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LABORATORY HOOD DESIGN

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The potential hazards to laboratory personnel are obvious when we realize that, depending on the substance involved, combustible gas and vapor concentrations over the range from 0.6 to about 10% will produce explosive mixtures, as will fine combustible dusts in concentrations over 20 milligrams per liter of air. The concentrations of toxic materials which will produce damage to the human body are much smaller and threshold limit values (TLV) for such substances as published by the American Conference of Governmental Industrial Hygienists are expressed in parts per million. Nickel Carbonyl, for example, because of its potential carcinogenic effect, has a TLV of 0.001 ppm. Even much smaller limits are applied where radioactive materials are involved; for example, the threshold limit value for Iodine ^{131} is 4.5×10^{-12} ppm. In addition to such materials of known toxicity where actual industrial experience has been attained, there are many materials now in laboratory stages of development where no toxicity data or real experience has been acquired. The need for adequate control to prevent exposures to laboratory personnel to all of these classes of materials is evident, and for all practical purposes, laboratory hoods are the means by which this control is attained.

The prime purpose of any hood, therefore, is to protect the operator, and this point cannot be overemphasized. Any design which interferes with good control should not be tolerated, for safety would be sacrificed. The operator has the right to assume that the hood provides the control needed and he will take liberties in his work that would not be taken if a hood was not available. It follows, therefore, that a poorly designed or improperly operating hood can create a higher hazard level than normally anticipated.

The adequacy of control is based on maintaining a good control velocity across the entire face of the hood. What this velocity should be is subject to the location of the hood within the laboratory, the interferences that exist from such sources as traffic, drafts from windows or doors, make-up air grilles, as well as the type of operation conducted within the hood. Many investigators have reviewed the criteria for control velocities based on containment of materials within the hood when interferences outside the hood are not a factor. Viles has shown that based on the molecular diffusion forces of gases and the particle sinetics (where particles ten microns and less are considered) a velocity of less than 50 fpm would assure containment. It is the other forces outside of the hood, therefore, that determine what face velocities are required.

To give some perspective to the air velocities encountered in laboratory areas, a draft from an open window may vary from 5 to 15 miles per hour (570-1700 fpm), a person walking by a hood at a normal pace travels at a rate of 3 mph (340 fpm), while most hoods have face velocities of 100 fpm or less (1.14 mph). And in fact 100 fpm is normally considered high.

However, there has to be some base lines for recommended hood face velocities. At M.I.T. we have found that if hood locations are satisfactory, outside interferences are minimal and the materials used are not extremely toxic or radioactive nor dispersed at high velocities, a minimum average face velocity of 80 fpm is required. We also stipulate that the velocity at any point cannot deviate more than 10 fpm from this average. In the case where highly toxic materials such as beryllium, nickel carbonyl, or radioactive compounds are used, the minimum average face velocity recommended is 100 fpm with no point in the face varying by more than 10% from this average.

When hood locations are not ideal, or special operations are involved, each case is individually appraised. It should also be stated that excessive face velocities are not desirable, particularly in areas with more than one hood, for this increases the need for make-up air which causes higher air turbulence within the room with subsequent increase in air disturbance at the hood face.

As stated previously, the velocity balance across the face should be maintained. The flow should be essentially perpendicular to the face opening. This balance is not obtained in the usual fume cupboard, where most of the air enters the top section of the hood with little control at the bench level. To attain balance, a slotted baffle and plenum is used in conventional hoods. Such a design should assure that a constant and uniform negative pressure is maintained in the plenum so each slot will exhaust its proportional amount of air. Good design usually results in slot velocities of 700-1400 fpm. A large number of slots can reduce turbulence within the hood, however, two and three slot hoods are common and this compromise is usually made so the slots can be made adjustable. This permits adjustment to handle high evaporative rates or overcome equipment blockage in the hood.

There are many hoods which are variations of this basic design. These include those with airfoil inlets, vertical sliding sashes, horizontal sliding sashes, bypass types, and constant velocity hoods.

