperative in providing information, demonstration displays, films, and general assistance. Appropriate films are also available from the National Fire Protection Association (NFPA). Announcements and posters were distributed a week before the presentations.

The first method used space in the employee cafeteria where interested employees could stop, look, listen, and ask questions during their lunch hours. A 15-minute fire prevention film was shown every half hour. A 15-minute demonstration on available fire equipment and smoke detector performance filled the remaining time. Fire escape

plans and drills were emphasized, since smoke causes panic and disorientation. A fire equipment display was also set up near the main entrance, with order forms available and where purchases could be made with the supplier or distributor.

At least two days are recommended for this method, since many people like to discuss their needs at home before deciding to purchase such equipment. Literature and order forms were also made available for several months following the program to permit additional purchases at the special rates.

The second method used was directed towards smaller offices where personnel could meet without upsetting work schedules. This program took up to one hour, since the ABC-TV documentary film on the U.S. fire problem was shown as an introduction. Following are some key points of the presentation, with some of the applicable statistics that emphasize the home fire problem:

Review the U.S. residential fire experience.

About 60 percent of the 12,000 annual fire deaths and 40 percent of the three billion dollars in property loss occurs in residences. Another 300,000 people are injured annually in fires.

About 18 percent of the fires are

electrical, 17 percent involve heating and cooking equipment, and 12 percent are due to smoking.

Fire deaths in the home generally are due to carbon monoxide and other toxic gases produced from burning furnishings when the family is asleep.

Children are the victims of clothing fires too often, because of playing with matches or near open fires while wearing flammable clothing. The latest revision to the Federal Fabrics Act requires children's sleepwear (sizes 7-14 X) to be fire retardant.

Review the relationship of fire prevention, protection, and planning.

Use a visual aid or demonstration (see sample diagram).

Discuss evacuation planning and periodic drills. (NFPA visual aids and leaflets may be passed out.)

Discuss reasonable fire safety precautions to follow.

Minimize fire hazards. Use non-combustible furnishings and construction materials as much as possible. Inspect for worn electrical cords, flammable liquids, trash, combustibles near light bulbs, on a frequent basis. Clean and maintain heating appliances in good operating condition periodically.

Sleep with bedroom doors closed.

Provide a fire warning system.

Continues on page 6

Nearly all hood designs presently in use attempt to provide protection in three ways: a mechanical shield, direction of air movement, dilution of contaminant by mixing with large volume of air inside the hood.

The mechanical shield comprises the hood sash. When an experiment is being set up the sash or door is in the raised position. In many experiments, the sash is lowered two-thirds the way down or even closed off entirely while an unattended experiment is being carried out. Only the occasional visit by the laboratory worker is needed. Care must be exercised not to lower the sash too much without causing too high an indraft velocity with attendant overcooling or the snuffing out of the Bunsen burner flame.

Protection is provided by the direction of air movement across the back of the worker (see Fig. 3) and into the hood proper, past

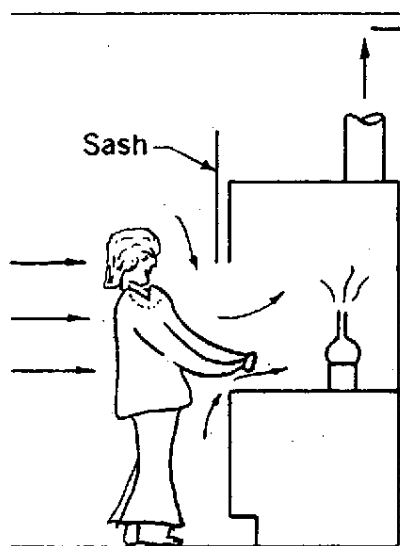
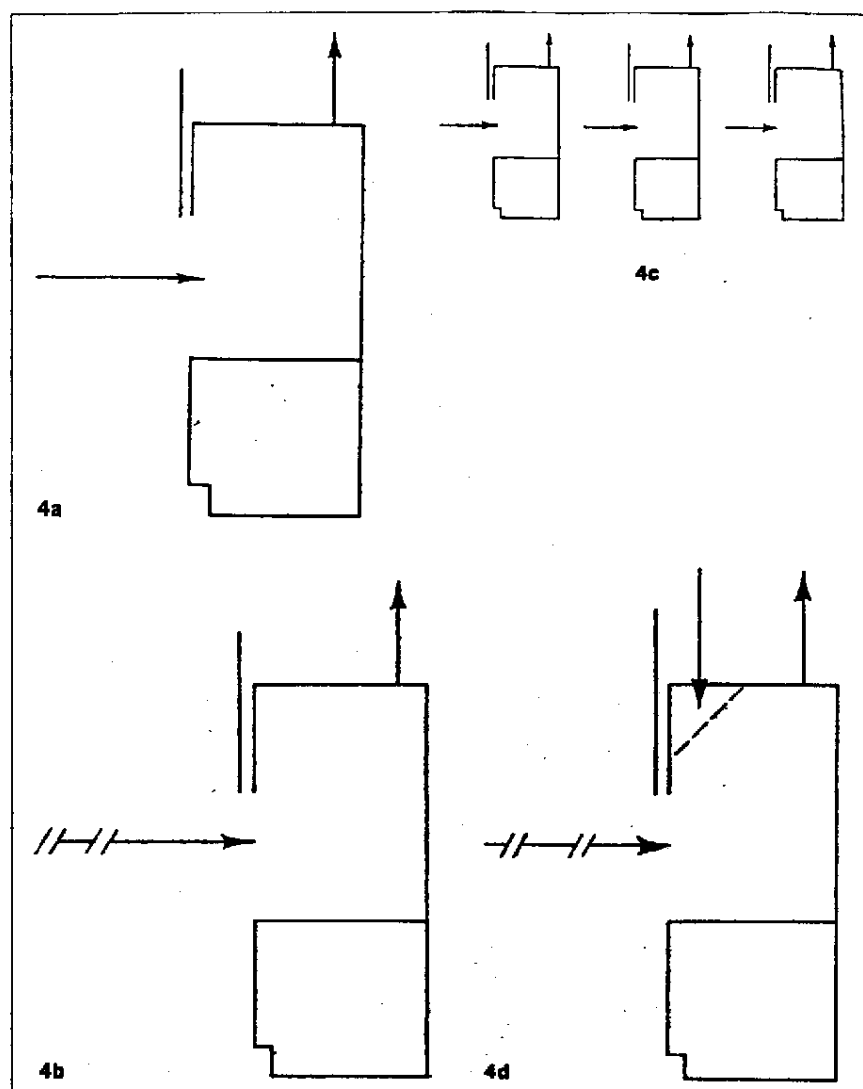


Fig. 3. Air moving across back of worker and into hood proper, provides protection, diluting contaminated air.

the equipment within the hood and thence into the exhaust system. Lastly, because large amounts of air are being moved through the hood, dilution of the contaminated air takes place readily and further reducing the hazard of breathing the air.

Eight basic hood designs have been used:

1. **Conventional hood** — all exhausted air taken from the room.



This is the simplest, low in initial cost, and effective. However, the amounts of exhaust air place a heavy burden on air conditioning costs and operation. (Fig. 4a)

2. **Conventional hood with reduced face velocity** — in an attempt to compromise hood effectiveness to reduce the air conditioning load chargeable to the hoods. Although low in relative cost, it does reduce air conditioning load but its effectiveness in removing fumes generated within the hood is weakened. (Fig. 4b)

3. **Conventional hood with face velocity** — Exhaust hoods may be needed at random intervals, and it is not likely that they would be simultaneously. As with other types of air conditioning loads,

there is a usage or diversity factor that is apparent, yet difficult to define. This factor depends upon judgment, experience, and logic. For example, a large number of hoods in a laboratory room does not necessarily mean all hoods will be operating at one time since the number of laboratory personnel would be limited and thus reflect on the number of hoods in operation. On the other hand, it is the policy of some laboratories to keep all hoods in operation 24 hours a day even though they will be used intermittently. So much depends on the management of the laboratory facility and it behooves the design engineer to explore the total operation with the ultimate user. (Fig. 4c)

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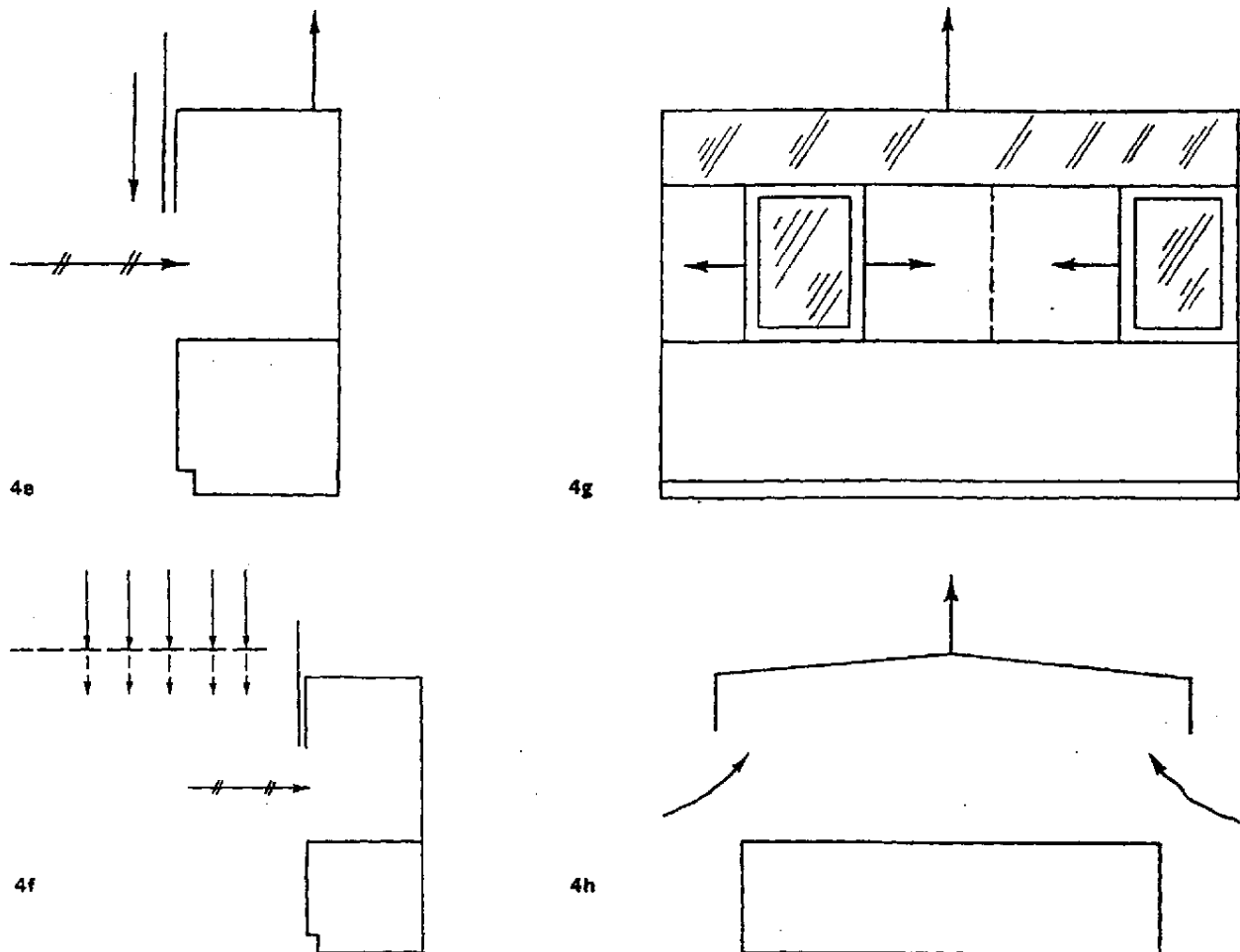


Fig. 4a. Conventional hood. All air taken from room. Fig. 4b. Conventional hood with reduced face velocity. Fig. 4c. Conventional hood with use or diversity factor. Fig. 4d. Internally supplied hood. Fig. 4e. Externally supplied hood. Fig. 4f. Perforated ceiling supply hood. Fig. 4g. Horizontal sliding sash door hood. (All room air make-up) Fig. 4h. Canopy hood.

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4. ~~Internally supplied hood.~~ In this type of hood required make-up air is fed directly inside the hood without affecting the overall room air conditioning. This air need not be cooled in summer and merely tempered in winter. Although an additional air handling system is required, the saving on the air conditioning load can offset this. Cost of this hood runs medium to high but ~~not fully designed and balanced~~ fume removal effectiveness ~~can be~~ poor. (Fig. 4d)

5. Externally supplied hood. Because of the additional duct system required such a system is relatively more expensive, relatively low cost effect on air conditioning, and because air is being exhausted across the face of the hood,

fume removal effectiveness is good. (Fig. 4e)

6. Perforated ceiling supply hood. This system allows ample opportunity for the unconditioned air to mix with room air and it becomes often necessary to sensibly cool but not dehumidify this auxiliary supply. Because, again, air is exhausted across the face of the hood into the hood, fume removal effectiveness is good. (Fig. 4f)

7. ~~Horizontal sliding sash door hood.~~ Compared to the conventional hood with its vertical sliding door upward, the horizontal sliding door unit presents much less area to be exhausted and total exhaust is reduced, relative cost of hood is low and since less air is exhausted from the room, air conditioning costs are low. Air con-

ditioning effectiveness and fume removal effectiveness are good. (Fig. 4g)

8. ~~Canopy hood.~~ This is local exhaust ventilation in lieu of an enclosed hood. Low are relative cost, air conditioning cost, air conditioning effectiveness, fume removal effectiveness (Fig. 4h)

In every case where air is drawn across the hood face (a, b, c, e, f, g, and h), it becomes apparent that supply must be from outside the hood to maintain the proper control velocity across the face of the hood. It has also been found that high velocity air streams must not be permitted to impinge on the face of the hood. In all of the cases listed, convenience to laboratory personnel was good to fair.

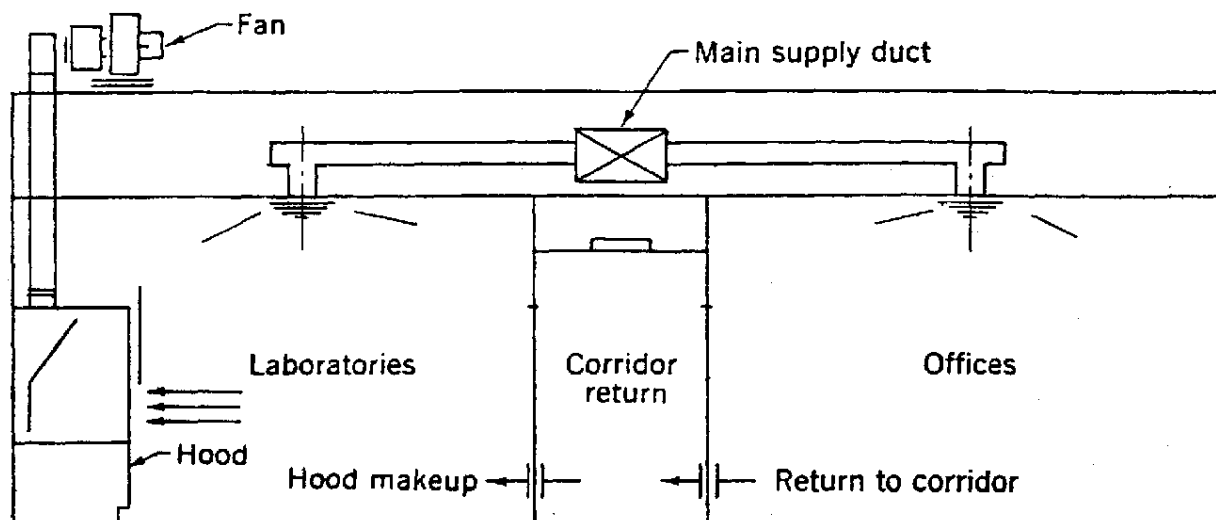


Fig. 8. An adequate supply of outside conditioned make-up air is supplied to lab space to balance air exhausted through fume hood.

practice to supply a little less make-up air in this manner than that being exhausted by the hoods. See Fig. 8. A slight negative pressure will be maintained, drawing air through door louvers from corridors or adjacent offices.

Air exhausted from a hood is never recirculated and as we know, the continuous loss of conditioned air increases initial and operating costs of heating and air conditioning systems.

