CONOCO

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Interoffice Communication

file laboratory hoods

To Distribution

From J. J. Hall

Date May 22, 1978

Subject Laboratory Hood Classification Schedule

Properly functioning laboratory hoods are an essential element in controlling exposures to chemicals in our laboratories. Face velocity in linear feet per minute is the critical parameter of hood performance. Much controversy has revolved around the search for a "magic number" suitable for all hoods under all conditions. Unfortunately such a number does not exist. There are a number of variables to be considered in selecting the proper face velocity, including:

1. Characteristics of the substance to be handled (quantities handled, toxicity, vapor pressure, etc.).

2. The amount of air disturbance expected at, or near the hood. (For example, the proximity of the hood to a door, walkway, or air conditioning grill).

3. The physical configuration of the hood including the size and shape of the normal opening, the presence or absence of internal baffles.

4. The uniformity of face velocities.

For maximum flexibility in the use of hoods, the ideal situation is to provide all hoods with air flows which ensure complete capture of all materials released within the hood. However, a savings in energy to condition make-up air, can be realized by tailoring each hood's performance to its specific use.

Outlined below is a hood classification schedule which can be used as a guideline, in conjunction with the variables mentioned above, to arrive at proper performance criteria for your laboratory hoods.

CLASSES OF HOODS

1. Class A Hoods: for handling highly toxic materials where complete control is required. For work falling into this cagegory, hoods should be designed to give an actual performance of 125 feet per 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, benzene, VCM, and materials having a similar high order of toxicity.

2. Class B Hoods: would be hoods designed to give an actual performance of 80 feet per minute face velocity. These could be used for any operations 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.

3. Class C Hoods: would be designated as those designed to give an actual performance of 50 feet per minute face velocity. 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 of the laboratories.

For assistance in determining proper classification, a list of typical compounds in each class is attached.

COMMENTS

1. Velocity readings should be taken in the center of twelve or more 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. The smoke tube test can show where distrubing air room currents cause reverse air flow or where there are obstructions to air flow in the hood.

2. In all cases the face velocities mentioned represent minimum average velocities. To assure reasonable uniformity across the hood face, no area should have a velocity less than 80% of the average value. At no point should there be a negative flow or air flow from the hood into the room. This can be easily checked visually through the use of smoke tubes.

3. 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 you have a particular problem or question, give me a call.

Jim

J. J. Hall

/vm

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LIST OF MATERIALS

(1) Typical Materials Requiring Class A Hoods

- Asbestos
- Benzene
- Boron Trifluoride
- Hexavalent Chromium
- Phosgene
- Vinyl Chloride

(2) Typical Materials Requiring Class B Hoods

- Acetic acid
- Acetic anhydride
- Aldrin
- Allyl alcohol
- Ammonia
- Antimony
- Barium
- Bromine
- Butyl cellosolve
- Cadmium oxide fume
- Carbon disulfide
- Carbon tetrachloride
- Chlordane
- Chlorine
- Chlorine dioxide
- Chlorobenzene
- Chloroform
- Chloropicrin
- Chloroprene
- Cresol
- Cyanide
- 1,2-Dichloroethane
- DDT
- o-Dichlorobenzene
- Dichloroethyl ether
- Diisobutyl ketone
- Dinitrobenzene
- Dinitrotoluene
- Dinitro-o-cresol
- Epichlorohydrin
- Fluoride
- Fluorine
- Formaldehyde
- Furfural
- Furfuryl alcohol
- Glycidol
- Hydrazine
- Hydrogen chloride
- Hydrogen cyanide
- Hydrogen fluoride
- Hydrogen peroxide 90%
- Hydrogen sulfide
- Hydroquinone
- Iodine
- Isophorone
- Isopropylamine
- Isopropyl glycidyl ether
- Lead
- Manganese
- Mercury
- Methyl cellosolve
- Methyl chloride
- Methyl styrene
- Nitrogen dioxide
- Ozone
- Phenol
- Phenylhydrazine
- Phosphoric acid
- Phosphorus
- Picric acid
- Silica (above 5% free silica)
- Sulfur dioxide
- Sulfuric acid
- Sulfur monochloride

(3) <u>Typical Materials Handled Under Class C Hoods</u>

Acetaldehyde
Acetone
Aluminum oxide
Amyl acetate
Amyl alcohol
Butadiene
Butanone
Butyl acetate
Butyl alcohol
Carbon dioxide
Carbon monoxide
Chlorobromomethane
Cyclohexane
Dichlorodifluoromethane
1,1-Dichloroethane
Dipropyleneglycolmethylether
Dust (nuisance, no free silica)
Ethyl alcohol
Ethylbenzene
Ethyl chloride
Ethyl ether
Ethyl mercaptan
Gasoline
Heptane
Hexane
Hexanone (methyl butyl ketone)
Iron oxide fume
Magnesium oxide fume
Methyl acetylene
Methyl alcohol
Methyl chloroform
Methylene chloride
Naphtha
Octane
Pentane
Pentanone
Propyl alcohol
Silica (less than 5% free silica)
Toluene
Xylene
Zinc oxide fumes

ventilation

Medical Research Division

Esso Research and Engineering Company

DATE: 2/23/60
REPORT: MRD-4-60
MR.4M.60

MEMORANDUM

ON

RECOMMENDATIONS FOR LABORATORY FUME HOOD INSTALLATIONS

The following has been assembled to bring together the best current information, from a number of sources (1-25), on laboratory hood design, performance and operation. Evaluations of laboratory hood performance are included as part of industrial hygiene survey work because these represent potential sources of exposure to toxic materials. Other groups are interested in hood ventilation as it influences heating, air conditioning and building ventilation requirements. It is for these reasons that this memorandum has been prepared.

While laboratory hoods are of industrial hygiene interest, the numerous Medical Research Division environmental evaluations around hoods used for normal work in petroleum laboratories have failed to reveal any significant exposures. On the other hand these do represent potential sources of exposure and for this reason industrial hygiene interest in hoods will continue. It is hoped that the information presented will be of assistance in the general area of laboratory hoods.

Why Use Laboratory Hoods

Fume hoods may be used to protect the health and safety of laboratory workers and to control obnoxious odors. Not all laboratories need fume hoods. Controls should be provided, however, for laboratory facilities in which any of the following conditions can be created:

1. An atmosphere of toxic or corrosive contaminants resulting from chemical or physical operations.

2. Infectious bacterial or viral aerosols.

3. Radioactive aerosols or fumes arising from the use of radiological materials.

4. Highly offensive odors.

5. Any other airborne contaminants adversely affecting the health, safety and comfort of laboratory personnel.

Why Planning is Necessary

Fume hoods should be considered in the early planning stages of a laboratory building, particularly if it is to be fully air-conditioned. Consideration must be given various fume hood types, sizes, capacities, and locations. This is necessary since these factors will affect:

1. The total building heating and cooling capacity.

2. Location and size of duct work.

3. Location and type of room air supply outlets in the laboratories.

4. Direction of air flow within the building.

5. Quantity, types and sizes of exhaust blowers.

6. Electrical power loads.

Important Design and Use Criteria

The following list of recommendations will provide a basis for judgement 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 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 air 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, must 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.

2. The back baffle in the hood should have **at least two 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.

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 operation using electrically controlled dampers. The dampers open into the plenum system only when the hood is turned on. Hood use factors of as low as 55 per cent have been noted in some laboratories. Advantage 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 at 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.

