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Disadvantages of Auxiliary Air Fume Hoods

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ABSTRACT

The disadvantages of auxiliary air chemical fume hoods are examined from existing research literature and also from original analysis. The disadvantages are numerous enough that the alternatives to auxiliary air fume hoods should be used to achieve the maximum in safety and energy cost-effectiveness.

INTRODUCTION

The disadvantages of auxiliary air fume hoods have been presented in technical literature for a number of years. Despite this fact, the auxiliary air fume hood is among the most commonly specified of fume hood types. This paper provides a review of recent research as well as original analysis to show the disadvantages of the auxiliary air fume hood. A number of design alternatives are presented.

The laboratory fume hood is an exhaust device used in the chemical laboratory. In its most common form, it consists of a box set onto a table or bench. The front of the box is open with a sliding glass sash (see Figure 1). The fume hood user reaches through the open front of the fume hood with his or her arms to manipulate chemical processes. The top of the fume hood is connected to an exhaust system to remove the fumes generated within the fume hood. The capture or containment of the fume hood is not perfect. The efficiency of a particular fume hood at capturing toxic chemicals must be compared with the permissible exposure limit for the user. If the exposure to chemicals is too great with the operation of a standard fume hood, then a total containment device, such as a glove box, may have to be used (see Figure 2).

The ventilation engineer should play more of a role in the selection of the fume hood for its particular application. Too often in the past fume hoods have been chosen by other members of the design team based on its appearance or cost. Effective dilution ratios for different hoods can vary by 20 to 100 times, even under ideal conditions.

The auxiliary air hood is also called an "add air hood," a "make-up air hood," and a "supplementary air hood." In addition to the air exhausted from the inside of the hood, this hood type supplies a portion of air immediately to the outside of the hood (see Figure 3). If the hood exhausts 1000 cubic feet per minute (cfm), then the amount of auxiliary air introduced at the hood face is usually between 500 and 700 cfm. The exact amount of allowable auxiliary air depends on the design and manufacturer of the hood. More variation in quality occurs in the performance of auxiliary air hoods of different manufacturers than with most other hood types.

There are two main rationales for the use of auxiliary air hoods instead of other hood designs. The first is for safety reasons. The auxiliary air hood washes the breathing zone of the hood user with supply air and blows away contaminants. This safety effect is often wiped out by other competing factors, as will be discussed in this paper. The second reason to use the auxiliary air hood is for energy-savings and accompanying operating cost reductions. The conception of the auxiliary air hood as an energy-saving device is that the air supplied to the hood is either untempered or partially tempered. The energy spent conditioning auxiliary air to room temperature is supposed to have been reduced or eliminated. Discussion below will serve to challenge all or part of these two rationales.

One important factor to consider in the design of HVAC systems with auxiliary air hoods is the density of hoods in the facility. The density is the number of hoods per square foot. The supply air needed to condition the space in each room must be compared with the amount of exhaust needed to make up the air to be exhausted through the fume hoods. If a room needs more supply air for air-conditioning than exhaust air for hood exhausts, there is little or no reason to consider auxiliary air hoods.

For example, if a 660 ft^2 laboratory room has a supply air requirement of 1980 cfm, then there would be no need to provide auxiliary air to a hood in that room that had an exhaust requirement of only 1200 cfm. The total amount of

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air available for makeup to the hood exhaust is the sum of the supply air to the room needed for air conditioning plus the amount of air needed for room negative pressurization. Air should be transferred to the laboratory from corridors and adjacent non-lab spaces to contain contaminants generated in the lab. This process of transferring air from adjacent spaces through cracks and leak paths is referred to as negatively pressurizing the lab. If 1980 cfm is supplied to our example lab, then 200 cfm might be the amount of air transferred to the room to maintain negative pressurization. The total amount of air available would be 2180 cfm before any additional makeup air would be needed, such as from an auxiliary air hood.