Operating costs can be reduced by supplying make-up air from an auxiliary system instead from the air conditioning system. The air so handled is filtered and tempered in winter only. Of the eight basic hood designs previously discussed, numbers d, e, and f, make use of the auxiliary system. The auxiliary air supply is introduced as we have seen and can be either of the central type or unitary type with an outside air inlet for each laboratory. In one air conditioned laboratory it was observed that a unitary system supplied outside air for make-up through the roof of the laboratory room using the face and by-pass principle. Correct selection of the type of make-up air system can be made only by an engineering analysis and flow sheet of the fume hood exhaust system.

One of the most important characteristics of an exhaust system, whether it be for laboratory hoods

or not, is that at some point the system must end and discharge to atmosphere. Unfortunately, while the exhaust system has ended at this point, the problems associated with that exhaust system may have just begun. If too much air discharged from an exhaust system is recirculated through the supply air distribution not much good has been accomplished. If by poor design the exhaust air is not properly located with respect to the intakes of other supply systems potentially disastrous results can be attained. Such poor designs are often commonplace at many facilities.

The real cure for this type of problem is not higher exhaust velocities, higher stacks, better weather caps, better separation of discharge and intake openings, or other, although one or more of these can contribute to the cure. The real remedy must start back at the source of the contaminant itself.

Because the pattern of natural air flow around buildings is not predictable, contamination control by the location of vent effluents and air intakes is difficult to put to practice. Halitsky² and Clarke³ have advanced theoretical knowledge and rules of thumb that aid greatly in the solution of such problems.

Air Distribution

As we have seen, air movement

within each room of a laboratory complex must be such that a definite flow pattern will be maintained down through the building along with flow from non-contaminated to potentially contaminated areas. To bring about this differential flow pattern, the natural barriers between the various classes of rooms will assist. The flow pattern will be assisted by supplying outside clean air to the non-contaminated and semi-contaminated areas and by exhausting air only from the moderately and extremely contaminated areas.

In general, supply fans should take suction from the upper portions of the building. In addition, the exhaust fans should discharge to the outdoors through stacks of varying heights depending on adjacent structures. In order to assist in the general housekeeping within the area, the building should be maintained at a slight positive pressure with respect to the outdoors. Laboratory rooms should be maintained at a negative pressure with respect to the surrounding rooms.

In order to have the supply and exhaust in any building in balance, there must be an adequate air supply for all exhaust needs. This certainly implies that there must be available an excess of air supply over that required for normal exhaust needs.

In actual laboratory installations, experience has shown that

when two fans are exhausting from the same space with no provision for make-up air, the stronger fan will take command and air will enter the room through the weaker fan system. When there are multiple exhaust hoods and no make-up air, when one hood is turned off,

In multiple hood exhaust installations, duct connections should be streamlined. Branch ducts should be provided with angular boots and not enter the main header at an angle of 90°.

Ductwork transporting fumes may be sized economically for a

and concentration of contaminants or chemical reagents, space conditions, cost, accessibility. Whatever material is selected, the duct joints must be leak-tight and the ductwork should have ample supports. All longitudinal seams should be run along the top side of the duct. (Fig. 10) And extensive duct system should have inspection and cleaning facilities. Systems that could develop heavy condensation loading should pitch toward a pocket in the bottom of the duct and provided with a trapped drain.

Usually Type 316 passive stainless steel is used for bacteriological, radiological, perchloric acid and other general chemical purposes. 316 stainless is easy to work but is not suitable for chemical hoods handling concentrated hydrochloric and sulphuric acids.

Although transite is almost a universal material for its chemical inert properties, it is not commonly used because of its high installed cost and other working disadvantages. Main disadvantages are the fabrication and the joints. However, the joints of round sections are relatively simple to fabricate.

Asbestos cement ductwork, because of its heavy weight, presents support and space condition problems of installation. The material absorbs moisture and could drip when saturated. It also has to be handled carefully during installation and maintenance because of its fragile nature.

PVC (polyvinyl chloride) and FRP (fiberglass reinforced polyester resins) are easy to handle and fabricate. These materials can be used for general chemical duty except where a highly solvent vapor such as acetone is handled.

Protected metal offered by a number of suppliers has found some use in this application. Black or galvanized steel coated with acid-resisting materials or coatings is used for light duty.

Fans and other moving parts of the exhaust system are also protected by special coatings. There are a number of protective coatings available but none has universal application. Final selection of coatings will depend on the reagents handled in the exhaust system. The fan bearings should be outside the gas stream separated

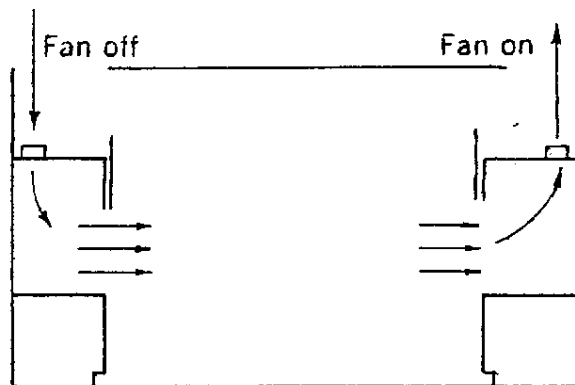


Fig. 9.

outside air can immediately down-draft through the idle fan. In situations when a fan must exhaust out of a room without an air supply, the capacity of the fan will be reduced from the original design flow and will result in less control at the hood. See Fig. 9.

The exhaust system being under negative pressure, keeping leakage due to poor duct construction or deterioration, will naturally flow into the duct system and contamination will be confined thereto. This is a relatively simple principle, but, nevertheless, many poor installations are found. The best place for an exhaust fan servicing hood is roof mounted. Then all exhaust ductwork on the suction side of the fan will be inside the building. If a hood exhaust fan is required to be located just above the hood and inside the building, then great attention must be paid as to the tightness of the discharge ductwork and stack. The fan on the roof is still the preferred location. When flammable material is handled, mounting the fan on the roof is a distinct advantage because explosion-proof construction may not then be required of the motor. This represents a distinct savings.

velocity of 2,000 fpm because it offers a good compromise between horsepower savings and duct space requirements.

Exhaust Duct Materials

In the usual newer buildings, ductwork is often concealed in ceilings or inside walls, making duct inspection and replacement a major problem. Where such inaccessibility exists it is reasonable to use ductwork with a long life expectancy. For the types of chemicals used in laboratory work, galvanized iron and black iron ductwork are highly susceptible to corrosion. Stainless steel, transite, polyvinyl chloride-coated steel or fiberglass-reinforced plastic ductwork will not require early replacement for such corrosive service but are costly. Actually, selection of materials for an exhaust system will depend on the nature

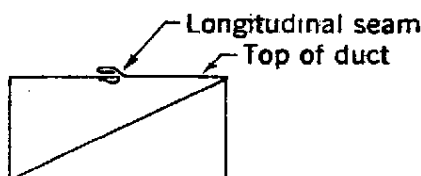


Fig. 10. All longitudinal seams should run along top side of the duct.

by the shaft seals. It is good practice to provide explosion-proof fan motors if fan is installed below the roof.

Exhaust Air Treatment

Gases that chemists bubble through reaction mixtures and then discharge to the hood are generally, by their nature, reactive enough to be completely eliminated by a scrubber of some sort. For materials of an acidic nature, a simple caustic scrubber is all that is necessary to assure essentially complete control. Similarly, for materials of a basic nature, a scrubber containing sulfuric or another acid can be used to advantage. For those materials that do not react rapidly with either basic or acidic solutions, a column filled with activated charcoal will almost always provide the desired control.

Some materials such as perchloric acid are highly soluble in water and hoods have been developed with a packed section built into the hood superstructure and provided with a water wash header. More on this will be covered under special systems.

A fume hood handling radioactive material should have a high efficiency filter. Exhaust systems for highly hazardous bacteriological experiments can be made safe only by incineration of the exhaust air stream, which is heated to about 650 F. to destroy the bacteria.

Special Systems

Lowered Sash Operation. A hood exhaust fan maintains proper capture velocity at the face of a laboratory hood when the sash is wide open, but the exhaust hoods' vertically sliding sashes are sometimes lowered to within a few inches of the work surface when the hood is in operation.

It should be recognized that exhaust hoods that would seldom be used with the sash wide open could unnecessarily impose as great a hood burden as those that would often be operated with the sash wide open. It has been found that partially closing a hood sash does very little to reduce the volume of air exhausted by the hood fan in typical installations.

A method or system in use to reduce unnecessary wasting of con-

ditioned air and also to achieve a more constant face velocity over the range of sash positions is the application of a 2-speed fan for each hood. When the sash is pushed up the fan runs at high speed. A micro-switch mounted in the hood is tripped by the sash when it is lowered below a certain predetermined position. The volume of air the fan will pull on low speed is adequate to maintain desired face velocity for the smaller cross-sectional area.

The proper placement of the micro-switch can be 50 to 60 per cent of the vertical face opening, i.e., the fan would go on low speed when the sash is lowered to 50 to 60 per cent of full opening. This holds for all exhaust hoods despite differences in hood dimensions and other variations in exhaust system configurations. It has been found to apply equally to hoods with minimum face velocities of 80, 100, and 125 fpm.

The volume of conditioned air that is normally lost is reduced by about one-third in most instances when the sash is below the switch position.

In a conventional hood with a single speed fan, the excessively high face velocities usually experienced at low sash settings and on persons using the hoods. Examples of research equipment and materials disturbed by high drafts include, among others, bunsen burners, fine powders, tissue slices, and thin paper. It should be obvious that some experimental work could be adversely affected by the unnecessarily high flow rate of cool room air over the work.

High drafts are uncomfortable. Further, still, when the laboratory technician stands in front of an operating exhaust hood his body presents an obstruction to the flow of air into the hood. Thus, a low pressure area develops in the space between the person and the hood. In extreme cases, this low pressure area can cause fumes to flow from the hood back into the room. The reduction in face velocity using the 2-speed fan reduces the probability of this potential hazard.

Type "S" hoods should be provided with exhaust fan speeds so

that at no point across the hood face should a velocity greater than 250 fpm exists. Another way to control this velocity is to provide by-pass dampers in the exhaust ductwork just downstream of the hood itself. By-pass hoods are made to accomplish this effect by providing this feature in the hood itself.

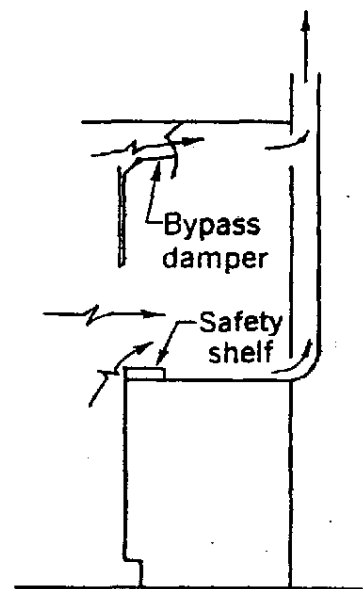


Fig. 11. Bypass hoods.

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Bypass Hoods. (Fig. 11) These hoods provide for a constant rate of room exhaust and uniform hood face velocities for any door position. They stabilize the room exhaust and consequently the room supply. The by-pass may be an integral part of the hood itself. As the hood doors begin to close, the damper starts to open. Thus, in any hood door position, the exhaust air quantity and hood face velocity remain constant. The resulting constant face velocity prevents the disturbance of flames and easily disturbed objects when the hood door approaches the closed position. One other important aspect and ~~advantage of the bypass hood is that the hood interior is continuously being purged of fumes even when the hood door is closed tight.~~

In some installations the by-pass effect is provided by the insertion of a sensitive barometric

damper properly sized to remain closed when a conventional hood is operating with doors open. As the doors are lowered, the change in static pressure inside the duct will open the damper to compensate for the imbalance and will keep the face opening velocity constant. When the hood door is completely closed room exhaust will remain fixed. However, the advantage of continuous purging of the hood interior by the integral built-in bypass does not exist.

Supply Air Hoods. There are two types of such hoods commercially available. The first type has auxiliary air introduced outside and in front of the sash, normally from the overhead position.

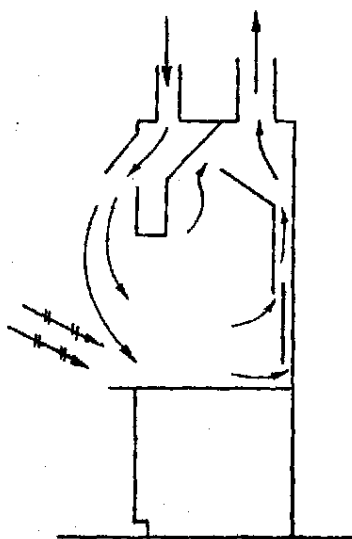


Fig. 12. Supply air hoods. This type has auxiliary air introduced outside and in front of sash, normally from overhead position.

(Fig. 12) In this design the auxiliary air supply is drawn into the sash opening as a part of the room air. Relative cost of such hoods compared to the conventional type is high. Since the amount of conditioned room air is reduced the relative cost of air conditioning is low. Air conditioning effectiveness, fume removal effectiveness, and convenience to laboratory personnel are good.

In the second type of supplied air hood the auxiliary air is fed directly inside the hood (Fig. 13). Relative cost is rather high, relative cost of air conditioning is low for obvious reasons, air conditioning effectiveness is good, but

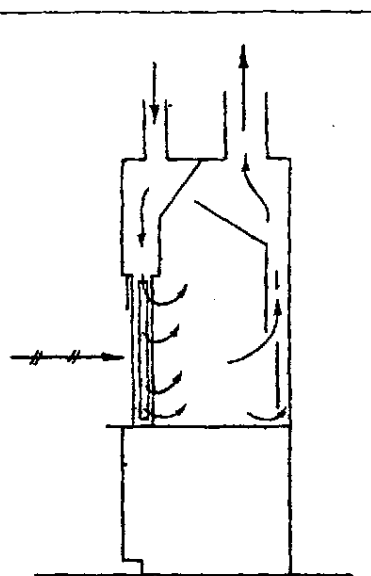


Fig. 13. Supply air hood where auxiliary is fed directly inside hood.

fume removal effectiveness is poor. Convenience to laboratory personnel is good. Because effective face velocities can drop below the safe value needed to prevent leakage of dangerous fumes, the use of this type is frequently discouraged by local government health officials.

Induction Venturi. For many fume exhaust applications such as those involving hazardous fumes or vapors, the conventional exhaust method of passing the gases through the fan case could be potentially dangerous. With exhaust from perchloric acid fume hoods in particular, a build-up of crystals can occur on duct walls and fans. This crystalline growth is explosive under normal conditions and special treatment of such a system is mandatory.

To overcome this problem, there are commercially available induction venturi systems with water wash facilities. Since perchloric acid crystals are highly soluble such systems are provided with spray rings or nozzles and are washed down internally at regular intervals. Drainage is provided to a trough attached to the back of the hood table. (See Fig. 14)

Operation of the system is accomplished by supplying a high velocity air stream jet inside a specially designed venturi. This in turn induces a flow of gas at

the inlet to the venturi. This induced flow can then be used to exhaust hazardous gases or fumes without any of the gas having to pass through the fan. Venturi is of stainless steel (316L). Blower is of mild steel. Such a system used to exhaust 1,200 cfm from a hood against $\frac{1}{2}$ " w.g. resistance requires a primary flow of clean air of 500 cfm and a $\frac{3}{4}$ hp fan motor.

There are other perchloric acid fume exhaust systems using special centrifugal exhaust fans of PVC construction. Such systems include a fume scrubber just downstream of the hood and upstream of the fan. The fume scrubber is also of PVC construction with access and inspection doors. Other parts of the scrubber include: raschig rings, water spray header and nozzles, eliminator blades, and baffles. All

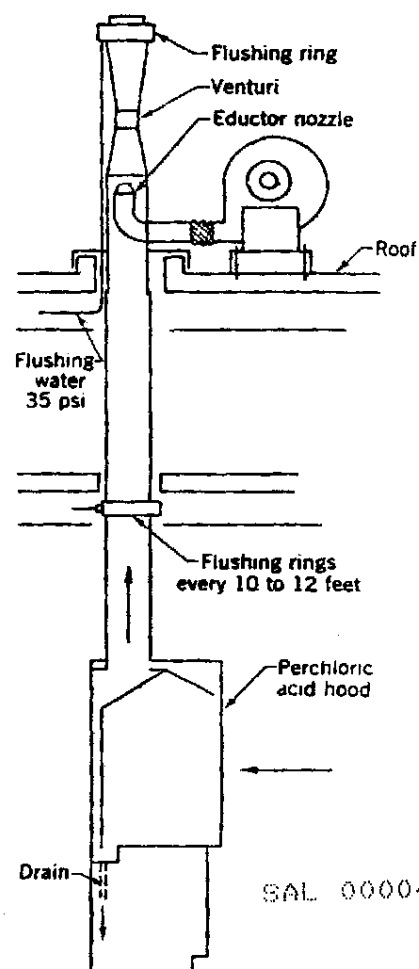


Fig. 14. Induction venturi, where drainage is provided to a trough attached to back of hood table.