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 (see schedule below).

D. 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:

1. Class A Hoods: for handling highly toxic materials where complete control is required. For work falling into this category, hoods should be designed to give an actual performance of 125 feet per 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.

2. Class B Hoods: would be hoods designed to give an actual performance of 80 feet per minute face velocity. These could be used for any operations 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.

3. Class C Hoods: would be designated as those designed to give an actual performance of 50 feet per minute face velocity. 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 of the laboratories.

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.

For assistance in considering this schedule, attached are three lists of materials suggested for use under these categories:

(1) Materials requiring Class A Hoods.
(2) Materials requiring Class B Hoods.
(3) Materials requiring Class C Hoods.

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 A hood. It is further our suggestion that any other materials not given on the attached lists be handled under Class B hoods until toxicity information is obtained from either the Medical Department or Medical Research Division. On the basis of such information, assignment to other hood classifications might be possible.

It will be noted that the figures dealing with face velocities, in the above paragraphs, represent the average face velocity which would be considered a minimum average. Certainly higher flows would be acceptable, but an air velocity of 250 fpm should not be exceeded at the face. Higher velocities can create air pattern difficulties and may upset physical processes conducted in the hood.

In order to insure a reasonable uniformity across the hood face, it is suggested that no area of the face should have a velocity less than 80% of the average value. In this regard, at no point should there be negative flow or air flow directed from the hood into the room, as shown visually by a smoke tube test.

It is recognized that the air flow rates may fall as much as 20% below the initial performance after a few years of hood operation. The designer must assess this depreciation in performance in order to maintain the hoods at the rated average velocities. Provisions for duct cleaning, fan wheel cleaning and replacement, fan belt changing, and the like are some of the factors that must be considered.

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 and disadvantages of this type schedule, however, should be emphasized. There will be the administrative or supervisory problem of seeing that these hoods are used for the category of materials for which they are designed. This will perhaps pose a problem on supervisory personnel within the laboratories.

The desirability of using glove boxes to handle highly toxic materials is gaining increased acceptance throughout industry. Here complete control is obtained with a minimum amount of air flow, usually less than 100 cfm per glove box. If the operations to be conducted allow, it is highly recommended that glove boxes be considered for those situations where highly toxic materials will be handled.

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LIST OF MATERIALS

(1) Materials Requiring Class A Hoods

.05 Arsine .05 ppm
Beryllium .002 mg/m3
Decaborane .05 ppm
Hydrogen Selenide .05 ppm
Lithium hydride .025 ppm
Mercury (organic compounds) .01 ppm
Nickel carbonyl .05 ppm
Organo-metallic compounds
Pentaborane
Phosphine
Sulphur Pentafluoride
Teflon decomposition products
TEPP (tetraethyl pyrophosphate)
Tetraethyl lead
Uranium compounds (soluble compounds)

(2) Materials Requiring Class B Hoods

10 Acetic acid
5 Acetic anhydride
Acetylene tetrabromide
.05 Acrolein
Aldrin
Allyl alcohol
Allyl chloride
Allyl glycidyl ether
Allyl propyl disulfide
Aniline
Antimony
Antu (alpha naphthyl thiourea)
Arsine
Asbestos
Barium
Benzene
Benzyl chloride
Boron trifluoride
Bromine
Butylamine
Butyl cellosolve
n-Butyl glycidyl ether
Butyl mercaptan
Cadmium oxide fume
Calcium arsenate
Carbon disulfide
Carbon tetrachloride
Chlordane
Chlorinated camphene, 60%
Chlorinated diphenyl oxide
Chlorine
Chlorine dioxide
Chlorine trifluoride
Chloroacetaldehyde
Chlorobenzene
Chlorodiphenyl (42% chlorine)
Chlorodiphenyl (54% chlorine)
Chloroform
1-Chloro-1-nitropropane
Chloropicrin
Chloroprene
Chromic acid and chromates
Cresol
Cyanide
2,4-D (2,4-dichlorophenoxyacetic acid)
DDT
Diacetone alcohol
Diborane
o-Dichlorobenzene
Dichloroethyl ether
1,1-Dichloro-1-nitroethane
Dieldrin
Diethylamine
Diglycidyl ether (DGE)
Diisobutyl ketone
1-1 Dimethylhydrazine
Dimethylaniline
Dimethyl formamide
Dimethylsulfate
Dinitrobenzene
Dinitrotoluene
Dinitro-o-cresol
Epichlorohydrin
EPN (o-ethyl o-p-nitrophenyl thionobenzenephosphonate)
Ethyl acrylate
Ethylamine

(2) Materials Requiring Class B Hoods (Cont.)

Ethylene dibromide
Ethylene imine
Ethylene chlorohydrin
Ethylenediamine
Ethylene oxide
Ferrovanadium dust
Fluoride
Fluorine
Formaldehyde
Furfural
Furfuryl alcohol
Glycidol
Hydrazine
Hydrogen bromide
Hydrogen chloride
Hydrogen cyanide
Hydrogen fluoride
Hydrogen peroxide 90%
Hydrogen sulfide
Hydroquinone
Iodine
Isophorone
Isopropylamine
Isopropyl glycidyl ether
Lead
Lead arsenate
Lindane
Manganese
Mercury
Mesityl oxide
Methyl acrylate
Methyl bromide
Methyl cellosolve
Methyl cellosolve acetate
Methyl isobutyl carbinol
Methyl mercaptan
Methyl styrene
Mica
Molybdenum compounds (soluble)
Monomethyl aniline
Nicotine
Nitric Acid
p-Nitroaniline
Nitrobenzene
Nitrogen dioxide
Nitroglycerin
2-Nitropropane
Nitrotoluene
Ozone
Paradichlorobenzene
Parathion
Pentachloronaphthalene
Pentachlorophenol
Perchloromethyl mercaptan
Phenol
Phenyl glycidyl ether
Phenylhydrazine
Phosgene
Phosphoric acid
Phosphorus
Phosphorus pentachloride
Phosphorus pentasulfide
Phosphorus trichloride
Picric acid
Propylene dichloride
Propylene amine
Propylene oxide
n-Propyl nitrate
Pyrethrum
Pyridine
Quinone
Rotenone
Selenium compounds
Silica (above 5% free silica)
Soapstone
Sodium hydroxide
Sodium fluoracetate
Stibine
Strychnine
Sulfur dioxide
Sulfuric acid
Sulfur monochloride
Talc
TEDP
Tellurium
p-Tertiarybutyltoluene
1,1,2,2-Tetrachloroethane
Tetranitromethane
Tetryl
Thallium
Thiram
o-Toluidine
Tolylene-2,4-diisocyanate

(2) Materials Requiring Class B Hoods (Cont.)