Airfoil inlets reduce air turbulence within the hood by eliminating or minimizing vortices which occur particularly at the hood edges. These airfoils usually allow space for mounting service fixtures thus eliminating the need for having them inside the hood or as projections below the bench surface.

Simple vertical sash hoods are very common and the sashes are often used as safety shields. They have one serious drawback in that as the sash is lowered, the air velocity increases and this can present problems. Horizontal sashes are often used to reduce the overall face opening of the hood and thus lower the total air flow requirement. Such sashes should be mounted in a single track so the total open area is constant. They should be capable of movement so that all areas of the hood are accessable. We have found that this type of hood requires frequent checking, for operators are apt to remove such sashes and leave them out which means of course the proper control velocity at the face is no longer maintained. These hoods present some problems in assuring that all areas of the hood receive proper ventilation. To help overcome this, we have designed sashes so that each has an open area and this is usually at bench level.

Bypass hoods are usually of two types, those that open and allow air to enter right into the exhaust duct or exhaust plenum, and those that open above the sash allowing air to enter the hood proper. In the latter as the sash is lowered to a certain height above the bench, air starts to bypass into the hood chamber. This type of bypass,can result in a face velocity increase of over threefold when the sash is lowered.

In recent years there has been a growing tendency to provide year-round air conditioning in laboratory areas. Because of the economics involved, architects and building planners began looking for ways in which the conditioned air loss could be modified. This is certainly understandable for most hoods require 1000 cfm or more for proper control and it has been estimated that each 200 cfm of air exhausted requires one ton of refrigeration capacity, costing about $1,000. To this, it was necessary to add from $50 to $75 per ton for operating costs annually. This need provided the impetus necessary for hood manufacturers to design and build "supply air" or "auxiliary air" hoods. Unfortunately, many manufacturers lost sight of the main purpose of a hood, that is, to protect the operator, and many of the methods proposed to save air-conditioned air resulted in potentially unsafe hoods.

In the early 1960's, we were asked by our building design group to evaluate commercially available supply air hoods. The criteria that was set before this review was that any supplied air hood design must 1) in no way compromise the basic purpose of the hood, which is to provide the operator with adequate protection under all operating conditions and 2) that the percentage of supply air must be sufficient (70% or more) to make its use economically feasible. At that time, none of the commercially available models reviewed could meet these requirements. It was then agreed that we would attempt to design an acceptable auxiliary air hood.

To make sure that we as Industrial Hygiene Engineers did not violate the number one rule mentioned previously, it was agreed that: 1) all make up or supply air would be provided outside of the hood face; 2) the supply air velocity and flow pattern would not affect the face control velocity; and, 3) that supply air could not result in displacement of contaminated hood air by carrying it back into the room.

Many supply systems were tried using lateral supply plenums, overhead plenums, combinations of overhead and lateral supply and eventually a design was developed that was applied to a sixteen hood installation in our Radioactivity Center. The supply system consisted of an overhead plenum which extended out from the face of the hood and tapered sides which extended from the plenum to the edge of the bench.

The plenum contained a slotted baffle plate, and two perforated plates with offset holes to obtain the balance desired. Dust-stop filters were installed as a means of "knocking out" the velocity as the air passed through the last hole plate.

With this design, it was possible to exhaust these hoods so as to maintain a velocity of 100 fpm at the hood face, supply 75% of the air being exhausted without interfering with the control velocity, and to entrain and exhaust over 90% of the air being supplied.

The air supplied is tempered during the cold weather months for as indicated during our studies, if incoming air temperatures were more than 5°F below room air temperatures, it became uncomfortable for the operator. During warm weather months however, differences as much as 20°F higher than room air have been experienced without complaints and without effect on overall hood performance. In this particular installation, two-speed exhaust fans were used. When the sash is lowered, a sash-operated switch automatically reduces the exhaust fan to low speed and shuts off the supply air system. By use of this technique, overall building balance is maintained because the same amount of room air is exhausted at all times. Filters were required in these systems and dampers were provided in each line and a manometer was installed across the damper and filter. This made it possible to impose "end filter resistance" preventing excessive hood flows when filters are clean. Dampers are adjusted manually to compensate for filter loadings. This system has performed very well aerodynamically with the only complaint being that the canopy was somewhat noisy. Some minor changes in the design have been recently tried on one unit and the noise problem minimized.