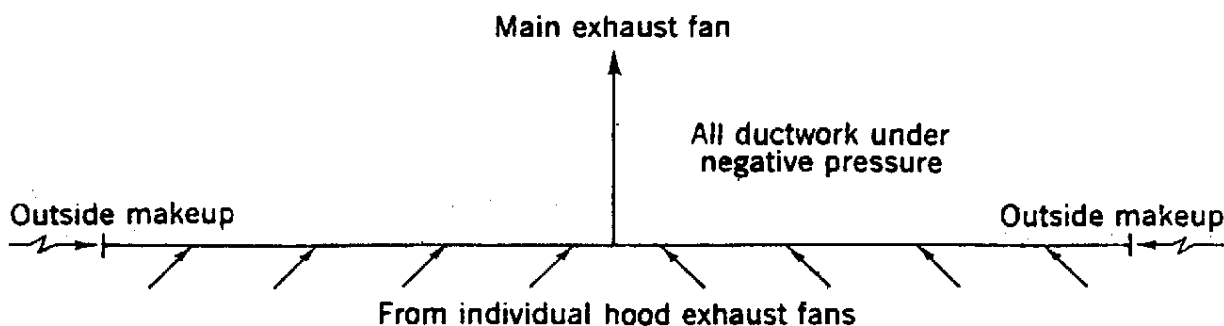


Fig. 15. Single exhaust fan system (designed by author) involves a multi-hood facility.

parts coming in contact with the air stream or the wash water must be of Type I PVC. The superficial velocity of air flow is 400 fpm on the design basis.

The centrifugal fan is of non-overloading characteristics and all PVC construction. Water spray headers run longitudinally inside the ductwork and are also PVC Schedule 80, $\frac{3}{4}$ in. diameter size. All duct joints and piping are field cemented.

Each perchloric acid hood should be provided with its own exhaust fan and duct system. Systems should not be manifolded and exhausted by one fan. Identify hood with warning sign. The washdown system should be turned on daily for at least 20 minutes. All ducts must be pitched back toward the scrubber. Non-porous materials should be used so that perchloric acid will not penetrate its pores. Inorganic flexible duct connectors should be used to isolate different parts of the system.

Organic compounds must be avoided in the construction of the system as well as the use of acids and contaminants other than those used normally for testing inside the hood.

Each system should be kept under 2,000 cfm and a hood face velocity of 150 fpm on the conventional basis.

Multi-hood Single Fan System. In every multiple-hood installation the following question frequently arises: Should each fume hood be provided with its own exhaust fan or should several fume hoods be serviced by a common exhaust fan? A common exhaust duct and fan system may be

used if the facility handles similar and compatible chemical reagents. Safest practice for perchloric acid hoods is a separate exhaust fan and ductwork for each hood.

In the consideration of exhaust systems for a chemical research facility, where the chemical nature of the reagents to be used cannot be predicted in advance, or cannot be controlled, safest procedure is to use separate and individual exhaust fans and ductwork for each hood. In all cases, the ductwork between the hood connection and fan suction would be under negative pressure. For safety's sake the fan should be located on the roof of the complex with fan discharge vertically up. In some cases it is not possible to place the fan on the roof, but must be located high against the underside of the roof construction. Then the fan discharge ductwork would be under a positive pressure with the possibility of fume leakage into the space. In this instance, ductwork must be carefully fabricated so as to avoid leakage and the longitudinal duct seam should be run on top of the duct.

One such single exhaust fan system designed by the author involved a multi-hood facility. Figure 15 depicts the installation. Each hood exhaust fan discharges into the main header which is open-ended to the atmosphere and provided with opposed-blade dampers motor operated. A centrally operated main exhaust fan located on the roof runs continuously, taking suction on the header. With all hood exhaust fans off the dampers are in the preset open position and most of the air

fed to the roof fan is outdoor air. As each hood exhaust fan is cut in, the static pressure within the header will build up. This build-up is felt by a static pressure sensing head and the dampers will begin to close. With all hood exhaust fans running the outside dampers will be in the closed position as the roof exhauster now takes suction from all hood fans. An alarm and light in the power circuit of the roof exhauster provides the necessary safety feature; on fan failure light will fail and an alarm will sound.

Perforated Ceiling Supply Hood. Another installation designed by the author consisted of an auxiliary outside unconditioned supply system with tempered air in winter. Discharge into the laboratory took place through a perforated ceiling at a maximum rate of 3 cfm per sq ft ceiling area. The auxiliary supply duct was provided with opposed-blade motorized dampers, one damper interlocked with an exhaust fan, one to an exhaust hood. The main auxiliary supply fan was provided with inlet vanes operable through a static pressure sensing head in the main discharge duct. With all hood exhaust fans off, main supply fan is off. As each hood exhauster goes on supply fan operates at constant speed but static in main supply duct operates to feed hood requirement. As each hood fan goes on, damper motor is actuated to the open position (two position) to permit more auxiliary to enter the perforated ceiling space. With all hood fans on, all interlocked dampers are open wide and supply fan is feeding the total

hood exhaust. As the demand for hood operation drops off, duct dampers will shut, static pressure in main header will build up to squeeze down on the inlet vanes. To provide some degree of cooling (not conditioning) and air conditioning supply is provided and is ducted to individual ceiling diffusers evenly distributed in the perforated hung ceiling. This provides spot cooling during time hood exhaust fans are in operation, and full conditioning when all hoods are off. Hoods are conventional with a face velocity of 100 fpm.

Expansion of Existing Hood Exhaust System. As we have seen, make-up air must not only be introduced into a building but also must be properly distributed. This problem of distribution was exemplified in an expansion problem for an existing multi-hood laboratory facility. The complex was originally provided with 100 per cent outside air supplied directly to offices and laboratories for cooling purposes. All the air was exhausted via hood exhaust systems. All lab rooms were kept under negative pressure.

Over a period of time, the addition of hoods and the need to update hood face velocities increased overall building exhaust rates. In this installation, thus, there built up a need to supply makeup air to two floors and 150 hoods. But there was a problem—limited space for equipment on the floor and no duct space overhead. How could the problem be approached? Here were the steps taken:

1. Investigate existing equipment for excess capacity. Check coil face velocities, control valve capacity, and duct velocities to assure them to be within limits of good design practice.

2. Do not arbitrarily increase speed and capacity of a unit based on fan alone to obtain needed makeup air since duct noise, moisture carryover, poor system temperature response, and undesirable grille discharge velocities can occur and create an undesirable system.

3. Study use of progressive

ventilation technique: reuse air presently being exhausted to supply other areas. This approach may be limited by local codes. Supply must be in the direction of increased air contamination.

4. Solution was to install makeup air units outdoors at grade and distribute outside air into spaces above a new perforated hung ceiling on each floor.

General. Exhaust stacks should be straight and discharge upward; no weather protection should be used. Fig. 16. Brief suggested that when open-face velocities exceed 125 fpm, the installation of an atmospheric damper should be included to prevent excessive indraft velocities when the open-face area is reduced upon sash closure.

At relative high face velocities, laboratory equipment placed within the hood should be so placed that the points of release of contaminant are at least 6 inches back from the hood face. This matter of technique is of paramount importance. By placing a $\frac{1}{4}$ inch thick edging 6 inches wide on the bench top near the hood entrance face is

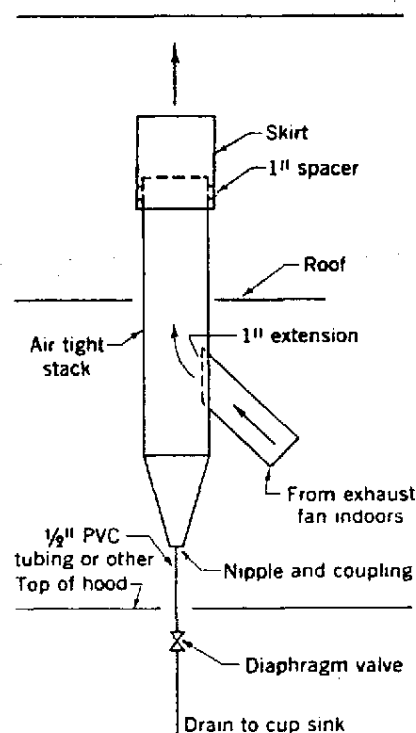


Fig. 16. Exhaust stacks should be straight and discharge upward with no weather protection.

suggested. Brief found that concentrated heat loads within the hood proper exceeding 1,000 watts per foot of hood width across created thermal vectors that require higher face velocities for control of vapor spill into the room.

Obstruction of lower hood baffle openings by large objects is discouraged. Blockage in the path of purging flow causes problems of control.

Design Procedure

For a most economical design and the use of the various criteria outlined herein the following procedure is suggested:

1. Set inside conditions of dry bulb temperature and relative humidity in the upper range of the comfort zone. Since relative humidity is critical to operating costs, place greater emphasis on this aspect.

2. Select a hood face velocity sufficiently high to control the type hazard, using the recommendations outlined in reference 1. Review hood operation carefully since not all hoods require same face velocities.

3. In cooperation with laboratory management determine the minimum number of hoods requiring continuous operation. Determine if a hood or hoods can operate intermittently or a minimum and estimate if its exhaust flow can be eliminated in so far as its effect on air conditioning load is concerned.

4. Avoid the use of hoods to store material and merely provide local exhaust.

5. Determine the acceptability of face screens or shields or horizontal sliding panels.

6. Locate hoods so that they are set clear of doorways and frequently traveled aisles.

7. Determine if laboratory management is willing to take a "slip" in room conditions when more air is exhausted than is originally planned.

8. Consider use of perforated ceiling supply hood arrangement with conditioned air supply through ceiling diffusers for spot cooling effect.

AAA

Industrial Hygiene Practices Guide

LABORATORY HOOD VENTILATION

This Guide was prepared by the Committee on Industrial Hygiene Practices from material contributed by the following authors:

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I. INTRODUCTION

Dusts, fumes, vapors, and gases are often released in the course of laboratory work. If the amount of exposure is minimal, general ventilation may be used to dilute the contaminant to a satisfactory level. However, local exhaust ventilation is a more desirable technique when the contamination originates in specific areas or when extreme toxicity or other factors make contaminant control by simple dilution impractical. Local exhaust is also recommended for controlling dusts and other particulate contaminants. The laboratory hood is a specialized type of local exhaust hood and is one of the most important of all laboratory safety devices. It requires thoughtful design, careful maintenance, and proper use if it is to be effective in preventing unsatisfactory exposures to laboratory workers.

II. LABORATORY HOOD DESIGN

A. Face Velocity

Under ideal conditions, air flow velocities of 20 fpm may be adequate to control the escape of particles of respirable size or the molecular diffusion of gases and vapors. In actual practice, however, rates of 50-150 fpm are used in laboratory fume hoods for two reasons.

First, room air currents often exceed 50 fpm and these can force or induce the flow of contaminated air out of the hood and into the laboratory.

Second, it is good engineering practice when working with hazardous materials to provide a margin of safety to insure that control will always be adequate.

Factors which must be considered when selecting the required degree of ventilation control are shown in Table 1. While this listing does not solve the face velocity selection problem, it does delineate the factors of hood use that are important. Procedures are available (Peterson 1959, 1963) for estimating hood face velocity requirements and these are useful for cases where a laboratory hood is to be used with specific chemicals and where the lowest possible safe face velocity must be used. However, when a given hood may be used for a wide variety of materials and operations, an exact estimation of face velocity for type of use becomes impractical. In these instances, it is more realistic just to consider several broad categories of hood use. The type of classification shown in Table 2 has been found to be workable and the velocities listed will provide adequate control under most conditions. In those cases where disturbing air currents at the hood face average more than 50 fpm or when the amounts of materials are unusually large, an upward revision of these values may be desirable. Other steps that should also be considered in critical cases include hood relocation, modification of the air supply system, or the use of a glove box.

B. Methods of Obtaining Uniform Face Velocities

An arrangement that helps greatly in obtaining uniform air flow both at the face and especially inside the hood consists of the multiple lateral slots shown in Figure 1. Although hoods with only top and bottom slots can provide a uniform velocity at the hood face, there is necessarily a dead spot at the center of the rear baffle. Compared with dual slots, multiple slot designs minimize chances for contaminants to reach the hood face. First, the contaminants are removed closer to their source. Second, air turbulence inside the hood space is considerably reduced.

The hood plenum and slots are proportioned so that the major portion of the resistance to air flow occurs in the slot openings and a uniform negative pressure is thus created in the plenum chamber behind the working zone of the laboratory hood. This may be accomplished by maintaining the total slot area at less than two-thirds cross sectional area of the plenum behind the rear baffle. For these conditions, the air velocity through each slot opening will be equal and the amount of air exhausted by each slot will be proportional to its area. Make all slots the same width but construct so that the top and bottom slots can be set to obtain uniform air flow at the time of installation but not so as to be easily adjustable by persons using the hood. Perforated back panels can also be used to provide uniform face velocity, but the holes in the baffle should be at least one-half inch in diameter to minimize their becoming clogged with dirt. Here again, the total hole area should not exceed two-thirds of the plenum cross sectional area. ~~At a velocity in the slots or holes should be above 1500 fpm~~

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Another important design feature of a laboratory fume hood is the bottom airfoil also shown in Figure 1. This arrangement eliminates an eddy zone that otherwise forms just above the hood floor. Thus, vapors evolved from spilled liquids are swept directly to the exhaust system and removed without being circulated to the hood face. Similar airfoils or 45° "picture frames" are often placed at the sides and the tops of the hood openings. While these features do reduce the amount of turbulence around the hood edges, the improvement in hood performance is not sufficiently great to justify lowering the hood face velocity recommendations of Table 2.

The high velocity air stream created when the hood sash is lowered may cause some problems. Above about 150 fpm, for example, bunsen burner flames and fine powders are disturbed and in no case should velocities above 300 fpm be permitted. By-pass arrangements can be used to prevent this by limiting air flow through hood face opening. Examples include:

GRAVITY TYPE: A counterbalanced swinging damper that opens progressively as the exhaust system static pressure becomes more negative when the hood sash is lowered. Easy to install but does not give accurate regulation.

DIRECT TYPE: As the hood sash is lowered, it uncovers an opening to the exhaust system which allows some of the air to by-pass the hood face. Simple and effective.

INDIRECT TYPE: As the hood sash is lowered, it actuates the damper through a mechanical linkage.

C. Air Conservation Features

A positive air supply is needed in each laboratory area to provide general ventilation for the room and makeup air for that exhausted through the laboratory hood. If makeup air is not supplied, then the laboratory hood performance will suffer. The cost of heating and conditioning the makeup air is appreciable and various methods of reducing the hood air flow requirements are often considered. Economy in the utilization of conditioned air for laboratory hoods can be achieved most satisfactorily by maintaining the required face velocity but restricting the open area of the hood face. A transparent horizontal sliding sash arrangement can cut the overall air requirements by 50% if two half-width panels are used. Similarly, if three panels are used, the open area reduction is 33% for a three track set-up and 67% for a two-track arrangement. This design also has an advantage over the conventional vertical sash because the full height of the hood opening is available. If panels 14-16 inches wide are used, they can also be used as safety shields.