Trichloronaphthalene
Trichloropropane
Triethyl amine
Trinitrotoluene
Thiorthocresyl phosphate
Uranium (insoluble compounds)
Vanadium
Warfarin
Yttrium and inorganic compounds
Zirconium compounds
Zylidine

(3) Materials Handled Under Class C Hoods

200 Acetaldehyde
1000 Acetone
Aluminum oxide
B Ammate (ammonium sulfamate)
100 Ammonia
200 Amyl acetate
100 Amyl alcohol
1000 Butadiene
250 Butanone
200 Butyl acetate
100 Butyl alcohol
5000 Carbon dioxide
100 Carbon monoxide
Cellosolve
B Cellosolve acetate
Chlorobromomethane
100 Chloroform
Crag herbicide
Cyclohexane
Cyclohexanol
Cyclohexene
Cyclohexanone
Cyclopropane
B Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethylene
Dichloromonofluoromethane
Dichlorotetrafluoroethane
Difluorodibromomethane
Dioxane
Dipropyleneglycolmethylether
Dust (nuisance, no free silica)
Ethyl acetate
Ethyl alcohol
Ethylbenzene
Ethyl bromide
Ethyl chloride
Ethyl ether
Ethyl formate
Ethyl mercaptan
Ethyl silicate
Ferbam (ferric dimethyl dithio carbamate)
Fluorotrichloromethane
Gasoline
HETP (hexaethyl tetraphosphate)
Heptane
Hexane
Hexanone (methyl butyl ketone)
Hexone (methyl isobutyl ketone)
sec-Hexylacetate
Iron oxide fume
Magnesium oxide fume
Malathion
Methoxychlor
Methyl acetate
Methyl acetylene
Methylal (dimethoxymethane)
Methyl alcohol
Methyl chloride — Class B
Methyl chloroform
Methylcyclohexane
Methylcyclohexanol
Methylcyclohexanone
Methyl formate
Methylene chloride
Molybdenum compounds (insoluble compounds)
Naphtha (coal tar)
Naphtha (petroleum)
Nitroethane
Nitromethane
Octane
Pentane
Pentanone
Perchloroethylene

(3) Materials Handled Under Class C Hoods (Cont.)

Propyl acetate
Propyl alcohol
Propyl ether
Silica (below 5% free silica)
silicon carbide
Stoddard solvent
Styrene monomer
Sulfur hexafluoride
Tertiary butyl alcohol
Tetrahydrofuran
Titanium dioxide
Toluene
Trichloroethylene
Trifluoromonobromomethane
Turpentine
~~Vinyl chloride~~ class A
Vinyl toluene
Xylene
Zinc oxide fumes

BIBLIOGRAPHY

1. Barrett, J. C.: Laboratory Hood Ventilation Design. Michigan's Occupational Health 4, (4) (Summer 1959).

2. Barrett, J. C., ventilation engineer, Michigan Department of Health, Lansing, Michigan: Personal Communication (Jan. 21, 1960).

3. Clay, H. B.: Controlling Fume Hood Exhaust in Atomic Energy Laboratory. Heat., Piping & Air Cond. 22:77-83 (July 1950).

4. Coleman, H. S., (editor): Laboratory Design. PP. 31-34, 61-68, 326, 327 and 370. Reinhold Publishing Corporation, New York (1951).

5. Doughty, F. O., DuPont Experimental Station, Wilmington, Delaware: Personal Communication (Jan. 27, 1960).

6. First, M. W.: New Techniques in Laboratory Ventilation. Air Engineering (August 1959).

7. Jepson, G. L.: Ventilation and Fume Hoods - Survey of Information. Presentation to laboratory sub-section of the National Safety Congress (Oct. 24, 1957).

8. Jepson, G. R., air conditioning and ventilation engineer, The Upjohn Co., Kalamazoo, Michigan: Personal Communication (Jan. 22, 1960).

9. Harris, W. B.: Laboratories for Handling Radioactive Materials. Heat. & Vent. 50:74-78 (Nov. 1953).

10. Holmes, R. E.: The Ventilation of an Atomic Energy Laboratory. Refrigeration Engineering 59:755-59, 808, 809 (Aug. 1951).

11. Kershaw, N. G.: Ventilating Radiological Laboratories. Chem. Eng. Prog. Symp. Series 52, (19):15-24 (1956).

12. Ketcham, N. H.: Testing Laboratory Hoods - Evaluation of Design Changes and Periodic Performance Testing. Amer. Ind. Hyg. Assoc. J. 19, (4):324-329 (Aug. 1958).

13. McNeil, G. L., and Burroughs, C. W.: Progress Report, Miami Valley Laboratories Fume Hood Design. Unpublished paper (Feb. 4, 1954).

14. Peterson, J. E.: An Approach to a Rational Method of Recommended Face Velocities for Laboratory Hoods. Amer. Ind. Hyg. Assoc. J. 20, (4):259-265 (Aug. 1959).

15. Peterson, J. E., The Dow Chemical Co., Midland, Michigan: Personal Communication (Jan. 20, 1960).

16. Preuss, L. E., and Watson, J. H. L.: Design and Construction of a Small Radioactivity Laboratory. Nucleonics 6, (5):11-26 (May 1950).

17. Robinson, K. E., ventilation engineer, General Motors Corporation, Warren, Michigan: Personal Communication (Jan. 18, 1960).

18. Ruddy, J. M.: Designing Fume Hoods for Medium Level Radioactive Conditions. Heat., Piping & Air Cond. 30, (3):128-131 (March 1958).

19. Saunders, G. T., Kewaunee Manufacturing Co., Adrian, Michigan: Personal Communication (Jan. 21, 1960).

20. Schroeter, F. J., safety engineer, Ethyl Corporation, Ferndale, Michigan: Personal Communication (Jan. 19, 1960).

21. Schulte, H. F., Hyatt, E. C., Jordan, H. S., Mitchell, R. N.: Evaluation of Laboratory Fume Hoods: Amer. Ind. Hyg. Assoc. Quart. 15:195-202 (Sept. 1954).

22. Sjogren, C. N., and Deal, J. M.: Design and Construction of a Petroleum Refinery Laboratory. Ind. and Eng. Chem. 41, (8):1657 (Aug. 1949).

23. Solomon, A. K., and Foster, C. A.: A Hood for Work with Radioactive Isotopes. Anal. Chem. 21, (2):304-306 (Feb. 1949).

24. Webster, S. H., Liljegren, E. J., and Powell, C. C.: Hood for Radioactivity Work. Nucleonics 10, (4):65-68 (April 1952).

25. York, J. E.: Ventilation and Air Conditioning for Laboratories. Heat. and Vent. 50, (11):79-86 (Nov. 1953).

Figure 1

Laboratory hood used at the General Motors Technical Center, Detroit, Michigan in their Radioisotope Laboratory. The box above the hood contains both a roughing and an absolute filter. Positive suction is assured by the controllers on the right which activate a second fan if the air flow drops below the pre-set value.