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Following this installation, additional investigations were conducted in a study sponsored in part by one of the major hood manufacturers. A new supply air hood was developed. This hood meets the same basic criteria reported earlier. Some of the improvements include airfoil sides and a special deflector plate (a pressurized bottom airfoil).

This hood has been tested at face velocities of from 60 to 150 fpm and at each of these exhaust volumes the supply air percentage has been varied from 50% to 75%. Under all of these conditions, the hood will capture and entrain the supply air at percentages greater than 90%.

With the special deflector plate which introduces less than 4 cubic feet per minute through the special perforated area, a sweeping effect is always maintained at bench level.

Special tests were conducted which indicated what would happen under imbalanced conditions. The exhaust volume was first set to provide an average face velocity of 100 fpm. The supply air was then set so as to provide 70% of the air exhausted. The exhaust volume was then cut back to a point at which the supply air now being provided was actually 100% of that being exhausted. This is the type of condition that might occur if for some reason the fan belt on the exhaust fan slipped or the fan became corroded. Under these conditions, some of the supply air was lost to the room, however, none of the air from within the hood that would represent contaminated air was entrained or displaced in any way so that it was carried out into the work area. This test was conducted using a specially designed uranine aerosol generating and sampling set up. This set up required nine (9) small generators placed across the face of the hood and located six inches back from the actual face. The air samples were then taken just outside of the hood and at various places throughout the laboratory. No evidence of contamination was detected. The hood was then set up so that again 70% of the air was being supplied and the face velocity of the hood maintained at 100 fpm. A small particle size uranine aerosol was then introduced into the supply air stream at a point just beyond the supply air fan. Air samples were then taken at the discharge channel, and in the exhaust plenum. Using the uranine fluorometric technique, the hood was found to be operating at 96% efficiency. That is 96% of the air being supplied was being entrained and exhausted. This same test was conducted using varying percentages of supply and exhaust. The entrainment efficiency was found to be greater than 90% over the entire testing range.

A total of 50 of these hoods were provided in our new Life Sciences Building. These hoods have been in operation about 3 years and acceptance by laboratory personnel has been gratifying.

A commercial model of this design is now available. The commercial model shown has side extensions which if used can slightly increase the percentage supply possible.

Some of the advantages of this type of supply air hood are worth mentioning. Because there is a protective air curtain of clean air just outside of the hood face, the operator is essentially always protected. Any momentary disturbance of the air patterns in the immediate area of the hood would disturb the supply air curtain, but would not disturb the control velocity at the face of the hood. Although I originally thought that a supply air hood could not be made as safe as a conventional laboratory hood, I now feel that a well-designed supply air hood is a better hood than a conventional exhaust hood.

There are many other fairly new innovations that I feel should be made standard on laboratory hoods. For example, I would like to see all laboratory bench tops be of the recessed type. This would do much to keep spilled materials from coming out of the hood. If this recess started at a point several inches within the hood, this would make all operators keep their equipment well within the hood face, which in turn would reduce the effective vortices which occur directly in front of the operator when air is coming around him. It should be standard practice today to have an airfoil inlet. Certainly the advantages out weigh the slight difference in cost. All interior surfaces should be easily cleanable and all of the service controls should be located outside of the hood face.

I think it is imperative that those concerned with hood installations do everything that they can to make sure that they get the best operating hoods and hood systems possible. The best way to achieve this is to have the most stringent specifications possible and a performance test should be included. Many of the performance specifications today are based on smoke studies. Smoke tests can be satisfactory. However, the evaluation is such that it is really a judgment decision. It would be much better, therefore, to have such performance tests based on a scientific evaluation. This type of specification could be written involving the uranine test discussed earlier in this paper. Specification should also be written for duct work material, types of fans, fan ratings, and overall noise level. Today while we are spending millions of dollars for laboratory facilities for our teaching and research personnel, I think it is only "just" that we provide for them as complete and perfect a system as possible.