LITERATURE SURVEY

The ASHRAE Handbook—1987 HVAC Systems and Applications—has a chapter on laboratories. The section on auxiliary air hoods says in part,

> Auxiliary air should not be introduced within the hood because less air is drawn through the hood face and the face velocity is lowered correspondingly. When auxiliary air is introduced across or in front of the opening, the flow pattern of the auxiliary air stream is critical to hood performance. When auxiliary air is dispersed into the laboratory, it often causes undesirable changes to room temperature and humidity; additionally, condensation on cold surfaces may result. Air turbulence can occur if the air stream strikes personnel working at the hood or any hood surfaces. Make-up air to the auxiliary air hoods should be heated during the heating season so that cold, moist, dense outside air does not fall below face opening. Cold air also makes the operator uncomfortable. The application of auxiliary air hoods should be based on the performance characteristics of the specific model, as determined by tests, and full consideration of the extreme level of toxicity that may occur within the hood. For proper hood performance, air balance must be carefully maintained. If the exhaust flow decreases while the auxiliary air flow remains constant, control may be lost. Also, laboratory air flow may reverse and flow from the laboratory into the corridor.

The *Industrial Ventilation Handbook* (ACGIH 1987) is an authoritative reference. To quote substantially from the section on auxiliary air hoods,

> Auxiliary air hoods are of proprietary design and a quantitative analysis cannot be provided here. Some designs blow contaminants out of the hood into the room; others are quite effective. The referenced performance test can and has been used to demonstrate the control level achieved in any specific design. Well-designed auxiliary air hoods perform as well as any other hoods in this regard. Some auxiliary air hoods, introducing untreated or partially treated air at low velocity, may degrade the room air conditioning if the auxiliary air is as much as 20°F warmer than the room air. This behavior may be observed with a smoke test, but it is difficult to quantify and there is not a valid, demonstrated quantifying test. If the laboratory air is to be maintained at some specified condition of temperature, humidity (and perhaps cleanliness), use of auxiliary air hoods may not be economic or energy-conserving as compared to regular airfoil hoods with well-designed room air supply.

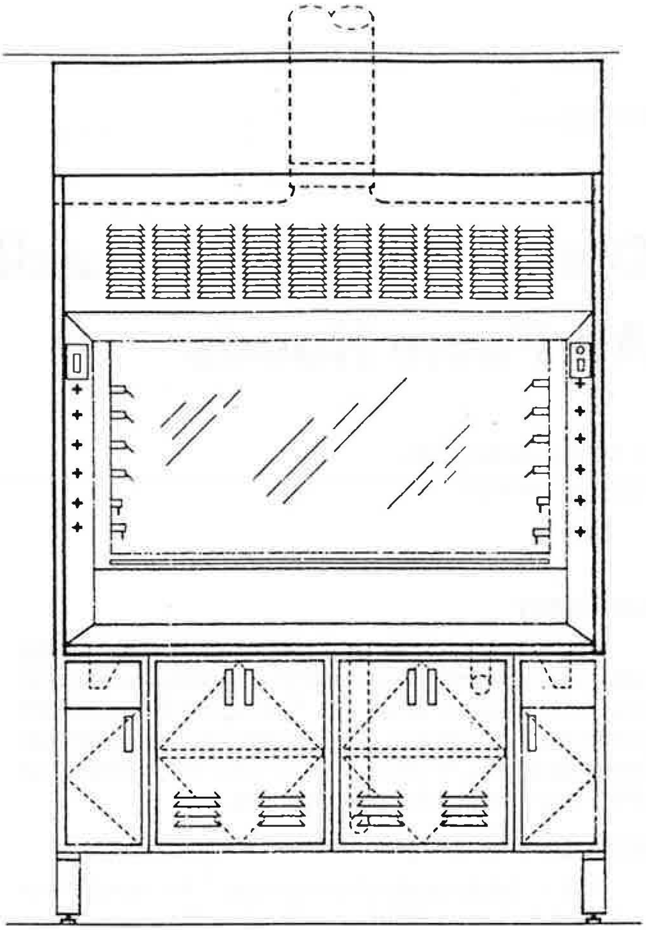

Figure 1 *Vertical sash fume hood*

Another reference (Braybrooke 1986) agrees in principle when referring to auxiliary air hoods by saying,