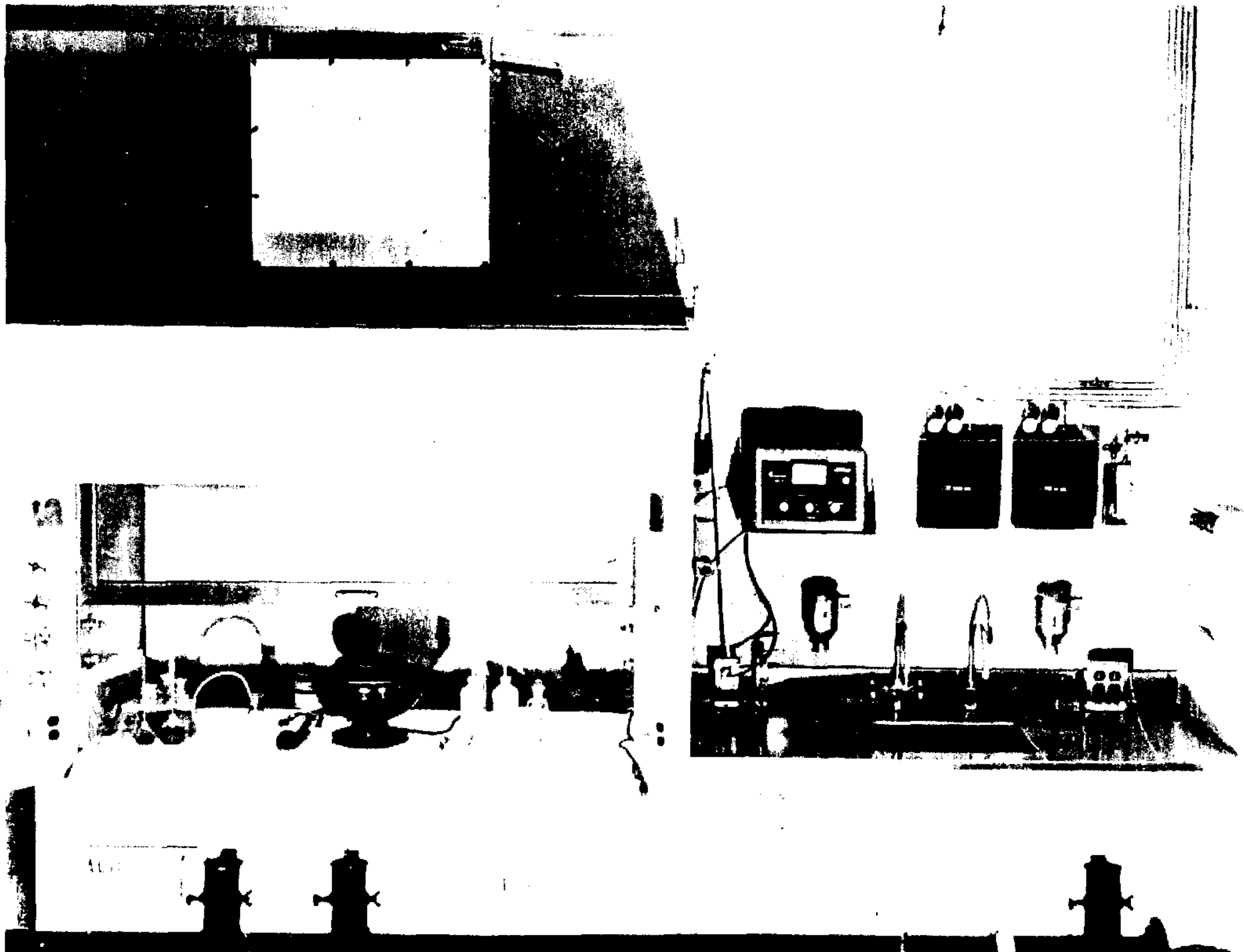


Figure 2

Laboratory hood used at the Dow Chemical Company, Biochemical Research Laboratory, Midland, Michigan. The supply from the grills located to either side of the hood can be exhausted even when the hood is not operating by the exhaust grill directly above the hood. The grill is rated at 15% of the hood volumetric exhaust rate.

60-MER-3

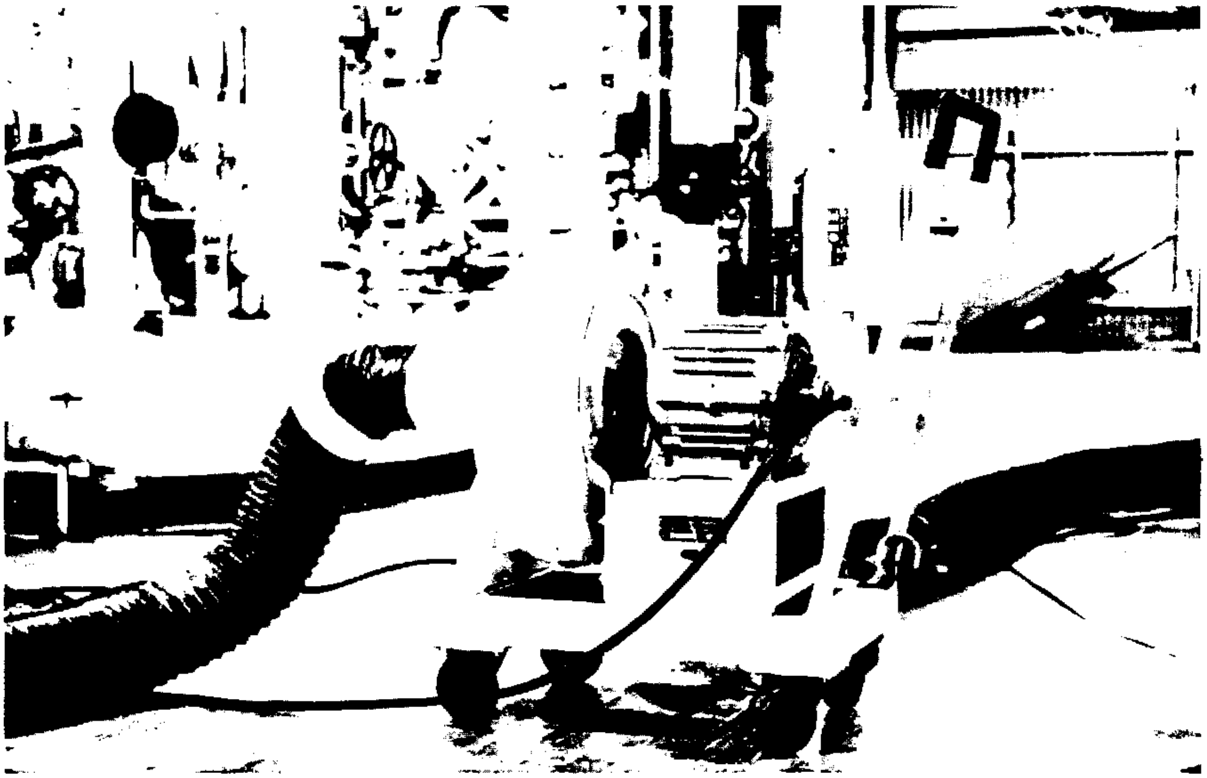
Figure 3

The auxiliary air supply hood is being checked for the directionality of the auxiliary air supply above the hood face. This hood is located in a special test room at Kewaunee Manufacturing Company in Adrian, Michigan. The room allows for variation of air supply, air exhaust, and hood features.