~~When applied, some limitations are~~ are sometimes suggested as a means of conserving conditioned air. Generally, ~~some limitations are~~ ~~not been favorable with these units~~ for two reasons. First, control of contaminants released inside the hood depends on the velocity of air through the hood opening. For this reason, designs that have unconditioned air delivered inside the hood do not save any room air

because the auxiliary air merely increases the volume of air exhausted and has no effect on the air velocity through the hood face and thus no effect on control. In some auxiliary air hoods, the ~~unconditioned air enters along the top, sides and bottom of the opening but in front of the sash. This design requires very careful balancing and extremely close control of supply and exhaust flow rates which is difficult to achieve in systems having multiple hoods.~~ As might be expected, this arrangement is also quite susceptible to contaminant escape caused by airflow disturbances from pedestrian traffic and cross-drafts. The most satisfactory and safest type of auxiliary air supply is that using a large perforated panel to introduce the auxiliary air near the hood at about the same velocity as the hood face velocity. This arrangement unfortunately requires the operator to work in a stream of unconditioned air. The second basic reason for the limited application of auxiliary air systems is that savings in refrigeration are overbalanced by the cost of a second supply system and by ~~increased maintenance costs.~~

D. Mechanical Design Features

1. Materials of Construction

Laboratory hoods are constructed of a wide variety of materials depending upon their anticipated service and allowable cost. Generally, asbestos-cement board has been found to be quite satisfactory for most services. Hoods intended for radioactive work are usually constructed of seamless stainless steel (joints welded, ground, and polished) because of the relative ease of decontaminating this material. Relatively inert

soapstone such as "Alberene Stone" is recommended for perchloric acid digestion service because of the potential explosive hazard of perchloric acid in contact with any oxidizable material. Here, some additional features are also desirable. The exhaust duct should be sloped so that it drains into a sump at the rear of the hood. Spray nozzles and drains should be installed in the exhaust system to wash the duct walls continuously while the hood is in use. This prevents the accumulation of condensed perchloric acid. Also provide sprays and a drain for washing the blower. Access doors are required to permit periodic inspection of the plenum, ductwork, blower and washdown system. Rigid polyvinylchloride plastic ducts are now generally used for perchloric acid service.

Although it is an optional feature, most laboratory hoods are equipped with movable transparent sash or panels that in addition to conserving air, provide a safety barrier in case an explosion occurs inside the hood. ~~Tempered safety glass~~ has generally been found to be the most satisfactory material for this type service, although quarter-inch or heavier acrylic plastic and tempered glass have also been used. ~~Under no circumstances should wire glass be used as a safety barrier in~~ the hood sash.

2. Utilities

Utilities supplied to hoods vary greatly depending upon the requirements of the specific laboratory. Listed below are those that are generally used along with some additional ones that are often supplied.

GENERAL SERVICE

Cold water
Compressed air
Cup sink
Electrical Outlet
(110 V/3 prong, grounded)
Lighting Fixture
(vapor proof)
Vacuum

SPECIAL SERVICE

Chilled water
Large sink
Hot water
Natural gas
Nitrogen
Voltage Controlled
Electrical Outlet

The controls for the hood utilities should be located outside the hood enclosure and in the side pieces for reasons of safety.

The sink or cup sink in a laboratory hood should be individually trapped and connected to the sewer system. A series of untrapped cup sinks having a common drain line is sometimes installed along a laboratory bench to handle condenser water. When connecting this line to the building sewer system, a separate trap must be used--not the trap serving the hood sink. This precaution is necessary to prevent the escape of odorous or volatile materials that may be poured down the hood sink. Laboratory hood sinks should not be used for the disposal of flammable materials.

3. Storage Space for Chemicals

A frequent misuse of a laboratory hood is that of storing chemical containers at the rear so that the bottom slot is obstructed. A vented cabinet for chemicals storage is therefore a valuable adjunct. The cabinet can be fitted into the hood understructure and ventilated by furnishing louvered doors and a 2-3 inch diameter connection to the hood plenum.

III. EXHAUST SYSTEM

A. Arrangement

Individual exhaust blowers for each laboratory hood provide the most flexibility for current or future use and allow changing the hood velocity if the use of the hood changes. Individual blowers also permit the isolation of chemicals that might result in an explosive mixture if a common duct were used. However, it is usually satisfactory to connect several hoods into a single system if each hood has safety stops to prevent the door from being closed completely. Buildings having relatively few laboratory hoods usually have individual blowers whereas those installations where there are large numbers of hoods are usually manifolded to a few large exhaust fans. Although the usual reason for selecting the manifolded arrangement is lower cost, there are several other advantages. These include (1) greater ease in balancing air supply and exhaust volumes and (2) simplified servicing of the mechanical equipment, (3) greater fan reliability, and (4) permits a more effective discharge stack.

B. Duct Requirements

The duct material and coating should be selected to withstand any anticipated corrosive materials. The ACGIH Industrial Ventilation Manual gives detailed information on the proper design of a ductwork system. Special attention must be given to ductwork layout to minimize chances for leakage of contaminants into the building. If possible, place the exhaust fan on the roof to eliminate interior ductwork under positive pressure. Otherwise locate the fan as close as possible to the discharge stack and carefully seal seams and joints on the discharge side.

C. Exhaust Fan

The type and size of fan selected depends upon the quantity of air required and the pressure drop through the exhaust system. Consult blower manufacturers for data. Special materials of construction and coatings are available where the exhaust fan will be placed in corrosive atmospheres. Where flammable vapors or explosive dusts may be encountered, an aluminum or bronze impeller is recommended to minimize chances of spark generation. Centrifugal blowers are generally used for laboratory hood exhaust systems and a belt drive is preferred so that changes in the laboratory hood exhaust system can be made without replacing the entire fan assembly. Avoid using fans with forward curved blades.

A roof location is generally best for the exhaust fans unless a special fan penthouse is provided as is sometimes done for large buildings. This arrangement reduces noise, heat, and chances of contaminant leaks in the laboratory area while still allowing easy access for servicing. To minimize noise in occupied areas, also use vibration isolators to mount the fan and flexible connections, such as neoprene coated glass fiber cloth, at the intake and discharge.

D. Exhaust Stack

To avoid recirculation of laboratory hood fumes, the exhaust stack should be located carefully in relation to the building air intakes. In critical cases, wind tunnel tests with models are recommended to determine the pattern of air flow over the building and the optimum location of the exhaust and intake openings. Generally, stacks extending

at least 10 ft above roof level for one-story buildings and at least 15 ft above roof level for taller buildings should be employed. Discharge should be directly upward at a velocity of at least 3,000 fpm to minimize chances of recirculation. One additional advantage of manifolding the exhaust of several hoods into a common discharge stack is the increase obtained in the momentum of the discharged air. Where the system operates continuously, only a simple stack is needed. For intermittent operation use either the low resistance, weatherproof type of stack in Figure 2 or a fan drain. Do not use weathercaps.

IV. TESTING AND MAINTENANCE OF LABORATORY HOODS

All new laboratory hoods should be checked for compliance with the design values and they also should be tested periodically thereafter with a regularly calibrated instrument. Anemometers of the swinging vane type, such as the "Velometer" or the heated thermocouple type are recommended for measuring hood air flow. ~~Measurements should be made at several points in the center of the hood face at equal area sections over the hood face with the doors wide open.~~ A visual check of the air flow pattern at the hood face with a ventilation smoke tube is also helpful because the smoke test can show where disturbing room air currents cause reverse air flow or where there are obstructions to air flow in the hood. In addition to the ventilation tests, there should be a regular program for checking fan speed and the condition of the ducts, fan belts, and lubrication.

If the tests show that the total air flow has become inadequate for the intended service, then (a) the hood slots and ducts may need cleaning, (b) the exhaust slots may be closed too much or obstructed by laboratory equipment, (c) the blower wheel may be corroded or dirt-laden, (d) the fan belts may be loose or broken, (e) there may be holes in the ductwork between the hood and the fan, or (f) the fan may be rotating in wrong direction. If any individual reading is less than 80% of the average, then the exhaust slots at the rear and the top of the hood need resetting to provide a uniform air flow.

For critical applications a sail switch or an air velocity actuated device may be used in conjunction with an alarm, light or bell to signal the need for attention.

A. R. JONES/mar
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TABLE 1

LABORATORY HOOD USE FACTORS AFFECTING
FACE VELOCITY REQUIREMENTS

Toxicity

- Threshold Limit Value (TLV)
- Maximum allowable concentration (ceiling)

Physical Properties

- Particle size)
• Bulk density) Dusts
• Ease of dispersion)
- Vapor pressure Vapors
- Pressure Gases

Conditions Affecting Generation and Dispersion

- Amount of material
- Release rate
- Release velocity
- Heat load
- Chances of leaks and spills
- Operator participation

TABLE 2

HOOD CLASSIFICATION

<u>Hood Class</u>	<u>Suitability</u>	<u>Minimum Air Velocity at Face of Fully-Open Hood, fpm</u>	
		<u>Average for Hood Opening</u>	<u>At Any Point</u>
I*	For radioactive materials, metal carbonyls, beryllium compounds, volatile carcinogens and other materials of extreme toxicity or hazard.	150	125
II	For any operation except those offering severe potential hazards. For moderate to highly toxic materials. Recommended generally for all laboratories.	100	80
III	Only for operations where hazard is not high. For materials of low to moderate toxicity such as acetone, ethanol, hydrocarbons other than benzene, nuisance dusts and fumes.	75	50

*Requires by-pass dampers to avoid excessive velocities.
Consider glove-box where maximum protection is required.

Figure 1
LABORATORY HOOD DESIGN FEATURES

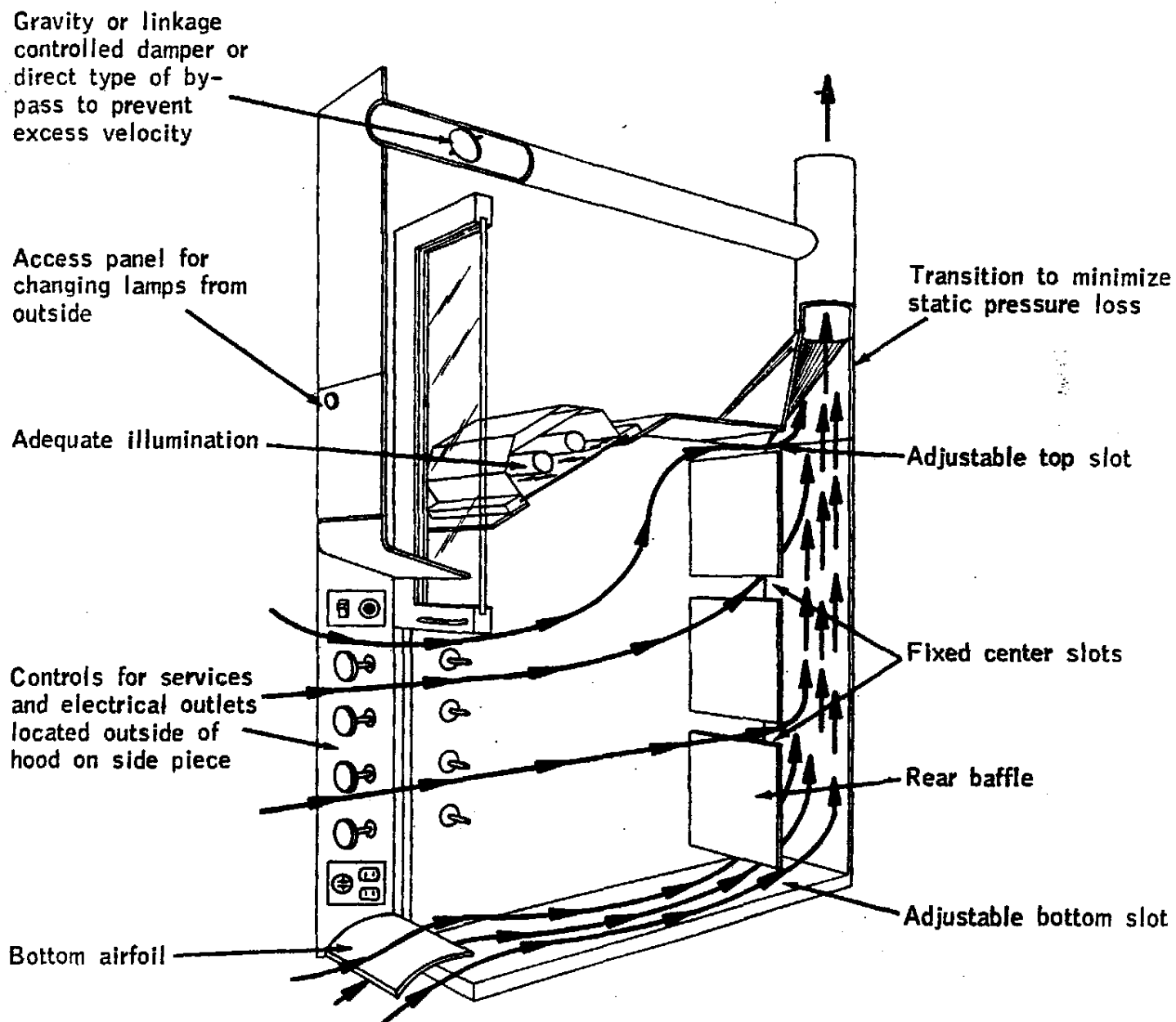
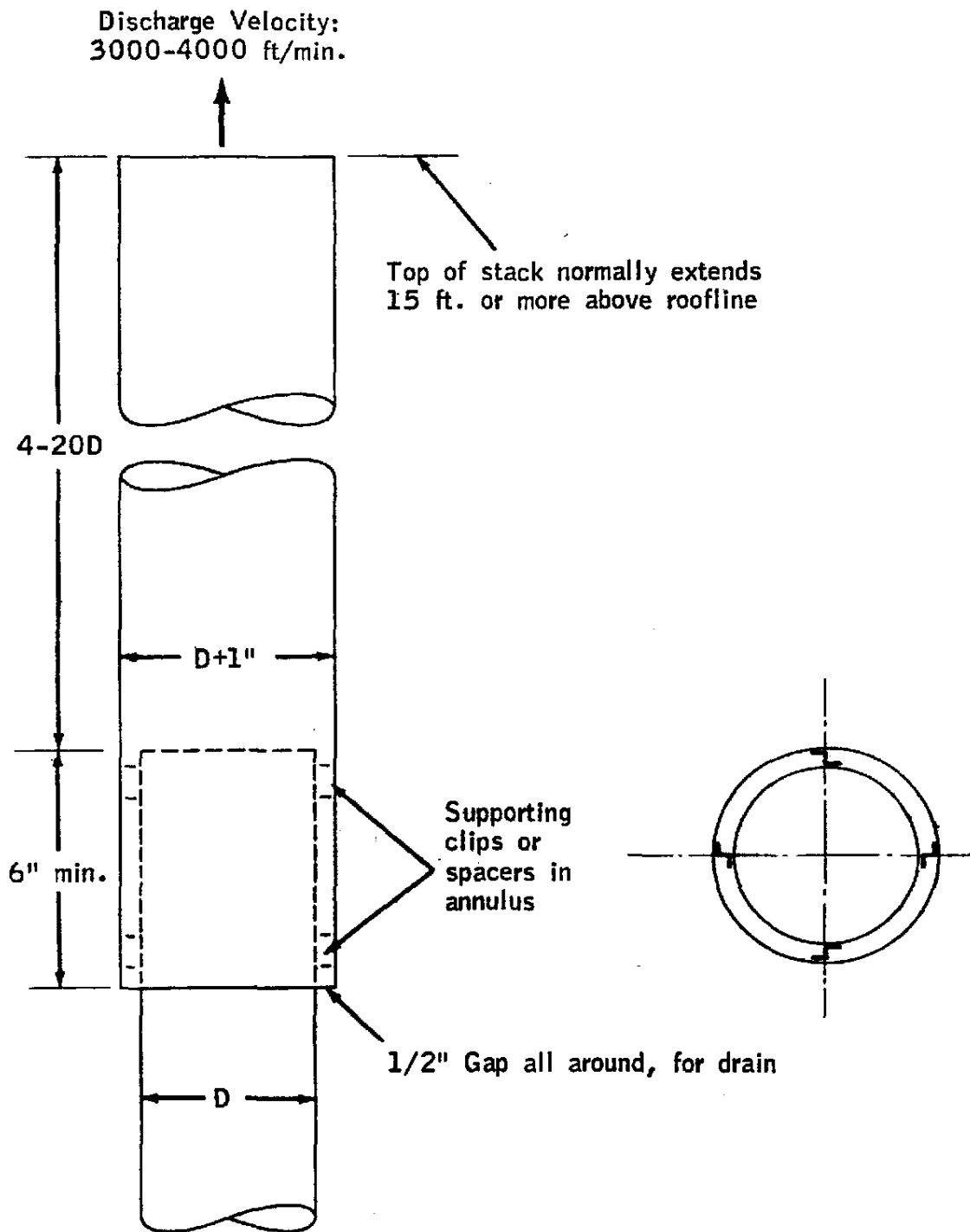


Figure 2
CONCENTRIC DUCT TYPE OF SELF-DRAINING STACK



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ESSO PRODUCTION RESEARCH COMPANY BUILDING is central building in this view. Three story, multi-winged portion at front and single story portion at rear are previously existing structures. The 65,000 sq ft, two story addition featured in this article lies between the two.