> This design would seem to save considerable thermal energy, particularly in the warmer months of the year. However, experience with these hoods has proven otherwise. A cautionary view of these hoods suggests the following:
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> 1. Energy consumption is frequently about as high as with the horizontal sash hood, due to the generally larger amounts of air needed to accomplish the same task. This requires more fan horsepower and more heating energy. Before using an auxiliary air hood, the designer should carefully determine the real air flow required to do the job and then make a thermal and electrical energy analysis for annual operation of the hood. This may approach or even exceed the energy requirements for a hood which exhausts only room air.
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> 2. These hoods generally require that supplementary air be introduced across or in front of the

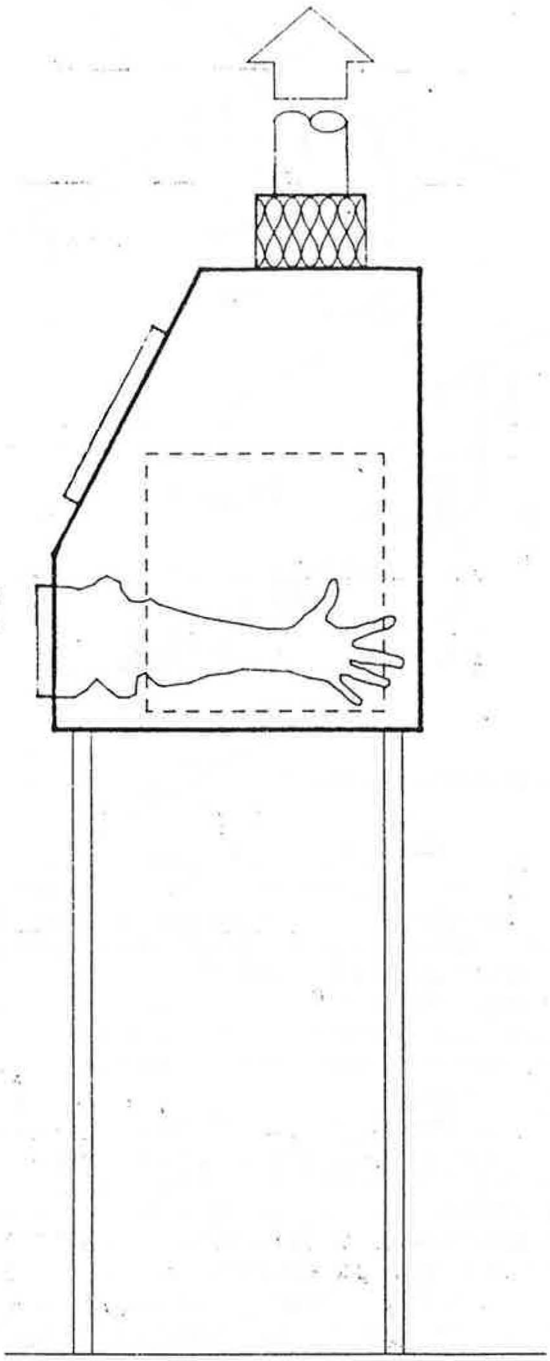

Figure 2 *Glove box*

opening. This has led to several undesirable effects: poor thermal environment for the scientist (both in temperature and in humidity); condensation on cold surfaces; turbulent air motion in the hood face opening (almost invariably driving air out of the hood at one point or another). For these reasons, some agencies which handle very toxic or carcinogenic substances have prohibited the use of auxiliary air hoods.

3. The initial cost of auxiliary air systems generally makes these hoods higher in first cost. For this reason, the system designer should make a life cycle study before recommending their use.