60-MER-4

Figure 4

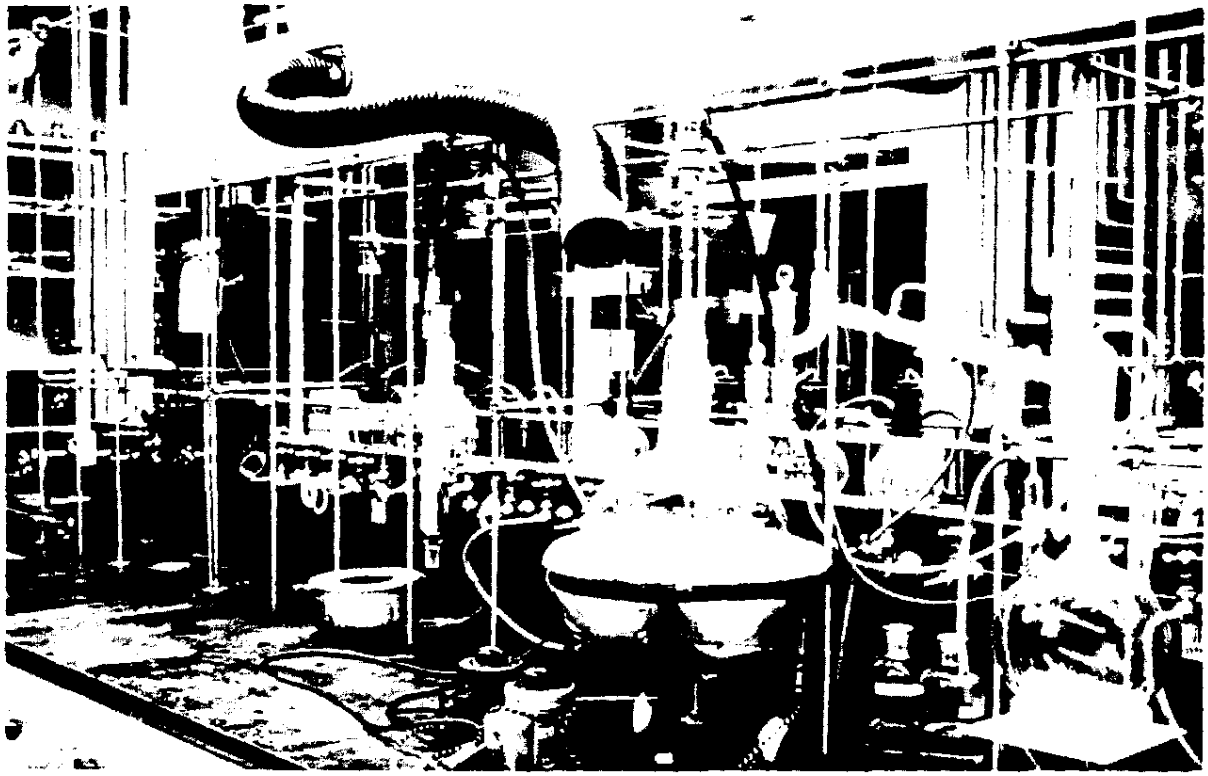
A portable blower and long lengths of flexible duct provide ventilation at remote locations at Upjohn Company. Non-sparking fan materials and closed motors provide fire protection.



60-MER-5

Figures 5 & 6

Flexible duct exhausters control vapors released on open laboratory benches at Upjohn Company in Kalamazoo, Michigan. An average velocity of 2,000 fpm is used at the open face of the duct.



60-MER-6

60-MER-7

Figures 7 & 8

A small hood with a 12" x 12" face and three 1/2" slots exhausts 270 cfm (slot velocity is 2,000 fpm) to control benzene vapors from a chromatography operation at Upjohn Company. The hood slides on nylon rollers and uses non-metallic flexible duct work. An aluminum slide in a galvanized valve housing directly above the hood prevents sparking for fire prevention.

60-MER-8

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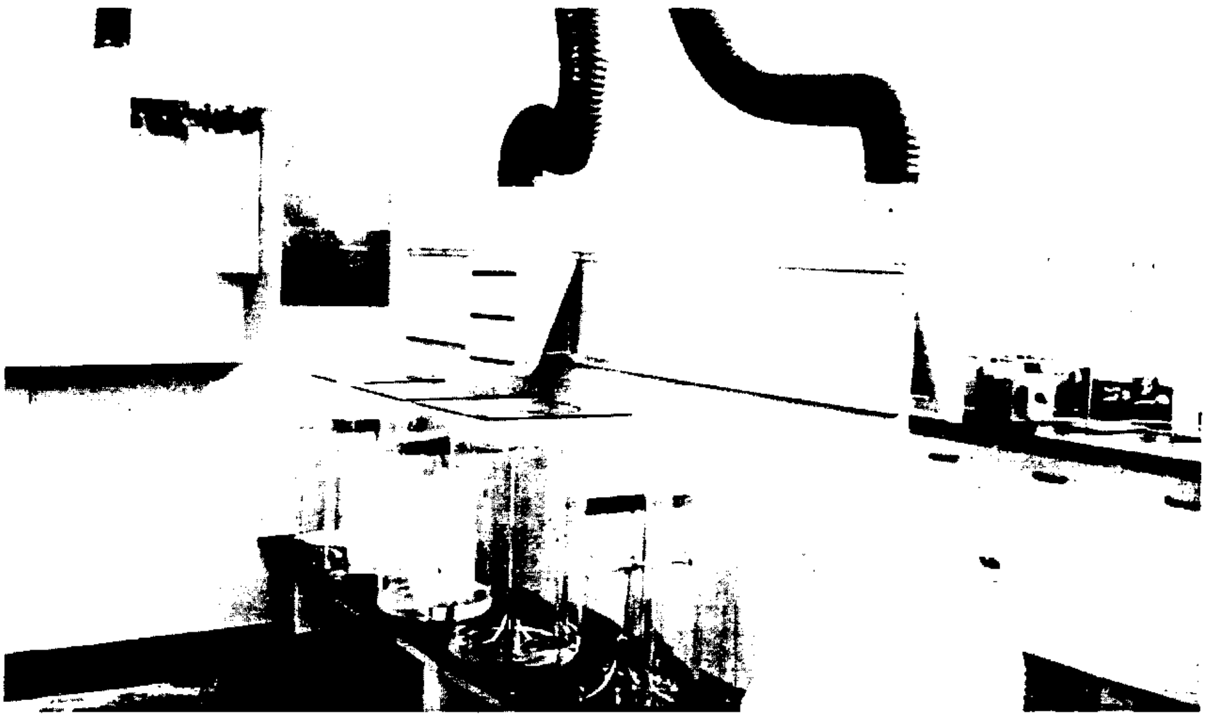
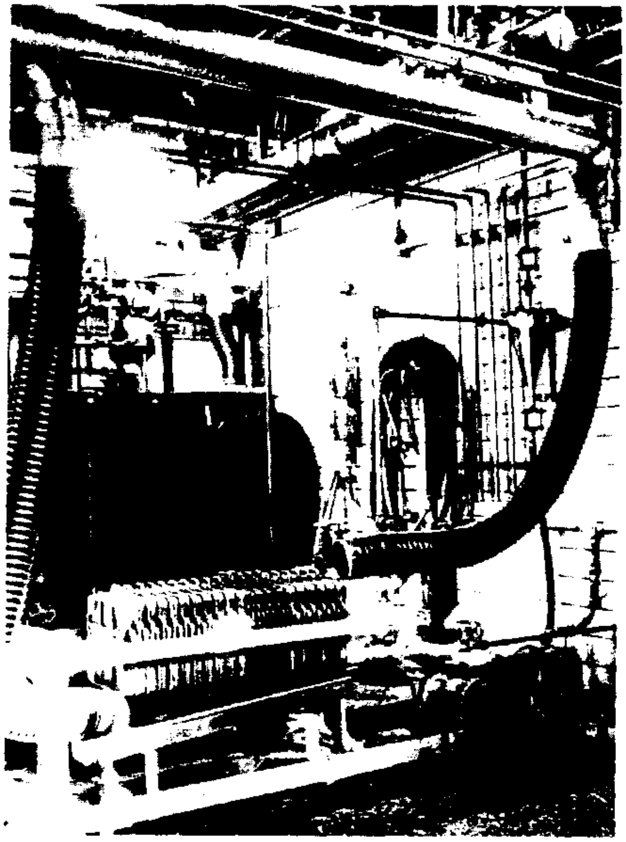


60-MER-9

Figures 9 & 10

Two ways of controlling fumes from a plate and frame filter press are shown in operation at Upjohn Company. A polyethylene sheet covering the press makes exhausting with flexible ducts placed at either end a rather easy job. In less toxic applications the flexible ducts alone provide the necessary withdrawal.