Ceiling Plenum Is Air "Source/Sink" In Air Conditioned Research Building

Two-speed exhaust hood fan operation and central plenum concept reduces air conditioning investment and operating costs while eliminating air balance problems.

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CONSTRUCTION of a 65,000 sq ft addition to Esso Production Research Company's 210,000 sq ft three story building in Houston in 1966 presented a number of air conditioning and ventilation problems.

Because of the wide variety of basic and applied research work carried on in the building (exploration and production research), a large number of environmental criteria had to be satisfied. Some laboratories needed vibration-free platforms, closely controlled temperature and humidity, and elimination of airborne pollen; many others needed protection against noxious or toxic dust, fumes, vapors, or gases that might be released from various research processes. Environmental control requirements were further compli-

cated by the fact that the degree of activity involved in the various kinds of research performed changes from time to time. The ventilation and air conditioning systems, then, had to have built-in flexibility so that a broad range of changing environmental demands could be satisfied.

Safety, flexibility, and economy were built into the overall program by correlating air conditioning design and exhaust hood ventilation design. Review of design plans and on-the-ground study show that during the two years that the building addition has been completed and in use air conditioning and ventilation are being accomplished more safely and economically than in previous installations.

Factors Affecting Design

The effect of the exhaust hoods on air conditioning is more signifi-

cant than that of any other construction or utilization factor in the building addition. Other important factors include: hot, humid climate; long summer season; high ratio of interior to exterior space; heat resulting from heavy usage of electricity; continuous operation of some temperature sensitive research work; and integration of the building addition with the chilled water system and heat loads of older parts of the building. These factors are interrelated and should be considered both for their effects and for the way in which they influence the effect of exhaust hood requirements on air conditioning.

Although exhaust hood ventilation volume requirements are sometimes very large, the building under consideration is not predominantly a chemical laboratory. Each room of the building falls into one of three categories depending on use. These are: 1) non-

laboratory rooms such as general offices; 2) physical science laboratories for electronic or optical work; and 3) chemical laboratories with exhaust hoods. A room can be changed from one category to another if necessary. Within chemical laboratories, the chemical substances used and the magnitude of operations vary with time and location. The most important design factor for the exhaust system is not the magnitude of the chemical operations but rather the variety and changing nature of the work.

The design objectives for this air conditioning and ventilation project can be expressed as follows:

1) Design a system that will economically maintain close temperature and humidity control in a 65,000 sq ft building addition.

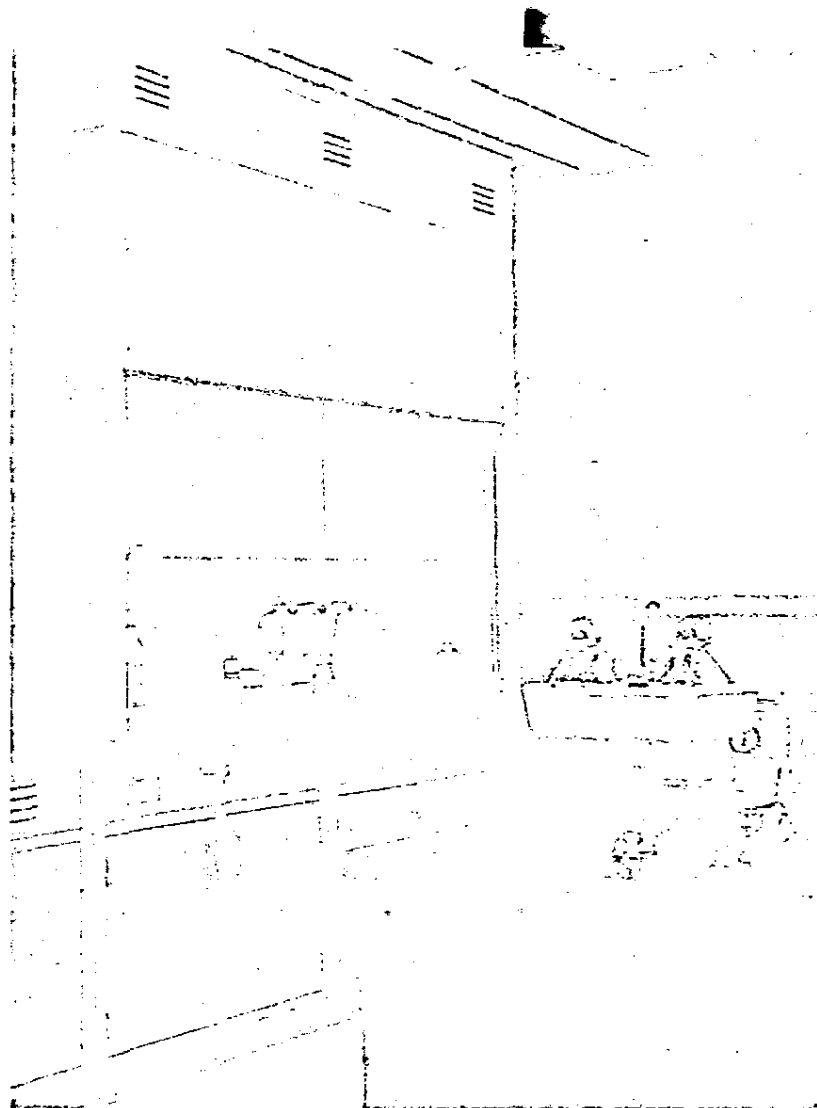
2) Include exhaust hoods that are to be used at random intervals and for various durations, and provide for possible future addition or deletion of some exhaust hoods.

3) Provide tempered or dehumidified outside air to the air conditioning system in varying volumes proportional to the magnitude of exhaust hood operation, and maintain proper air balance throughout the building.

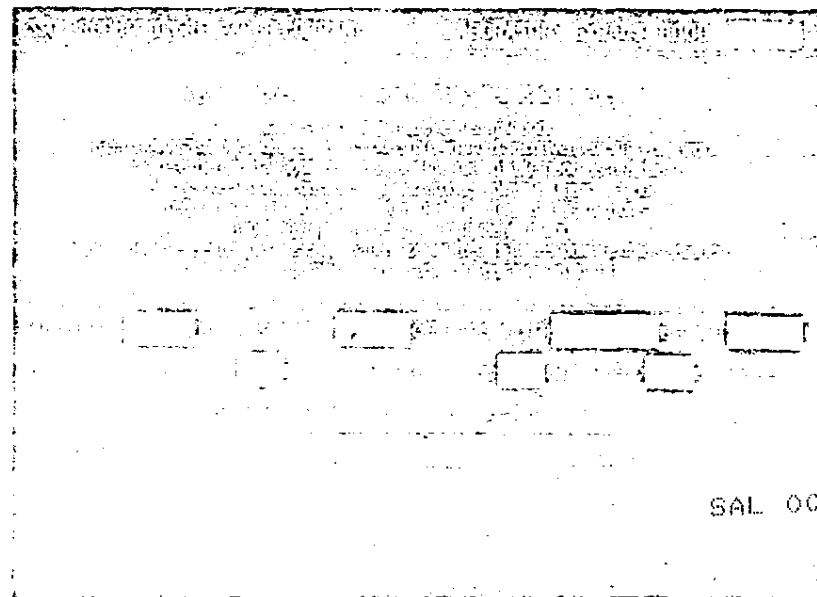
Reducing Hood Burden

In a hot, humid area such as Houston, high air conditioning costs are imposed by requirements to replace air exhausted through hoods. These high costs, sometimes referred to as "hood burden," are well recognized within the industry. An informative study and demonstration of these costs by Jeremiah R. Lynch of the U. S. Department of Health, Education, and Welfare was published in the January 1967 issue of *Heating, Piping & Air Conditioning*.

The EPRC Building is maintained at 75 F and 50 percent RH year 'round. Extreme outside conditions anticipated are 96 F DB and 80 F WB in summer and 17 F DB in winter. Most of the hoods can be classified as "counter top height enclosed cabinet exhaust hoods with single vertical sliding sash installed in front and served



TYPICAL EXHAUST HOOD in new addition. Supply air diffuser and slotted air troffers to central plenum are seen in ceiling. Service corridor runs behind wall at right, which is rear wall of laboratory.



METAL NAMEPLATES are attached to all hoods. Special information is typed in unprinted aluminum rectangular areas (which appear either black or white here depending on incidence of light).

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by a roof mounted fan." The 32 exhaust hoods vary in size and configuration, but most of them have a maximum sash operating height of 33 in. and a sash width of 4, 5, 6, or 8 ft. Minimum face velocities are set at 80, 100, or 125 fpm depending on the material to be exhausted.

An exhaust hood fan maintains proper capture velocity at the face of a hood when the sash is wide open, but the exhaust hoods' vertically sliding sashes are sometimes lowered to within a few inches of the work surface when the hood is in operation. It was recognized that exhaust hoods that would *seldom* be used with the sash wide open could unnecessarily impose as great a hood burden as those that would *often* be operated with the sash wide open. Partially closing a hood sash does very little to reduce the volume of air exhausted by the hood fan in typical installations.

Some individual hoods can exhaust well in excess of 2000 cfm of air and thus require that an equal volume of outside air be drawn into the building and treated. If future conditions so dictated, the face velocities of the exhaust hoods could be changed and more exhaust hoods could be installed or some could be removed.

The composite of all exhaust air requirements at any given time is the "instantaneous hood burden" for the building addition. The summation of the instantaneous hood burden over a period of time, expressed in cubic feet of outside air introduced, represents an increase in air conditioning operating costs. This is because additional energy has to be expended to bring the replacement air to the correct temperature and humidity conditions.

The highest expected value for the instantaneous hood burden is a component of the maximum building cooling and heating loads. The initial cost of the air conditioning installation is determined by the maximum building cooling and heating loads.

While the costs of cooling equipment and cooling operating costs are more significant in this instance, the reasoning also applies

to heating costs. The term *air conditioning* is intended here in its broadest sense, which includes heating and cleaning of air.

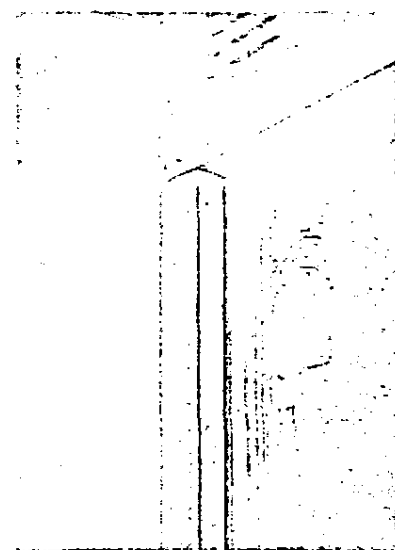
To reduce unnecessary wasting of conditioned air and also to achieve a more constant face velocity over the range of sash positions, a two-speed fan is installed for each hood. When the sash is pushed up, creating a large face opening, the fan runs at high speed. A microswitch mounted in the hood is tripped by the sash when it is lowered below a certain position. The volume of air the fan will pull on low speed is adequate to maintain desired face velocity for the smaller cross section area. Using 1800/1200 rpm fans and motors (1:2 $\frac{2}{3}$), the proper placement of the microswitch to meet the criteria was found to be 57 to 60 percent of the vertical face opening. The theoretical placement, taking into account basic fan laws and changes in system characteristics resulting from lowering the sash, would have to be computed separately for each exhaust hood. The theoretical answer would, in all cases, have to be less than 66 $\frac{2}{3}$ percent of the opening. In this installation, the empirically determined value of approximately 58 $\frac{1}{2}$ percent is valid for all exhaust hoods despite differences in hood dimensions and other variables in exhaust hood system configurations. It applies equally to hoods with minimum face velocities of 80, 100, and 125 fpm.

The amount of conditioned air that is ordinarily lost to the atmosphere is reduced by approximately one-third in all instances when the sash is below the microswitch position.

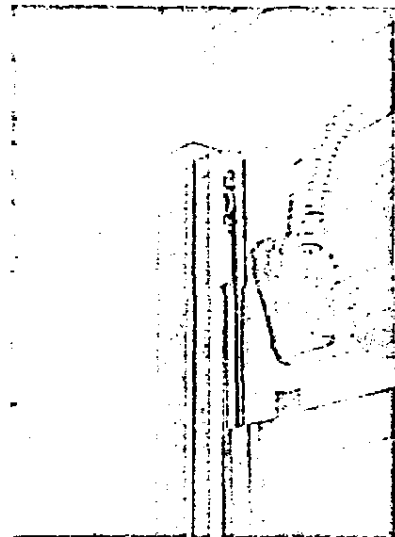
Two-Speed Fan Operation Is Key

The excessively high face velocities usually experienced with vertical sliding sash exhaust hoods at low sash settings can have undesirable effects on experiments and on persons using exhaust hoods. A valuable byproduct of the two-speed exhaust hood operation is the reduction of excessively high face velocities at low sash settings.

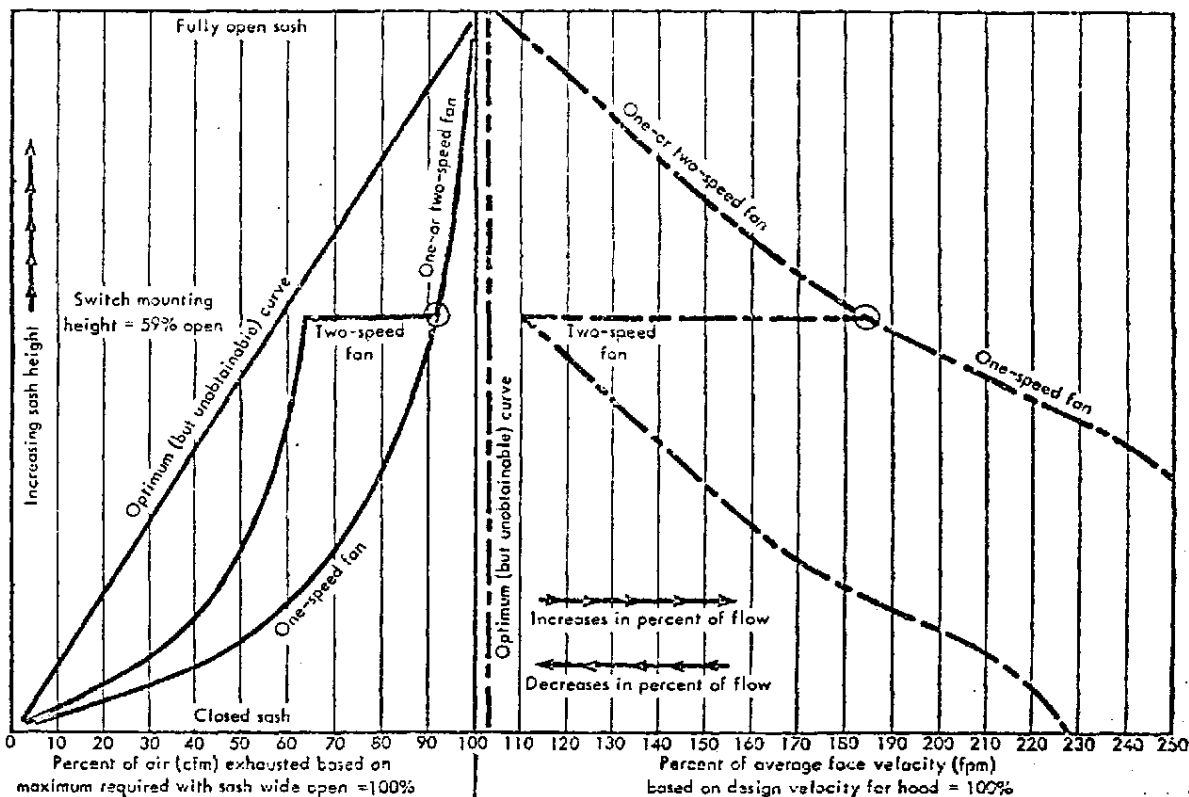
Examples of research equipment and materials disturbed by high

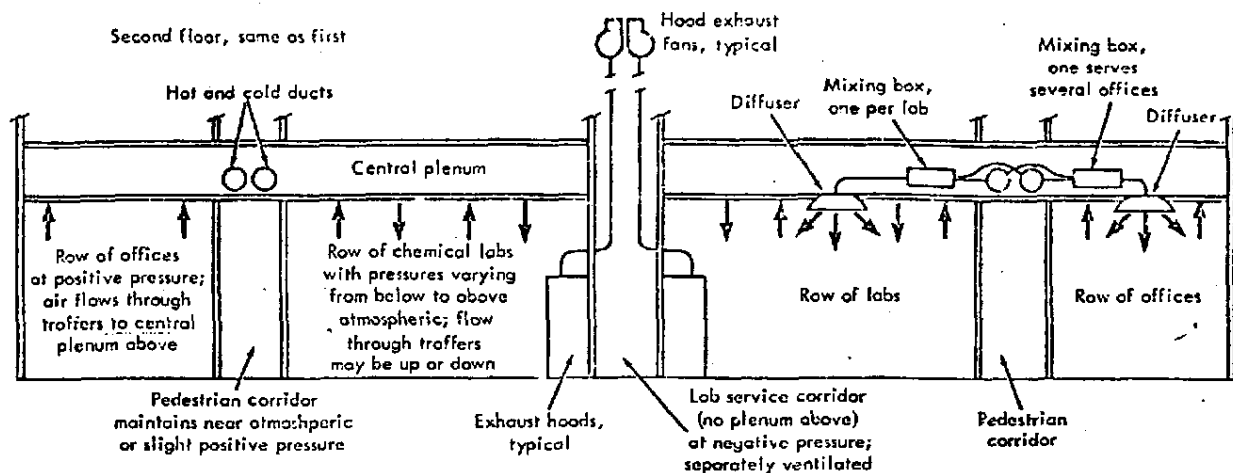


UPPER PORTION of front of exhaust hood with one panel removed to expose microswitch for two-speed fan operation. With sash raised, as in top photo, switch is held in position, causing fan to operate at high speed. A large portion of the available face area below is open. With sash lowered, as in bottom photo, fan operates at low speed. Switchover point is at approximately 58 $\frac{1}{2}$ percent opening.