A respected safety guide (National Research Council 1981) has this to say about auxiliary air hoods,

> In recent years, the "supplementary-air hood" has become popular. This hood directs a blanket of untempered or partially tempered air vertical to the hood face between the operator and the sash. As much as 70% of the total air exhausted by the hood can be taken from a supplementary air source, resulting in considerable savings in energy. However, careful balancing of both the velocity and direction of the incoming air is required to achieve even air distribution across the hood face; if such a hood is operated with the sash closed, the supplementary air is of little value and may even upset the general laboratory ventilation. Consequently, the design and installation of a laboratory ventilation system employing supplementary-air hoods should not be attempted without the aid of a qualified ventilation engineer.

A recent experimental study (Knutson 1987) further explores reasons for hood failures. The test method used for analysis is ASHRAE Standard 110-1985 for testing fume hoods. The test showed some improvement in performance with the addition of auxiliary air to some hoods. However, another hood was 71 times worse with the addition of auxiliary air. Another test on the same hood showed a slight decrease in performance with 50% auxiliary air and an extreme decrease in performance with 70% auxiliary air. Another study (Caplan and Knutson 1982) suggests that the maximum differential in temperature between auxiliary air and room temperature be 20°F (11°C). If the auxiliary air is hotter or cooler than the room air by more than this amount, then the density difference due to temperature will make the auxiliary air hard for the hood to capture.

Another experimental study (Peterson et al. 1983) identified factors for good hood performance. Hood face velocities between 65 to 125 feet per minute were studied. Regular room air supply was studied as well as special perforated diffuser ducts. Auxiliary air hoods were looked at as well as conventional hoods. In some cases, decreasing the amount of auxiliary air or its velocities increased hood performance. The study also noted that auxiliary air hoods do not seem to have any overall safety advantages over conventional fume hoods. Further testing showed that auxiliary air temperatures below laboratory temperatures may impair hood performance. Good room air supply distribution was found to be the most important factor in this test on increasing or degrading hood performance.

A study (Neuman and Rousseau 1986) analyzed the energy cost savings of variable-volume hoods with constant face velocity controls. Another study (Neuman and Guven 1988) simulated the operation of a variable-volume auxiliary air system as compared with a variable-volume system with conventional hoods. In the building simulated, the total mechanical system cost with auxiliary air hoods was $4,403,000 with a total annual utility cost of $794,000. Comparable costs with conventional hoods were $3,969,000 and $605,000 per year. In this example, the auxiliary air hoods had a higher first cost by 10% of the cost of the whole mechanical system and a higher operating cost of 30% over using conventional hoods.

AUXILIARY AIR HOOD DISADVANTAGES

One of the important disadvantages of the auxiliary air hood is the poor use that is made of the ventilation air for general room ventilation. Fume hoods are only one part of the laboratory ventilation system. Chemicals may be spilled inside the laboratory and outside the auxiliary air hood. These spills need to be diluted by the air supplied to the room for general ventilation. If a lab has 10 air changes per hour of 100% outside air, this does not mean that all chemical fumes will be removed in six minutes. The more fresh air ventilation provided to laboratories with chemicals, the better. Since auxiliary air should be tempered for safety reasons, it should be introduced into the laboratory room to provide additional fresh air ventilation. Auxiliary air hoods are designed to introduce air in such a way that the auxiliary air is drawn into the hood with minimal mixing with room air. Because of this, the auxiliary air is not being used to dilute toxic chemicals that may already exist in the laboratory room environment outside of the fume hood. If a supply of air is necessary to make up the exhaust requirements of the hood, it should be tempered to room temperature and introduced away from the hood to provide maximum ventilation benefit from that air. The use of that tempered makeup air in an auxiliary air hood would seem to be a waste of the ventilation benefit of that air.

The literature survey has revealed a number of disadvantages to the use of auxiliary air fume hoods. The claims of superior safety for auxiliary air hoods do not seem to be substantiated by the literature survey. The references cited state that equivalent safety in an auxiliary air hood is only achievable if it is more carefully designed and situated than a comparable hood without auxiliary air. Many of the energy savings claimed for auxiliary air hoods have been attributed to using untempered outside air. This practice degrades the temperature and humidity conditions inside the laboratory. Also, the safety of the auxiliary air hood is decreased by using untempered outside air. The research cited showed that the auxiliary air should be tempered to room temperature. The auxiliary air should be no colder than room temperature and may be slightly warmer than room temperature. This requirement for tempering the outside air wipes out most of the energy savings possible for auxiliary air hoods. In some building configurations, the energy to move the auxiliary air through smaller branch ducts to the hood will cause the auxiliary air system to use more energy than a comparable system with conventional hoods.