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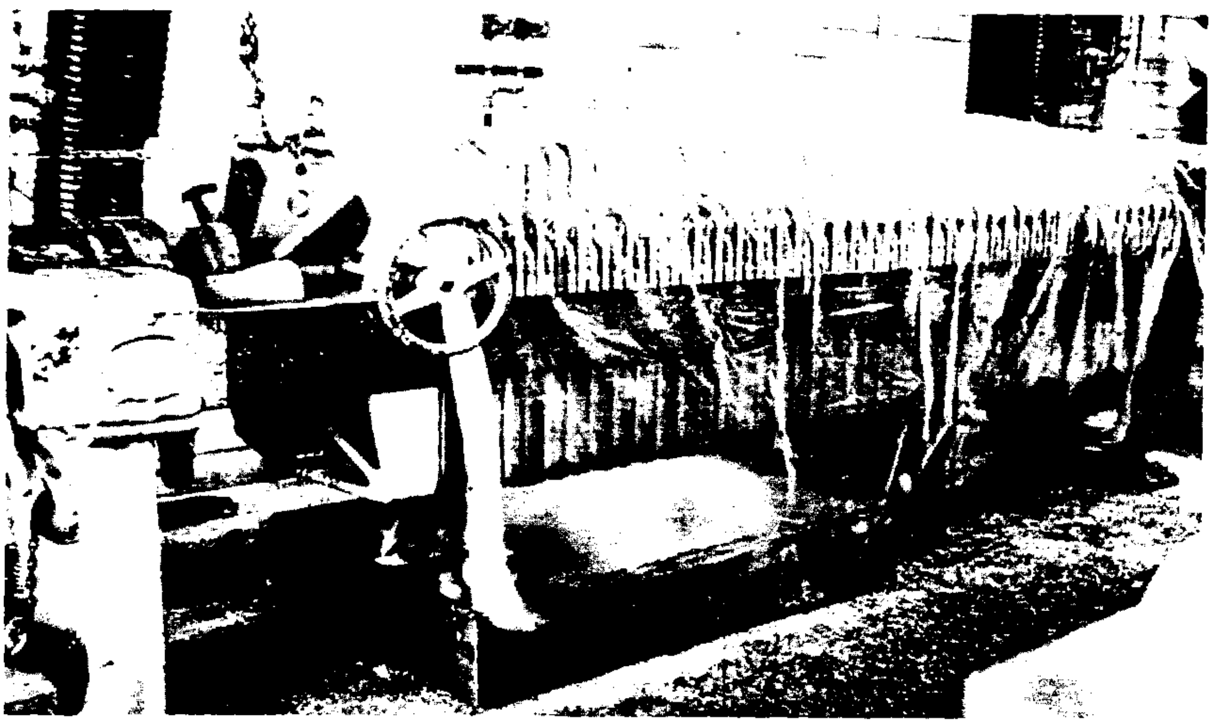
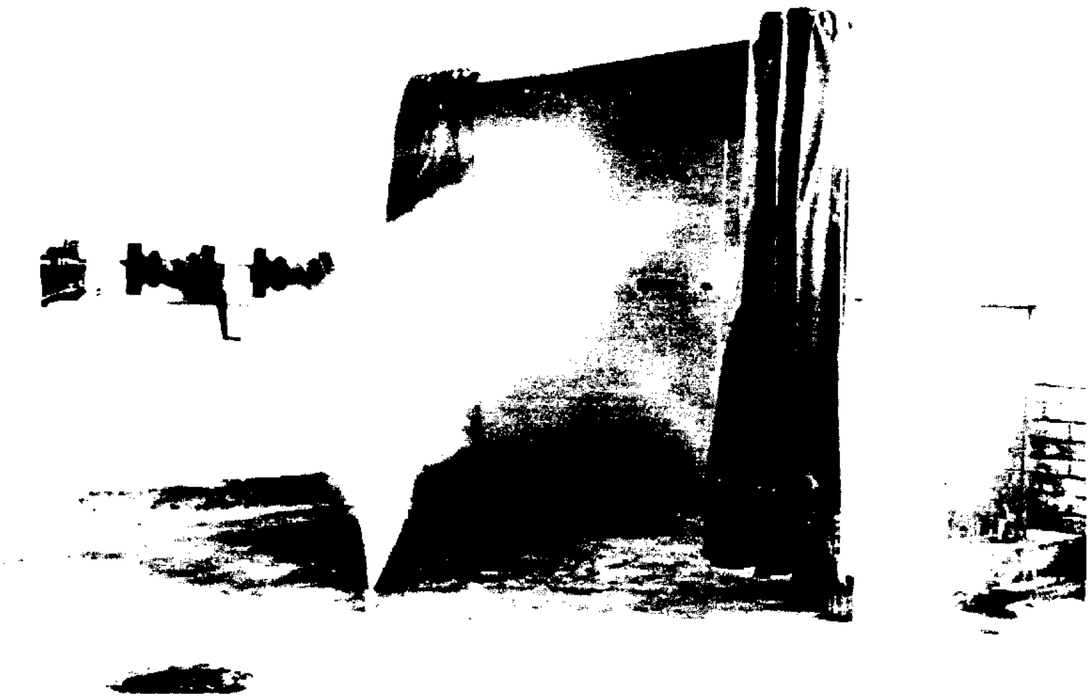