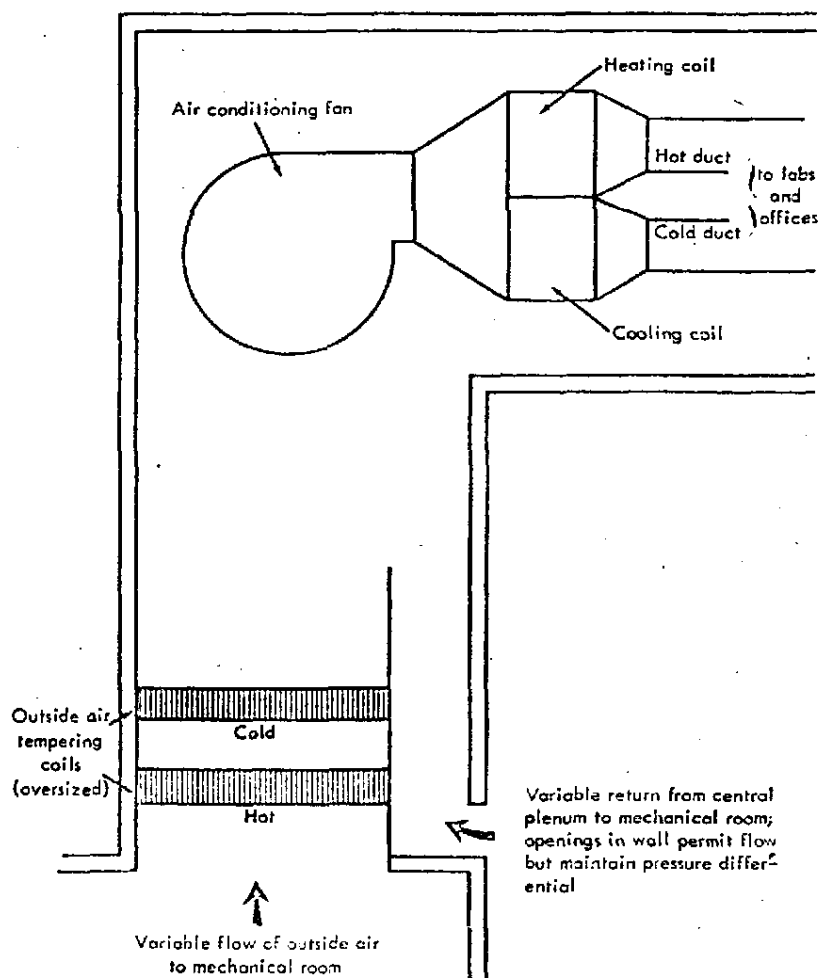


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SECTION through new addition illustrates arrangement of offices, pedestrian corridors, labs, service corridor, and central plenum.



TEMPERED OUTSIDE AIR and air from central plenum are supplied to inlet of air conditioning fan. Proportion depends on number of exhaust hoods operating.

all rooms are provided with slotted air handling troffers that serve as return air grilles opening into a large central plenum overhead. Because of their number and size, the openings afford considerably more total cross sectional area than would be required to permit the amount of air supplied to a room to flow from the occupied space to the plenum. As a result, there is very little pressure drop across the slots. The central plenum opens to the inlet of the high pressure air conditioning fan through a series of manually set dampers, which impose a pressure drop. Thus, the central plenum is one source of air for the fan. Recall, however, that the fan inlet is also connected directly to an oversized outside air tempering unit. For this reason, the pressure maintained at the high pressure fan inlet is virtually atmospheric, and the fan does not tend to impose a negative pressure on the central plenum. Instead, the fan receives from the central plenum volumes of air that are surplus to the plenum as controlled by positive displacement of air within the plenum. At those times when few exhaust hood fans are operating, a considerable amount of return air is pushed from the central plenum to the inlet of the air conditioning fan. When many exhaust hood fans are operating, correspondingly less air returns from the central plenum to the air conditioning fan. The fan receives proportionately more of its re-

intervals, and it is not likely that all would be used simultaneously. As with other types of air conditioning loads, there is a usage factor or diversity factor that is apparent, yet difficult to define. The two-speed fan system which allows hoods to exhaust less than maximum air volume increases the diversity factor.

Having decided on a high pressure dual duct air distribution system early in the design of the building, engineers gave consideration to possible later additions of exhaust hoods. With all factors studied, a judicious selection for the maximum makeup air was made. The outside air tempering units, complete with hot and cold coils, were sized for this flow volume. The tempering units do not normally handle this large volume.

Each laboratory has its own mixing box and thermostat. Some offices and other rooms, served from the same high pressure air system as the laboratories, share thermostats and mixing boxes in groups of three. The supply air volume for each space was designed to meet its cooling and heating requirements *without specific regard to the need for the room's exhaust hood makeup air*. Where a large laboratory has only one small hood, the supply air may exceed maximum requirements for exhaust hood air. For example, in the case of a large laboratory with a heat load requiring 1200 cfm of air for cooling and with only one hood capable of pulling a maximum of 900 cfm, no special consideration for satisfying the exhaust hood air requirement is needed. The method of providing for the more common situation where maximum exhaust hood air requirements exceed room supply air will be developed in this discussion.

The Design Philosophy

The addition to the building is so arranged that all laboratories are toward the core or center of the addition. Each laboratory backs up to and shares a common wall with a service corridor that runs the length of the addition. This configuration adds to flexibil-

ity by making all laboratory services readily available to each laboratory. It also facilitates technical maintenance.

In addition to increasing initial equipment costs and operating costs for air conditioning, exhaust hoods usually pose certain control problems. These include excess face velocity problems, already discussed, which occur when hood sashes are lowered. In addition, exhaust hoods often make it difficult to introduce the proper amount of outside air at all times and to achieve and maintain good air balance throughout the building. To seek a solution to these difficulties, attention should be directed to air distribution concepts.

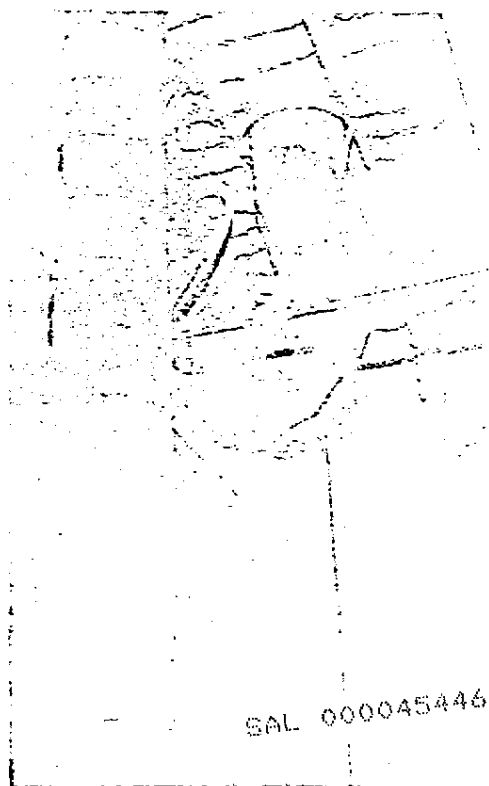
The selection, sizing, and placement of appropriate supply air diffusers and the determination of proper air velocities and volumes are important aspects of air conditioning design. Often there is more than one "correct" solution for a room. Some rooms could be served with two or three air supply diffusers, assuming all other features were compatible with the number of diffusers selected, and either sidewall or ceiling diffusers might suffice. Other variations are possible. It is often possible, therefore, to consider esthetics, cost, and future flexibility in selecting from among the several correct solutions. Supply air design is not a simple matter of making things big enough. While satisfactory results do not demand extreme accuracy, providing diffuser sizes or air volumes appreciably larger than needed can defeat the effort to achieve good comfort conditions as surely as errors in the opposite direction (undersizing).

SERVICE CORRIDOR view shows vertical section of galvanized exhaust hood duct at left and horizontal runs at top center. These are short and have only two bends per duct. They are of stainless steel since experience showed that galvanized duct might not withstand corrosive liquids that could condense out on surfaces. Corridor has ample space for more ducts. It is sealed off from occupied spaces and has forced ventilation pulling air out at the roof.

A somewhat similar aspect of air conditioning is the work of selecting proper sizes and locations for return air grilles. Both aspects deal with the science of air flow, although return air design is somewhat less critical and time consuming than supply air design. This can be appreciated when one considers that while both the supply and return air systems have to transport the proper quantity of air, the supply system must also provide for correct throw, velocity, induced air, and direction.

In many instances there would be esthetic and economic objections to making the return air system, and more specifically the return air grilles, larger or more numerous than necessary. But the return air system can be designed and built larger than the minimum requirements without negating good air conditioning results. If there were accruing benefits from oversizing the return air system—say if it aided in solving air balance problems—and if the benefits exceeded any esthetic or economic disadvantages, then the oversizing would be justified.

At the EPRC building addition,



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quirements through the outside air unit as a result.

In effect, the rooms, including the laboratories, are open at the top to a large pool of slowly moving air, which is conditioned and only slightly warmer than room air. (Of course, the visual impression is that of a normal, attractive ceiling.) Consider an individual chemical laboratory room that has several large exhaust hoods, all in operation. The air required by the hoods exceeds the air supplied to the room by the fan, and no air flows from the room to the central plenum through the slotted air handling troffers, there being no positive displacement of air toward the plenum. In fact, air flows down into the room from the central plenum as a result of the slight pressure in the plenum coupled with the slight negative pressure the hood fans impose on the room. The pressure differentials involved are minute, but the cross sectional area for flow is great.

When large quantities of air are exhausted by the hoods in a particular room, air from the central plenum enters across the full expanse of ceiling at low velocity. If the air flowing from the plenum to the chemical laboratory is a degree or two above the thermostat setting, as it usually is, the warming effect is sensed by the thermostat, which tends to reset the supply air temperature to compensate and maintain comfort conditions in the room. The flow of air from the central plenum into the room directly follows any changes in exhaust hood operation, such as turning off a hood fan or changing fan speeds. The main air conditioning fans are in no way deprived of air when laboratories draw from the pool of return air because the fans have unimpeded access to outside air. The source of air to the main air conditioning fans automatically divides between tempered outside air and central plenum air so that the system satisfies all makeup air needs. This capability is a function of the design and occurs without any sophisticated control system or special sensors or dampers beyond what is typical for this gen-

The design has not affected the cost of conditioned air that needs to be exhausted from laboratory hoods. Each cubic foot of air exhausted through a hood has been conditioned at a price. But by reducing the amount of air that is sometimes exhausted through hoods, the design eliminates the wasteful portion of the costs.

The design has also eliminated the problems of air balance and other air conditioning problems frequently encountered in air conditioned laboratory buildings that have exhaust hoods.

Evaluating the Results

Test data obtained under a variety of operating conditions have verified that air flow cannot become unbalanced in this building with the current distribution of exhaust hoods. It is felt that the features of the system will be adequate, without modification, to accommodate such future additional exhaust requirements as may reasonably be expected at this facility. Like any mechanical system, this or a similar system has limitations and must not be overtaxed. Otherwise, safety and proper operation could be compromised. Proper sizing and selection of system components must be based on knowledge of the facility's initial and future exhaust requirements and an evaluation of the components' characteristics.

Some readers, particularly those used to dealing with processes that are continuous and more exclusively of a toxic chemical nature, may object to this design on the grounds that laboratory air should not be recirculated. Like all brief admonitions, the statement "laboratory air should not be recirculated" must be studied and understood, not simply followed blindly. To discuss the caution properly, we must define each term. (What constitutes "laboratory air"?) We must know the intent of the caution and the types of situations to which it applies.

In this building addition, all chemical work takes place in proper exhaust hoods, and all undesirable air, aerosols, and the like are

ly is recirculated.

Excellent safety practices and special safety precautions are in effect throughout the laboratory building, which includes older portions without two-speed exhaust hood fans and central plenums. Also, there is a regular schedule for special medical examinations for those employees who work with materials that have health implications.

On rare occasions, chemical odors have been detected in old areas of the building, indicating some failure of earlier exhaust ventilation systems to capture all chemical materials. This has not occurred in the new addition with its special ventilation features. There have been no injurious ventilation shortcomings anywhere, but nevertheless all old exhaust hoods were recently retested, and many were adjusted or modified in an effort to insure optimum protection and see that everyone is afforded a work environment comparable with that in the new addition.

A 5500 sq ft laboratory building at the same site, completed in July of this year, has ventilation features very similar to those described herein.

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Conclusions . . .

It is hoped that those who consider this design in detail will concur in the conclusion that for this application the design with two-speed exhaust hood fans and a central plenum has achieved the following:

- 1) Reduced air conditioning investment.
- 2) Reduced operating costs.
- 3) Eliminated air balance and associated problems.
- 4) Most important, provided an environment with additional comfort, convenience, and safety for scientists and laboratory technicians.

The objectives of this air conditioning and ventilation project were satisfied. It was primarily the two-speed exhaust hood configuration, used in conjunction with the special features of the air conditioning distribution system, that

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION MEETS:

Speakers Decry "Mysterious Air Treatment Devices"; Discuss Laboratory Hood Design; Defend Unvented Makeup Heaters

Over 1400 engineers, physicians, chemists, nurses, physicists, and other professional personnel attended the annual American Industrial Hygiene Conference, held in Washington, D.C., from May 14 through 17. The meeting, sponsored by the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists, was described by the association as one of the most successful ever, both in attendance and number of technical papers presented. Abstracts from a few of the 130 papers conclude this report.

The Donald E. Cummings Memorial award for outstanding contributions to the knowledge and practice of the profession of industrial hygiene was presented to Herbert T. Walworth. Mr. Walworth, Director of Industrial Health and Hygiene for the Kemper Insurance Group, was the 16th person to receive the award, first given in 1944 and named for a pioneer in industrial hygiene.

Mysterious Air Treatment Devices. *Melvin W. First, Sc.D., consulting and research engineer, Newton Highlands, Mass.*

Large numbers of air treatment devices of no discernable merit are being purchased by the public at large and by commercial and industrial institutions. Some have been promoted in vigorous nationwide advertising campaigns for the relief of respiratory ailments in spite of the fact that toxic irritants such as ozone are emitted. These practices should be a matter of grave concern to professional specialists in this field lest sound practices be condemned indiscriminately with the worthless by a disillusioned public.

Four classes of mysterious devices based on fanciful theories derived from ill-understood scientific fragments are:

- (1) odor control by "counteraction" or "destruction with ozone"

- (2) air ionization for therapeutic purposes
- (3) air sterilization by disinfectant-coated fibrous fibers, and
- (4) control of dust soiling by "self-charging electrostatic" filters and electrical devices which "shatter" particles.

Laboratory Hood Design (Part 1). *Melvin W. First, Sc.D., consulting and research engineer, Newton Highlands, Mass.*

Rapid increases in the number of fully air conditioned laboratories has focused attention on the fresh air requirements of fume hoods. Since, for safety's sake, no part of the exhaust air may be recirculated, the heating and (especially) the cooling load requirements for exhaust air often represent a major part of the total.