The air motion from the commonly designed auxiliary air hood causes an uncomfortable draft on the head and shoulders of fume hood users. Many users have blocked or disconnected the auxiliary air to the hood because of this discomfort. This interference with the auxiliary air will cause an imbalance in the room pressurization unless the room is rebalanced and provided with additional supply air.

The auxiliary air hood is more difficult to balance and test than other hood types. The auxiliary air hood is more prone to decreased safety conditions from relatively small changes in room pressurization and air distribution. Active pressurization control is made more difficult by using auxiliary air hoods. Tracking systems have an additional supply air volume to measure with auxiliary air hoods and differential pressure systems have more supply air inlets to the room to control. For some reason, the auxiliary air hood seems more subject to errors in connection in the field. The chances of hooking up the auxiliary air to the hood exhaust are great enough to be of concern. The resulting condition of blowing contaminants in the face of the hood user is a real safety hazard. Most hood alarms are not configured to indicate this condition because they measure ductflow velocity, not direction.

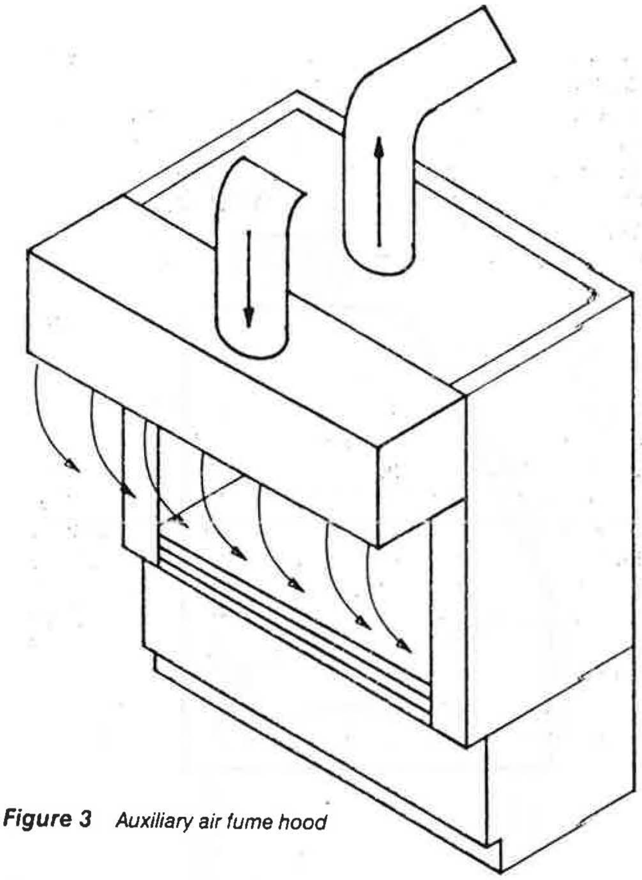

Figure 3 *Auxiliary air fume hood*

As was demonstrated by the literature survey, most laboratory buildings using a large number of auxiliary air fume hoods have higher first costs than if conventional fume hoods were used. The auxiliary air hood is more expensive to construct than conventional fume hoods. The auxiliary air hood results in additional fans, tempering coils, and ductwork. Even in those systems where auxiliary air results in lower energy costs, the payback period can be very long due to the higher initial construction cost.

The use of auxiliary air hoods makes remodeling difficult. With auxiliary air hoods, to add or move a hood requires that an exhaust duct and a supply duct both be added or relocated. Because of the increased difficulty of making changes in auxiliary air fume hood systems, there may be fewer hoods provided as laboratories expand due to the cost of renovation. This could lead to a decrease in safety since maintaining the number of fume hoods is a prime safety criterion, as is providing fume hoods at convenient locations to the fume hood user. The user must be encouraged to use the fume hood by its proximity.