60-MER-11

Figure 11

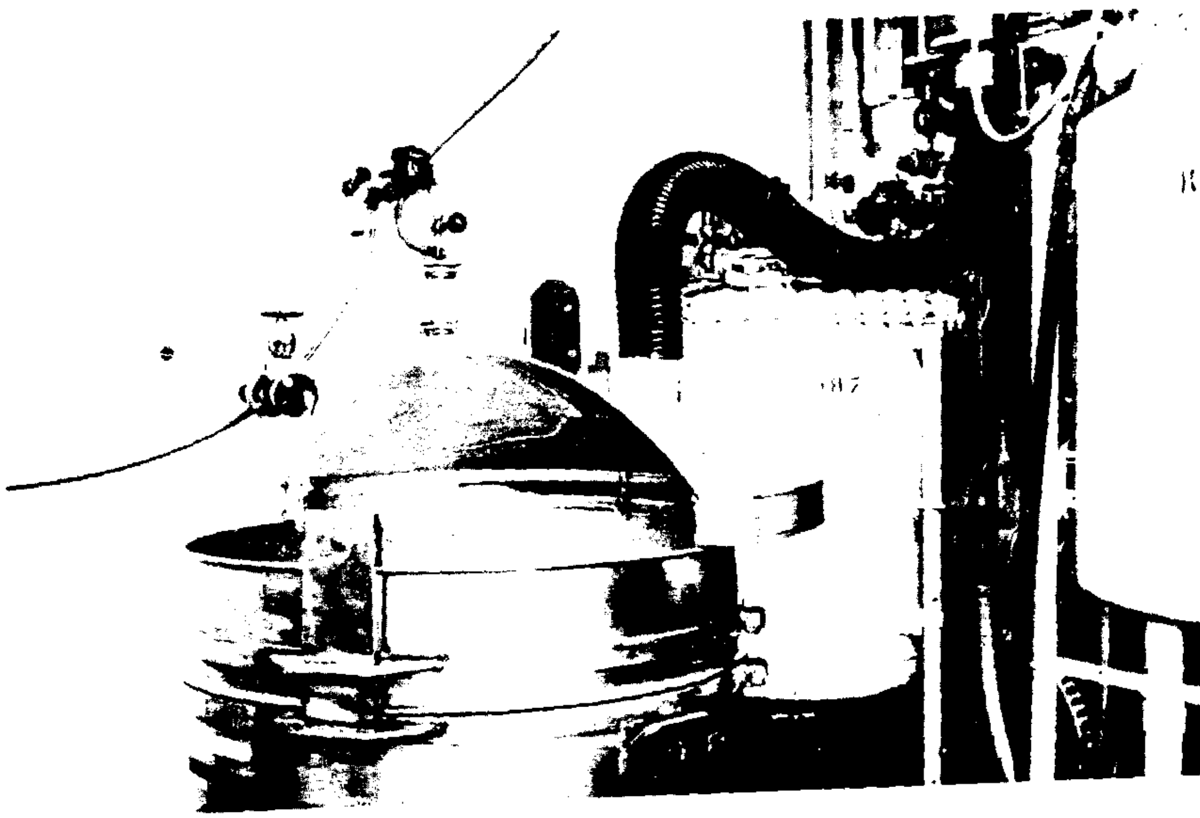
A walk-in enclosure at Upjohn Company shown with canvas curtains at either side is being checked for its effectiveness. The enclosure is used to capture fine dusts and vapors released within the enclosure.



60-MER-12

Figure 12

A filtering drum is shown with a lateral quarter-circular exhaust hood. Vapors released during the pouring of the filter mix are captured by this hood at Upjohn Company.



60-MER-13

DATE: September 23, 1958
REPORT NO. MRD-30CM-58
MR.19M.58

1958

ventilation

SUGGESTED LABORATORY HOOD CLASSIFICATION SCHEDULE

This memorandum outlines a classification schedule for laboratory hoods in order to take advantage of lower air flow requirements for hoods where work does not involve handling of highly toxic materials. Basically, the air flow for each hood category is related to the toxicity of the materials handled within the hood. These principles can be applied to both existing installations or in the design of new facilities.

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 having 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:

1. [redacted] for handling highly toxic materials where complete control is required. For work falling into this category, hoods should be designed for and give an initial performance of 150 feet per 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 similar materials having a high order of toxicity.

2. [redacted] would be hoods designed for and giving an initial performance of 100 feet per minute face velocity. These could be used for any operations 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.

3. ~~Class C Hoods~~ would be designated as those designed for and giving an initial performance of 60 feet per minute face velocity. 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 of the laboratories.

LIST OF MATERIALS

(1) Materials Requiring Class A Hoods

Arsine
Beryllium
Decaborane
Hydrogen selenide
Lithium hydride
Mercury (organic compounds)
Nickel carbonyl
Pentaborane
Phosphine
Sulphur Pentafluoride
Teflon decomposition products
TEPP (tetraethyl pyrophosphate
Tetraethyl lead
Uranium Compounds (soluble compounds)

(2) Materials Requiring Class B Hoods

Acetic acid
Acetic anhydride
Acetylene tetrabromide
Acrolein
Aldrin
Allyl alcohol
Allyl chloride
Allyl glycidyl ether
Allyl propyl disulfide
Aniline
Antimony
ANTU
Arsenic
Asbestos
Barium
Benzene
Benzyl chloride
Boron trifluoride
Bromine
Butylamine
Butyl cellosolve
n-Butyl glycidyl ether
Butyl mercaptan
Cadmium oxide fume
Calcium arsenate
Carbon disulfide
Carbon tetrachloride
Chlordane
Chlorinated camphene, 60%

(2) Materials Requiring Class B Hoods, cont'd.

Hydrogen peroxide 90%
Hydrogen sulfide
Hydroquinone
Iodine
Isophorone
Isopropylamine
Isopropyl glycidyl ether
Lead
Lead arsenate
Lindane
Manganese
Mercury
Mesityl oxide
Methyl acrylate
Methyl bromide
Methyl cellosolve
Methyl cellosolve acetate
Methyl isobutyl carbinol
Methyl mercaptan
Methyl styrene
Mica
Molybdenum compounds (soluble)
Monomethyl aniline
Nicotine
Nitric Acid
p-Nitroaniline
Nitrobenzene
Nitrogen dioxide
Nitroglycerin
2-Nitropropane
Nitrotoluene
Ozone
Paradichlorobenzene
Parathion
Pentachloronaphthalene
Pentachlorophenol
Perchloromethyl mercaptan
Phenol
Phenyl glycidyl ether
Phenylhydrazine
Phosgene
Phosphorus
Phosphorus pentachloride
Phosphorus pentasulfide
Phosphorus trichloride
Picric acid
Propylene dichloride
Propylene amine
Propylene oxide
n-Propyl nitrate

(3) Materials Handled Under Class C Hoods, con't.

Carbon dioxide
Carbon monoxide
Cellosolve
Cellosolve acetate
Chlorobromomethane
Chloroform
Crag herbicide
Cyclohexane
Cyclohexanol
Cyclohexene
Cyclohexanone
Cyclopropane
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethylene
Dichloromonofluoromethane
Dichlorotetrafluoroethane
Difluorodibromomethane
Dioxane
Dipropyleneglycolmethylether
Dust
Ethyl acetate
Ethyl alcohol
Ethylbenzene
Ethyl bromide
Ethyl chloride
Ethyl ether
Ethyl formate
Ethyl silicate
Ferbam
Fluorotrichloromethane
Gasoline
HETP
Heptane
Hexane
Hexanone
Hexone
Iron oxide fume
Magnesium oxide fume
Malathion
Methoxychlor
Methyl acetate
Methyl acetylene
Methyl alcohol
Methyl chloride
Methylal
Methyl chloroform
Methylcyclohexane
Methylcyclohexanol
Methylcyclohexanone

SEE PAGE 2

LABORATORY FUME HOODS

and their exhaust systems

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In the planning of a new laboratory (or in the revitalizing of an old one), one of the most important considerations is the selection of the hoods to be used and their location within the laboratory. However, despite the importance of this subject to the health, safety and efficiency of laboratory occupants, many aspects of the choice may be inadequately considered because of a lack of good communication among those involved or simply because the range of choice and the consequences of poor selection are not realized. This article can do little or nothing about improving communication among those involved in the specification-purchase sequence; instead its purpose is to bring together the important considerations associated with the selection of a laboratory hood.