Some measure of economy may be achieved by using the lowest hood face velocities consistent with safety. Most laboratory procedures can be conducted safely in a well designed hood with a minimum face velocity of 70-80 fpm when the fume cabinet is located in an area free from draughts and out of traffic flow. Essential hood design features for minimum flow include a smooth, converging entry shape and flow distribution baffles at the rear. These minimize air turbulence and differences in flow velocity at different locations in the hood face. For especially hazardous operations (isotopes, beryllium dust), a minimum face velocity of 100 fpm is generally specified when optimum conditions exist; and even higher velocities may be preferred to provide additional safety factor.

Because minimum exhaust air volume, even when employing excellent hood designs and placement, usually amounts to 800-1200 cfm per fume hood, further air conditioning economies have sometimes been attained by intro-

ducing a part of the hood exhaust volume inside the hood enclosure in the form of untempered outside air. This arrangement produces turbulence currents inside the hood enclosure and when hood face velocity is reduced to 25-30 fpm, safety is sacrificed. Air flow measurements and smoke observations indicate clearly that air supplied directly to the interior of a fume hood has no influence on the volume of room air required for safety and, in fact, produces no discernable beneficial effect. The only factor of importance is air flow which makes a contribution to the maintenance of hood face velocity.

Laboratory Hood Design (Part 2). *Richard Chamberlin and F. J. Viles, Jr., Massachusetts Institute of Technology, Occupational Medical Service, Cambridge, Mass.*

Proper design of supply air hoods requires that the supply air be introduced outside of the hood face and in such a manner that the operator is always breathing clean air.

Studies have been conducted to determine the advantages of several supply plenum designs, and their positions. Included were the use of lateral supply plenums, lateral supply plus overhead, overhead with and without full and tapered sides, and overhead supply with supplemental lateral supply at the base.

The lateral supply system was found to work well on small hood openings provided the temperature of the incoming air did not vary considerably from the room air temperature. When the incoming air was 10 deg F higher than the room air, particularly for hoods greater than 4 feet wide, an additional overhead plenum was required to overcome the rising effect of the lateral supply due to density difference of the air. In-

(Continued on page 126)

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AMERICAN INDUSTRIAL HYGIENE ASSOCIATION MEETS:

(Continued from page 75)
coming air at temperatures of 20 deg or more below room temperatures caused the reverse effect and indicated that for cold weather operations the incoming air would need to be tempered. The maximum discharge velocity for lateral supply plenums, without causing turbulence, was found to be 100 LFM.

With overhead plenums, the discharge velocity was increased to 140 LFM and the air density problem particularly under warm weather conditions was minimized. Provision of side enclosures with the overhead plenums increased the percent of supply air that could be provided without effecting hood control and loss to the room environment.

The maximum percent supply achieved was 60% for overhead plenum types, 70% for overhead

with side enclosures and 80% for combination enclosures with both lateral and overhead supply plenums. Markedly improved face velocity profiles in front of the hood operator is obtained particularly with designs involving lateral supply air.

This study showed that where the cost is warranted, supply air laboratory hoods can be designed that do not interfere with the principles of good hood control.

Health Hazards and Control of Direct Fired, Unvented, Makeup Air Heaters. *George M. Hama, Bureau of Industrial Hygiene, Detroit Department of Health, Detroit, Mich.*

A study was made of one type of direct-fired makeup heater (also known as a line type gas burner, flue-less makeup air heater or unvented makeup air

heater). The burner investigated takes from the passing air stream at least 2% of the total air required for complete combustion at the maximum firing rate and is supplied from an external blower all the air required for combustion at minimum firing rate.

Air determinations were made for carbon monoxide, carbon dioxide, oxides of nitrogen, aldehydes, sulfur dioxide water, vapor and unburned hydrocarbons with the burner operation under normal and adverse poor maintenance conditions.

Studies were made on one unvented makeup air heater under laboratory conditions and several direct fired makeup heaters in actual industrial operations. Test data indicates that toxic and nuisance contaminants were below the maximum allowable concentrations.

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Industrial Hygiene Practices Guide

LABORATORY HOOD VENTILATION

This Guide was prepared by the Committee on Industrial Hygiene Practices from material contributed by the following authors:

H. J. Ettlinger, M. W. First, and R. N. Mitchell.

Supplementary information and comments were obtained from:
R. S. Brief, J. H. Clarke, J. E. Peterson, and J. H. Rook.

I. INTRODUCTION

Dusts, fumes, vapors, and gases are often released in the course of laboratory work. If the amount of exposure is minimal, general ventilation may be used to dilute the contaminant to a satisfactory level. However, local exhaust ventilation is a more desirable technique when the contamination originates in specific areas or when extreme toxicity or other factors make contaminant control by simple dilution impractical. Local exhaust is also recommended for controlling dusts and other particulate contaminants. The laboratory hood is a specialized type of local exhaust hood and is one of the most important of all laboratory safety devices. It requires thoughtful design, careful maintenance, and proper use if it is to be effective in preventing unsatisfactory exposures to laboratory workers.

II. LABORATORY HOOD DESIGN

A. Face Velocity

Under ideal conditions, air flow velocities of 20 fpm may be adequate to control the escape of particles of respirable size or the molecular diffusion of gases and vapors. In actual practice, however, rates of 50-150 fpm are used in laboratory fume hoods for two reasons.

Evaluation of Laboratory Fume Hoods

H. F. SCHULTE, E. C. HYATT, H. S. JORDAN and R. N. MITCHELL
Industrial Hygiene Group, Los Alamos Scientific Laboratory
Los Alamos, New Mexico

AN EVALUATION of laboratory fume hoods was originally undertaken with the aim of obtaining data on the numerous types of existing hoods at Los Alamos and for developing design specifications for new hoods. In no instance in the field of hood application is the designer asked to reconcile as many contradictory requirements as in the design of laboratory fume hoods. For this reason, there are many custom-built hoods offered for sale and fume hoods appear to serve as favored subjects for advertising copy. The word "fume" in this paper is meant to include vapors, gases, smokes, mists and other airborne materials.

Design Data and Test Methods

A SURVEY of the literature showed that the only design criterion specified in various handbooks was that of face velocity and the recommended value of this varied from 50 to 150 feet per minute.^{1,2,3} Even the manual on industrial ventilation of the American Conference of Governmental Industrial Hygienists which has become a standard reference work contains little but contradictory information on this equipment.¹ Stockdale and Turner studied several hood types by means of smoke tests and developed a hood which they state operates satisfactorily at 50 feet per minute face velocity.^{4,5} Others also have used combinations of smoke and face velocity tests.^{3,6,7,8} An inquiry addressed to hood manufacturers regarding their methods of testing yielded absolutely no information.

Proposed Method of Testing

THE PRINCIPAL criterion of hood performance is the effectiveness with which fumes are captured, retained and exhausted

under normal conditions of use. Normal use in this sense would include average room air currents, activity of personnel in front of and partially inside the hood, and the generation of fumes in almost any part of the hood. The desirable air pattern for a hood, therefore, is one with a stable, continuous flow of air from the face to the exhaust slots. Any feature which causes the air to become unstable and change direction would be undesirable.

Smoke for the study of flow patterns was generated by means of five-minute smoke candles and also by means of the unit shown in Fig. 1 which burns a mixture of sawdust and motor oil. An attempt was made to develop an odor test to give quantitative results but this was unsuccessful. The test procedure used was to observe the flow patterns revealed by smoke generated in various parts of the hood under varying operating conditions. These conditions included different face velocities, cross draft velocities, thermal loadings, slot openings, en-

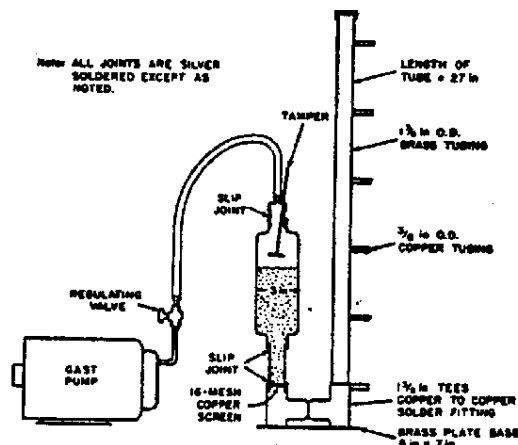


Fig. 1.
Smoke generator.

This document is based on work performed at the Los Alamos Scientific Laboratory under the auspices of the Atomic Energy Commission.

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Fig. 2.
Effect of cross draft velocity in excess of the face velocity.

trance shapes and others where such factors could be varied on specific hoods.

Results

Cross Currents and Face Velocities—Studies indicated that cross currents and other random air movements are a major factor affecting the stability of the air flow within the hood. It was found that whenever the velocity of the cross currents equals or exceeds the face velocity, serious disturbances of the hood air flow pattern results. The degree of this disturbance is practically independent of hood design. To insure proper performance of a hood under conditions of normal use, the face velocity thus must exceed the expected cross draft velocity, which means a design face velocity of at least 100 feet per minute. This is based on actual measurements of cross drafts and air movements produced by operating personnel. Velocities less than this value do not provide adequate control under normal conditions of use. Conservation of heated or cooled air at the expense of an adequate control velocity simply is not justified. In this investigation, controlled cross drafts were induced with a variable speed fan and were measured parallel to the face of the hood with a velometer. The effect of cross draft velocity in excess of face velocity is illustrated in Fig. 2.

It is this detrimental effect of cross drafts

which nullifies attempts to provide an independent source of unconditioned or untempered air to a hood. Tests were made on one hood where air was brought in along the sides and top of the hood face to supply about one half of the total amount of air exhausted by the hood. Smoke tests on this hood are shown in Fig. 3. Correspondence with other engineers and observations made in other laboratories have convinced us that the independent air supply is not a solution to the problem of saving heated or cooled air.

Location of Hood in Room—Careful consideration should be given to the location of the hood in the laboratory, although here many compromises have to be made. It is desirable to minimize the effects of thermal air currents from heating units and currents from doors, windows and supplied air inlets. A perforated ceiling as a supplied air source to a room was found to be almost ideal in its noninterference with hood operations.^{5,9}

Tests on one recessed radiator showed air currents with velocities as high as 100 feet per minute which would seriously interfere with the hood operation. Also, heat from a radiator located near a hood is largely wasted through the hood exhaust. Since most hoods will be used for operations that potentially may result in a fire or explosion, the hood should be located so that the exit from the laboratory will not be blocked in case of such an accident in the hood.

Exhaust Loading—It has been reported



Fig. 3.
Smoke test on hood having untempered air supplied through grills on side and top of hood face.

that heavy thermal loads inside a hood cause large variations in hood performance.^{10,11} To test this, a hood with a work surface 2'x3', a face area 2½'x3' and an average face velocity of 80 feet per minute was equipped with three 1200 W hot plates and four Meeker burners. With only the hot plates in use, the air temperature in the upper part of the hood was 8° C. above room temperature and there was no effect on flow pattern or face velocity distribution. There was no leakage of smoke from the upper part of the hood. With the four Meeker burners operating as well as the hot plates, the upper air temperature reached 38° C. above room temperature. Again, there was no adverse effect on flow pattern or face velocity. This is illustrated in Fig. 4. However, there was an appreciable leakage of smoke around a poorly fitted by-pass damper in the upper part of the front of the hood. This is due to the thermal head created by the difference in density between the heated air inside the hood and the air outside. This thermal head is larger than the small static suction required to pull air into the hood.

Repeating these same tests at a face velocity of 50 feet per minute, again, showed no effect of heat on the face velocity but an unfavorable effect on the air flow pattern. The leakage of smoke was considerably increased and some even leaked out of the upper part of the hood face. Obviously, this is an extremely heavy thermal loading and is much more severe than is likely to be encountered in actual practice. In the test



Fig. 4.

Smoke test showing lack of effect of high thermal loading on air flow pattern.



Fig. 5.

Air currents moving toward the hood face along the side walls and bottom of a hood with corner posts and depressed base.

procedure, all hoods were tested with a thermal loading of one Meeker burner per foot of hood length and in no case was there a serious disturbance of the air flow pattern.

~~When a plane surface intersects the air stream~~—The study revealed that any plane surface intersecting the air stream would cause serious disturbance of the air flow pattern within the hood and, in many cases, cause air to flow toward the face of the hood. If such a disturbing surface is at or near the hood face these air currents may be quite serious. For this reason, hoods without corner posts, center posts or excessively depressed bottoms were found to give the best pattern of air flow. Hoods that have such obstructions have currents of air moving along the side walls and bottom toward the face of the hood as illustrated in Fig. 5. Fumes captured in these currents will move toward the face and be recaptured by the main air stream only at the very edge of the hood opening. Under these conditions, the slightest external disturbance by cross drafts will actually aspirate such fumes out into the laboratory.

The inside of the front of the hood above the opening is another surface that will cause air to move toward the face. Fumes captured in this air flow will run down this



Fig. 6.

Smoke moving down the inside surface of the hood and being recaptured at the face opening.

surface and form a sag of variable depth before being recaptured by the incoming air again, at the face of the hood. This is illustrated in Fig. 6. Tests on one hood indicated that an air foil along the top of the hood opening or streamlining the top of the hood had no practical value in improving this condition, at least within the limits imposed by the operations carried on inside the hood. Sinks were found to create unfavorable air patterns and it is felt that the front side of any sink should be a minimum of six inches back from the face of the hood. Hoods, therefore, should have a smooth and as continuous a surface as possible. Air foils along the side and bottom of the hood entrance improve the air flow somewhat by eliminating the vena contracta. With face velocities of 80 to 100 feet per minute, an ordinary unobstructed entrance will create a vena contracta about six inches inside the hood face and extending to within one inch of the side walls. This will cause a slight disturbance to any fumes generated right at the edge of the hood and this condition could be corrected by air foils. It is doubtful, however, that the installation of air foils could be justified if the cost was appreciably in excess of that required for

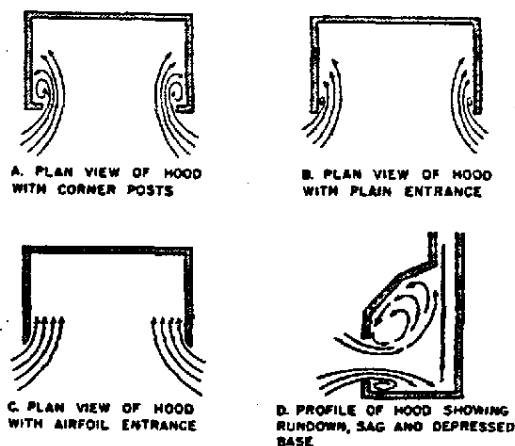


Fig. 7.

Air flow patterns in hood.

an ordinary unobstructed entrance. Fig. 7 illustrates the air flow pattern in these various hood types.

~~By-passes~~ **By-Passes**—The matter of doors on a laboratory fume hood is largely one of personal preference. There is no doubt that they represent a convenient safety shield that may be put into place quickly. However, as far as the action of the hood itself is concerned, it is doubtful whether doors aid in any manner. It is felt that hoods equipped with doors also should be equipped with some sort of by-pass to minimize fluctuations in the face velocity of the hood and in the amount of air supplied to the laboratory. Our tests verify the generally accepted fact that ~~velocity of 200 feet per minute will seriously disturb fumes and gases in the hood.~~ By-passes must be carefully designed and constructed. The type of by-pass actuated by means of a mechanical linkage has proven superior to gravity-operated or electronically controlled by-passes. The gravity-type by-pass similar to a furnace draft damper has the disadvantage of not forming a fume-tight seal in the top of the hood and does not give completely satisfactory control over the face velocity. The differential pressure produced by the low rate of air flow into the hood is not sufficient to make the by-pass a positive acting one. Extreme precision is needed in the mounting and bearing assembly of such a by-pass if it is to function satisfactorily. A system of hoods

each equipped with an electronically controlled by-pass was included in this study. The operation of the electronic controls was highly unstable and the mechanism tended to "hunt" continuously. It became necessary to disconnect all controls and servo motors and lock the control damper in a fixed position.