ALTERNATIVES TO AUXILIARY AIR FUME HOODS

The first design alternative is to design with the best available conventional hoods. This should provide the maximum in safety at a reasonable construction cost. For those proponents of the makeup air concept, it is possible to design a system to introduce makeup air that has been tempered to room temperature or above. This still provides a savings in cooling energy in the summer while avoiding the problems associated with the actual use of the auxiliary air fume hood. This makeup air system shares most of the first-cost disadvantages of the auxiliary air hood system but does make better use of the tempered makeup air to provide additional ventilation air to the room.

A third alternative is to use fume hoods with restricted face openings. For example, a fume hood with horizontal sliding sashes uses much less exhaust air than the auxiliary air hood. (See Figure 4.) The horizontal sliding sashes restrict the face opening to usually about 50% of the opening in a vertically rising sash. This limited opening provides superior safety by providing better containment of fumes and better shielding for the fume hood user. In the analysis below, a comparison was made of the utility cost of a horizontal fume hood with an auxiliary air hood. A similar alternative would be to use a vertical rising sash hood with a sash lock that prevents it from opening to more than 15 in high. This device also saves energy and provides superior containment and safety when compared with the auxiliary air hood. The ventilation engineer must obtain the cooperation of the fume hood users to use these types of hoods. Despite their increased safety, the more limited accessibility of the horizontal and vertical hoods with sash locks makes them slightly more inconvenient to use. This inconvenience is a concern mainly when undergraduate students are using the hoods.

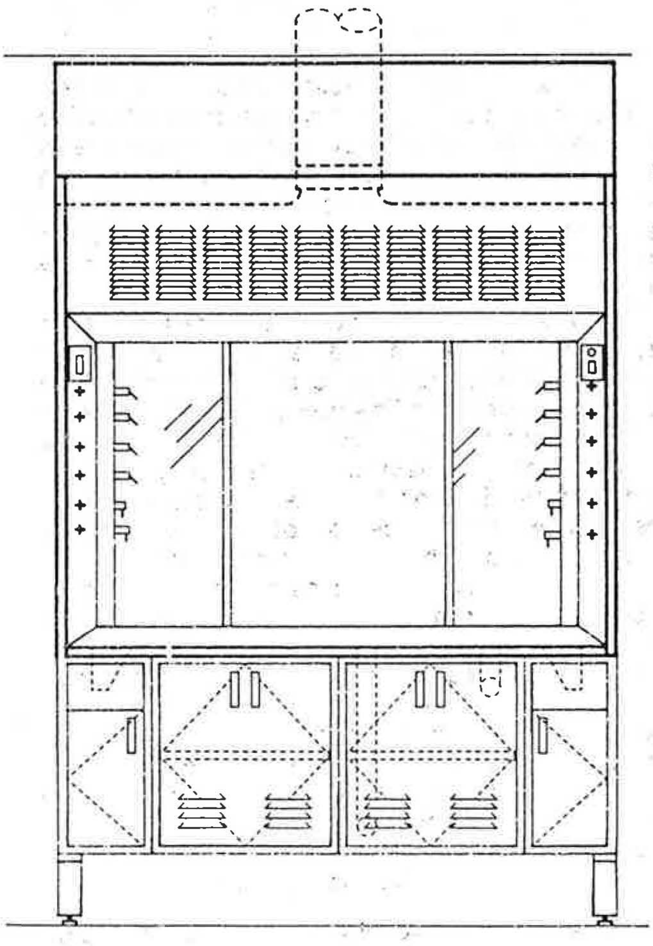

Figure 4 *Horizontal sash fume hood*

The analysis that follows shows the horizontal hood has an advantage over the auxiliary air hood. The literature survey showed that the variable-volume hood with constant face velocity controls is the best energy- and cost-cutting alternative. The advanced controls necessary to make variable-volume hoods safe also provide the greatest degree of operating cost savings. In addition, the controls and monitors on these hoods provide greater accuracy, leading to increased safety for the user. The greater safety provided by the constant face velocity variable-volume hood can be paid for in less than a year (in most cases) out of energy cost savings.