Slots and Plenums—An ideal laboratory fume hood would be exhausted through the entire back of the hood and then directly outside. Normally, however, the space behind the hood is limited and the exhausted air must be carried by ducts upward or downward from the hood. Thus, it is common practice to exhaust through slots in the rear usually located at the top and bottom of the rear wall of the hood. The slots may have individual ducts or may be open into a plenum behind the hood. The relative amounts of air flowing through each of the two slots are usually made adjustable to provide for an even distribution of face velocity. This may be done either by making the slot width adjustable or by dampers in individual ducts leading to each slot. The former method is least desirable since the adjustment is readily and frequently made by the user who has no air flow instruments to check on the adjustment. As a result, such hoods are usually found out of balance. Also, in many

cases, the depth of the plenum behind the hood may be smaller than the slot width and, hence, little is accomplished by small adjustments of the slot width. The most satisfactory arrangement appears to be a separate duct of proper design for each slot with a control damper in each duct.

Location of Blowers—Normally, a hood will be utilized to control a toxic or irritant substance and, therefore, it will be undesirable for such a substance to escape from a hood or from a conveying duct before reaching the discharge point outside the building. Hoods should have the blower located at the discharge end in order to maintain a negative pressure in the conveying ducts.¹² Generally, this is not a problem when hoods are connected together in an exhaust system. Unfortunately, it seems to be a prevailing practice to install individual blowers in a housing immediately above the hood proper.

Exhaust Ducts—Experience at Los Alamos would seem to indicate that down draft hoods with ducts underneath the floor give little trouble from condensation. It is also an easier task to maintain washdown sprays in such ducts. Hoods connected to overhead ducts have given trouble due to condensation and scale particles falling back into the hood. Therefore, if hoods are to be

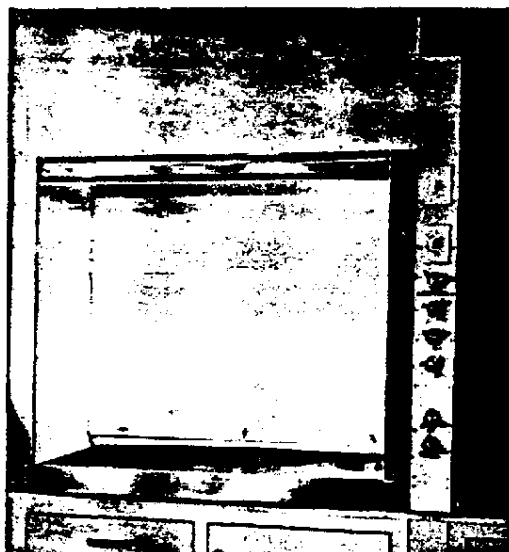


Fig. 8.
Los Alamos Hood A.

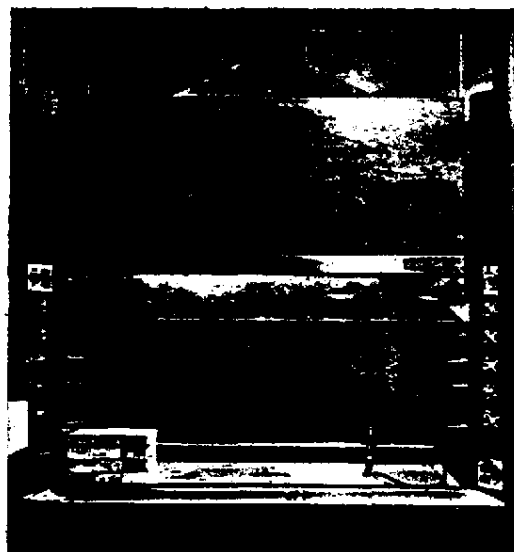


Fig. 9.
Los Alamos Hood B.

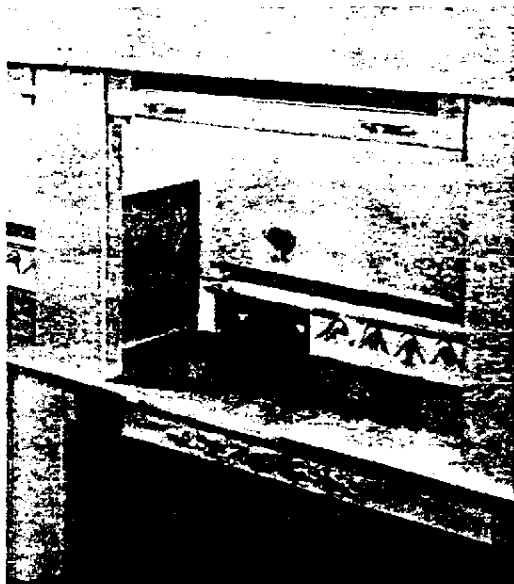


Fig. 10.
Los Alamos Hood C.

connected to overhead ducts, the location and design of the top slot should insure that dropping particles or droplets will not fall onto the work surfaces of the hood. While the matter of individual hood filters and washdown sprays behind the hoods was not investigated in this study, the need for such equipment should be considered carefully when the system is being designed.^{13,14}

Utility Connections—The number and variety of utility outlets within the hoods apparently are increasing. The latest Los Alamos hood has a total of 20 outlets for 12 different services. The placement of this number of outlets may create an obstruction sufficient to disrupt the flow pattern. This is especially true if the outlets are placed on the side wall close to the hood face. The mounting of utility connections should be such as to insure ease of access for repair and maintenance.^{9,15}

Characteristics of Specific Hoods

HOOD MANUFACTURERS have designed and installed many more types of hoods than can be described in this paper. Therefore, this review will be limited to a number of hood types installed at Los Alamos which illustrate specific hood features.

Los Alamos Hood A (Fig. 8)—This par-



Fig. 11.
Los Alamos Hood D.

ticular hood is characterized by a sharp edged entrance and a mechanically linked by-pass which exhausts air near the floor. In actual use, these hoods have an average face velocity of 125 to 150 feet per minute. In spite of this high face velocity, the sharp edged entrance visible in the above figure causes back flow and cross drafts will often pull material out from the face of the hood. There is an air flow adjacent to the front half of the side walls and inside the corner post with a velocity of 100 feet per minute toward the hood face.

Los Alamos Hood B (Fig. 9)—This hood is characterized by streamlined entrances and is commercially advertised as the Oak Ridge type hood. This hood is very satisfactory under normal operating conditions as long as an average face velocity of 100 feet per minute is maintained.

Los Alamos Hood C (Fig. 10)—This hood has a blower located above the hood and has a by-pass damper actuated mechanically by the door. It also has a lower slot raised six inches above the hood base. Tests on this hood demonstrated the adverse effect of corner posts and the fact that the ordinary unobstructed base was comparable in effectiveness to a base equipped with an air foil.

Los Alamos Hood D (Fig. 11)—This hood is one installed in our own laboratories. It is characterized by streamlined entrances and individual ducts with dampers for both top and bottom slots. It has a gravity-type by-pass at the top of the front of the hood. This hood operates at an average face velocity of 100 feet per minute and has given very satisfactory performance under normal operating conditions. The by-pass does not operate quite as well as anticipated and smoke will escape through the by-pass under heavy thermal loading.

Los Alamos Hood E (Fig. 12)—This hood has a streamlined entrance, no doors and is twelve feet long. This hood was specifically designed for the digestion of urine samples with nitric acid and operates satisfactorily for this purpose.

Los Alamos Hood F (Fig. 13)—This hood is included by reason of the fact that it is one of the most common types found in industry and universities throughout the country. It has no by-pass and showed the same adverse effects of corner posts. However, at an average face velocity of 100 feet per minute, it gives satisfactory performance.

Los Alamos Hood G (Fig. 14)—This hood has a nearly plain entrance and was originally

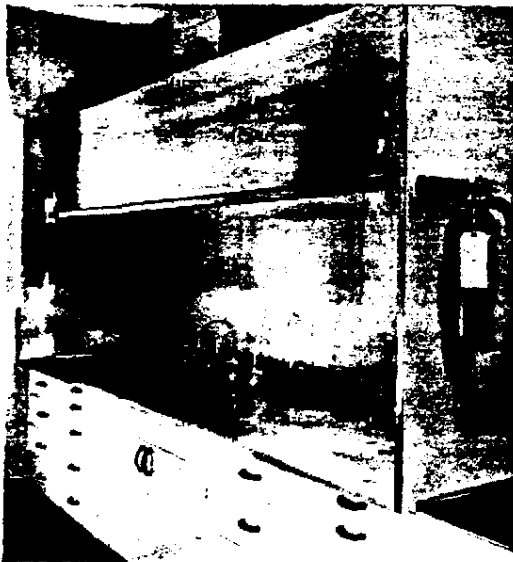


Fig. 12.
Los Alamos Hood E.



Fig. 13.
Los Alamos Hood F.

ally installed with an electronically controlled by-pass. The control for this by-pass consisted of a balanced hot wire located in a small opening on the side of the hood, the air flow through this opening increasing as the hood door was pulled down. As previously mentioned, this control was unstable and was finally disconnected and the control damper locked in position. The hood operates satisfactorily under normal conditions with the doors open.

Conclusions

1. ~~A minimum face velocity of 100 feet per minute and a minimum velocity of 80 feet per minute at the hood face is necessary for hoods handling substances of moderate toxicity.~~
2. The hood should be located in the laboratory at such a point as to minimize hazards to personnel in the event of fires or explosions and in so far as possible should be away from the cross drafts, high velocity supplied air inlets and other sources of air disturbance.
3. Normal heat loadings will not adversely effect the performance of a hood with an average face velocity of 100 feet per minute.

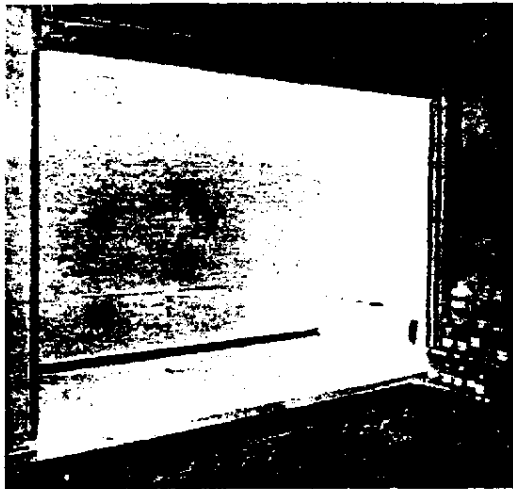


Fig. 14.
Los Alamos Hood G.

Hoods with very high heat loads should have the major portion of the air exhausted through the top slot.

4. The hood entrance should be kept free of obstructions and irregularities such as corner posts, sinks and excessively depressed bases. A slight improvement in the air pattern is obtained by use of air foils.

5. A hood door does not contribute to the performance of a hood but may be desirable for protection in case of a spill or an explosion. When doors are used, a mechanically operated by-pass of proper design is desirable to keep the face velocity below 300 feet per minute when the sash is closed to a six inch opening and to provide a constant room exhaust rate.

6. Provision should be made for adjustment of the relative quantities of air drawn through the top and bottom slots. This adjustment is best done by means of dampers located outside the hood and not readily accessible to the user.

7. Hood blowers should be located at the discharge end of the exhaust system to

maintain a negative pressure in the conveying duct.

8. Utility connections for hoods should be installed in such a manner to insure maximum access for repair and maintenance and minimum interference with air flow near the face of the hood.

9. Conservation of heated or conditioned air can only be obtained by minimizing the size of the hood opening rather than attempting to introduce unheated air at the hood face or reducing the face velocity.

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STANDARD PROCEDURES FOR TESTING FUME HOODS IN PLACE — AN UNFULFILLED NEED

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For many years, the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., *Guide and Data Book*, Applications Volume, has contained a chapter on Laboratories and a section on Fume Hoods¹ but the information is confined to a general description of various types of laboratory fume hoods and comments concerning good and bad practice in their installation and use. General requirements for safe operation are described, performance tests are recommended, and methods of testing are suggested, but such methods have not been standardized nor have minimum standards of performance been agreed upon.

Four years ago, ASHRAE's Technical Committee 4.3 on Industrial Environment became concerned with the frequent misuse or poor performance of fume hoods and the lack of any nationally accepted design criteria and test procedures to assure the safety of laboratory personnel.

Although there was already a great deal of public concern and technical interest in connection with urban air pollution, building designers and research administrators seemed to be unaware of air pollution problems within some of their own laboratories, often caused by inadequate performance of fume hoods.

Fume hoods of one kind or other have been used for more than fifty years and, as often happens with such familiar equipment, their

Architects, mechanical designers, and laboratory administrators have often assumed that the installation of a fume hood manufactured by a commercially-responsible company (a name brand, if you will) will insure a safe and satisfactory atmosphere for the laboratory worker. However, after reviewing several hundred science buildings, the Architectural Services Staff of the National Science Foundation reported in 1965 that much work needs to be done to develop design criteria and performance standards for fume hoods and to achieve wide dissemination

and understanding of the basic principals of fume hood design, installation, and use.² Improved product design alone is not enough, for variations in placement, use, and balance of the laboratory air conditioning system may override the product design features and result in unsatisfactory and unsafe operation.

For example, ~~the minimum face velocity for a fume hood is 50 fpm when the fume hazard is low and should be 150 fpm when fumes may be highly toxic.~~ Most authorities agree that this may be as low as 50 fpm when the fume hazard is low and should be 150 fpm when fumes may be highly toxic. But a person walking past the front of the hood at only one mile per hour may cause an air movement of 88 fpm, 33 fpm greater than the minimum face velocity for hood safety. A more normal indoor walking speed of two miles per hour might cause an air movement of 176 fpm, 26 fpm greater than the maximum face velocity recommended for a hood.

The ~~velocity of fume hood air flow~~ in or through the laboratory is obviously undesirable and may make safe operation almost impossible regardless of the hood design. Any air currents external to the hood may disturb the air pattern of the hood and cause fume outfall. In addition to foot traffic, these may be caused by thermal convection from a nearby heat source, movement of conditioned air supplied to the room, or rapid operation of doors or windows in the laboratory. Any air motion at the hood face in excess of the hood face velocity disturbs face air flow and may cause outfall.

Although safe operation is of prime importance because the comfort, health, and even the lives of people are involved, the advent of year-round air conditioning for laboratory buildings has greatly intensified the economic problems associated with the selection and utilization of fume hoods. The ~~high volume of air flow required to exhaust~~ by fume hoods adds substan-

enced engineer and made by a reliable manufacturer. Fume hood manufacturers contend that their designs are adequate and they have no control over the problem applications caused by location, air conditioning system balance, etc. Research proposed would include only the most commonly used hood types: standard air-foil laboratory hoods; and air-foil hoods with auxiliary air supply.

The scope of the work would include (1) a thorough literature search to determine what research has been done and reported in this area; (2) determination of the minimum face velocity that must be maintained for control of hazardous operations performed within the hood when such hood is properly located (i.e., when ambient air movement and outside interferences are minimal); (3) determination of the limits of practical outside interferences such as foot traffic and general air currents that can be tolerated without adversely affecting the control provided by the laboratory hood when the minimum face velocity is maintained (this may require field observations of the ambient air movement and outside interferences likely to be encountered in actual hood installations); (4) development of standard tests to be used for evaluating the factors mentioned in (1) and (2) above; (5) establishment of basic design criteria for auxiliary air supply type hoods to maintain the hazard control features provided by a standard air-foil laboratory hood; (6) development of a standard test procedure for evaluating performance of the hood with auxiliary air supply, such test procedures to be applicable under imbalance conditions (i.e., where supply air quantity is the same as the exhaust quantity); and (7) development of a standard test procedure for determining the percentage of supply that is entrained and exhausted.

It is intended that test procedures developed as a part of this research will take

into account interferences typically encountered in laboratories and will thus provide a standard method of generating the performance data published by the hood manufacturer. The tests would usually be made and performance characteristics certified by the manufacturer. Such standardized performance requirements could also be used in the specifications issued by the purchaser.

A somewhat less complicated standard procedure would be developed for testing and evaluating the hood performance in-place to assure that no unforeseen conditions exist (beyond those anticipated by the standard) which would interfere with the safe and uniform functioning of the hood.

There seems to be general agreement that standard test procedures are needed to assure safe performance of laboratory fume hoods as they are actually used. ASHRAE is willing and anxious to develop such procedures in an impartial way and is even willing to pay part of the cost of research needed.

Considering the number of laboratory fume hoods installed annually and the potential hazards involved, there is surely enough interest among users and manufacturers to assure financial support for the remaining part of the cost.

I am sure that we are not many years away from air quality standards for the air *inside* buildings. When such standards are set, there will be no allowance for the malfunction of fume hoods. The crash program required at that time to improve fume hood design and application will cost many times more than the proposed research.

I hope that we will anticipate the need and be ready *before* there are legal requirements in this field.

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