Auxiliary air hoods do not provide greater levels of safety than well-designed conventional fume hoods. The auxiliary air hood is not the energy saver and cost cutter as was originally thought. Even its job of safely introducing supply air into the laboratory room is being superseded. Special high-volume, low-velocity diffusers have been developed for laboratory use. These diffusers are able to provide supply air that does not disturb the operation of the conventional fume hood. Research has shown that the supply air velocity at the face of the hood should be less than one-third the hood face velocity (Caplan and Knutson 1982). Auxiliary air hoods are no longer necessary in order to safely introduce the large amount of makeup air needed for chemical fume hoods.

APPROXIMATE HOOD OPERATING COSTS

Simple manual approximations were made to estimate the annual utility cost of auxiliary air fume hoods as compared with horizontal fume hoods. Calculations are shown for buildings in Florida, Mississippi, and Minnesota. In each case, the horizontal fume hood has significantly lower operating costs than the auxiliary air fume hood.

The auxiliary air hood is assumed to exhaust 1250 cfm with 750 cfm of tempered make-up and 500 cfm of room air supply. This corresponds to a six-foot bench hood with 60% auxiliary air. The horizontal hood is assumed to have 700 cfm of exhaust that is conditioned room air. Design calculations are made for an assumed building size with 60 fume hoods with a share of the fan operating expense apportioned to each fume hood. Each hood is assumed to operate at full volume 8760 hours per year. A bin method is used to estimate the amount of energy needed to condition or temper the 100% outside air used in the ventilation system. Table 1 shows the results for operating cost comparisons for Florida, Table 2 for Mississippi, and Table 3 for Minnesota. Cost savings for using the horizontal hood were 25% to 36%.

CONCLUSIONS AND RECOMMENDATIONS

The ventilation engineer is responsible for the health and safety of the building's occupants. The choice of auxiliary air hoods may not be of any safety benefit in the long-term use of laboratory buildings. Numerous operational disadvantages have been discussed that make the selec-

TABLE 1
Utility Cost Comparison — Florida

#	Cost Component	Horizontal Hood Cost Contribution	Auxiliary Air Hood Cost Contribution
1	Heating Room Make-up Air	184	132
2	Heating Hood Make-up Air	—	123
3	Cooling Room Make-up Air	1480	1058
4	Cooling Hood Make-up Air	—	103
5	Additional Space Cooling	—	184
6	Supply Fan	890	1780
7	Exhaust Fan	890	1190
TOTALS		$3444	$4570

Savings for using horizontal hood equals $1126/hood/year.

TABLE 2
Utility Cost Comparison — Mississippi

#	Cost Component	Horizontal Hood Cost Contribution	Auxiliary Air Hood Cost Contribution
1	Heating Room Make-up Air	386	277
2	Heating Hood Make-up Air	—	316
3	Cooling Room Make-up Air	619	492
4	Cooling Hood Make-up Air	—	83
5	Additional Space Cooling	—	132
6	Supply Fan	614	1228
7	Exhaust Fan	614	819
TOTALS		$2233	$3347

Savings for using horizontal hood equals $1114/hood/year.

TABLE 3
Utility Cost Comparison — Minnesota

#	Cost Component	Horizontal Hood Cost Contribution	Auxiliary Air Hood Cost Contribution
1	Heating Room Make-up Air	650	465
2	Heating Hood Make-up Air	—	592
3	Cooling Room Make-up Air	205	146
4	Cooling Hood Make-up Air	—	1
5	Additional Space Cooling	—	44
6	Supply Fan	558	1116
7	Exhaust Fan	558	744
TOTALS		$1971	$3108

Savings for using horizontal hood equals $1137/hood/year

tion of auxiliary air hoods a poor choice in most cases. Safer, energy-efficient alternatives exist, such as horizontal hoods and constant face velocity variable-volume hoods, which should replace the auxiliary air hood whenever possible.

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