Jack Peterson received his B.S. (with honors) in chemical engineering from Washington State University in 1951, and M.S. in chemical engineering from the University of Michigan in 1952. He began work at The Dow Chemical Company in 1952 on special assignments; joined the Biochemical Research Lab, Environmental Research Section, a year later. Jack is married and has two children, both boys; his principal hobby is amateur radio (call letters are WA8GTM).

Jim Peay was employed as a tool engineer while attending Ohio State University part time until 1945, and joined Kewaunee Manufacturing Company in 1949 as chief designer, Stainless Metals Division. He was appointed assistant plant manager in 1951 and sales engineer in 1956, specializing in laboratory fume hoods and glove boxes. Married, Jim has seven little Peays in his pad.

IN ESSENCE THIS ARTICLE is an expanded "check list" to be used by the person designing and specifying a laboratory hood. Items discussed are not in order of importance, but rather, are in a more or less logical sequence. The word "hood" and the phrases, "laboratory hood", "exhaust hood" and "fume hood" are used as synonyms. They all refer to the exhausted enclosures normally found in laboratories. Hoods without powered exhausters are not considered, nor are glove boxes or other special equipment.

Materials of Construction

Exterior—If the hood is to have a separate interior portion, the materials used for constructing the exterior will depend mainly upon the importance of esthetics and cost.

Under-structure—In most cases, the type of support used for the hood proper is of little importance structurally. However, if the hood is to be used for handling radioactive materials where lead bricks may be used for shielding, the support should be designed to accommodate a distributed load of 150 to 250 lbs. per sq. ft. and a single concentrated load of about 500 lbs. per sq. ft. in addition to the weight of the hood itself.

Glass—Most laboratory hoods are equipped with windows or a sash. Laminated safety glass is usually the best type of glass to be used for this purpose. However, heat within the hood causing localized hot spots on the glass in excess of 165F can cause it to crack; in such cases tempered glass is preferable. In no case is "wire glass" suitable; a minor explosion inside the hood could cause the formation of a large amount of pre-shaped "shrapnel". Similarly, plain window glass (either plate or sheet) is usually not used for this purpose.

Interior—The material used for the interior of the hood will depend mainly upon the materials to be handled within the hood.

If the hood is to be used for handling radioactive materials or infectious organisms, ease of decontamination may be the single most important factor to be considered when selecting the lining material. Smooth, continuous, non-porous and corrosion-resistant surfaces are a necessity for these applications. Both asbestos-cement material and stainless steel have been used, either bare or protected with strippable or non-strippable acid-resistant coatings. Bare stainless steel has been almost unanimously preferred for work with infectious organisms. Protective coatings may provide a corrosion or contamination barrier useful under some conditions of service; however the lining material itself should be basically resistant to the materials used in the hood.

If stainless steel is chosen as the hood lining material the finish to be specified deserves consideration. That is, the smoothest finish is generally the easiest to decontaminate. Probably the most popular finish for stainless steel is designated as "Number 4 satin polish finish"; this finish has a comparative roughness of about 20 to 40 micro inches RMS (root mean square). On the other hand, a less expensive finish (with a gray appearance rather than a shiny luster) designated as "Number 2B" is actually smoother, with a comparative roughness of about 11 micro inches, RMS.

Hoods used for general chemical work should, of course, be lined with materials that are resistant to the chemicals to be handled. Most commercial hood manufacturers offer an asbestos-cement or similar material that, coated or uncoated, is generally useful.

If the hood is to be used for handling perchloric acid or other potent oxidizers, inorganic materials such as stainless steel (usually type 316) or soapstone (with inorganic cement at the joints) are probably the most suitable materials for the hood lining.

In any case, smooth, non-porous lining surfaces relatively free from cracks, joints, ledges, etc. are desirable. There is one place, however, where a ledge is functional. A horizontal or sloping ledge about 6 in. wide and ½ in. high at the front lip of the hood working surface will help to retain spills within the hood and will also aid in keeping apparatus and chemicals away from the face of the hood. (Fumes released in the interior of the hood are more easily retained than those released near the face.)

Accessories

The accessories that can be added to a bare laboratory hood are limited only by the ingenuity of hood manufacturers and by the pocketbook of the purchaser. Where possible, controls for them should be located outside of the hood in the relatively uncontaminated air of the laboratory. Such controls should be easily manipulated, easily differentiated one from the other, and located conveniently where they assist rather than impede the hood user.

Electrical Power

Three-pronged receptacles for 110-v electrical power are recommended so that equipment (equipped with three-pronged plugs) will be automatically grounded as the line cord is plugged in. Receptacles outside of the hood will not be subjected to trouble from corrosion, fouling, etc. caused by contact with materials handled.

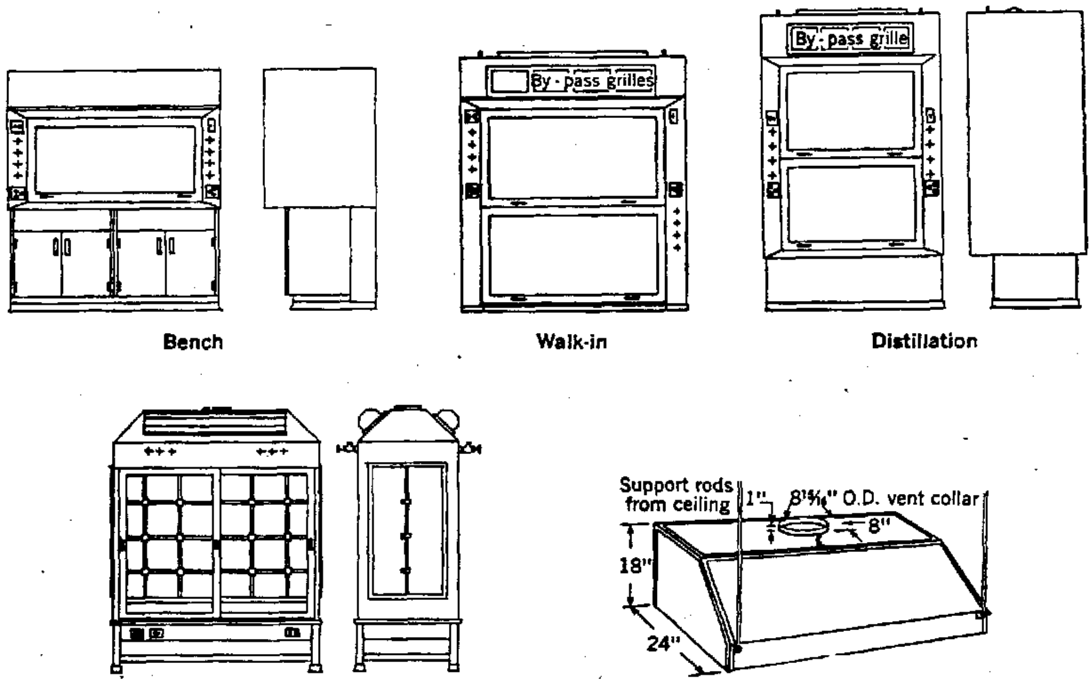
Plumbing Services

If other than "normal" service fixtures are added (such as for oxygen, deionized water, etc.) installation of special valves may be necessary. An acid resistant coating (other than chrome plating) is usually desirable for all fittings inside the hood.

Safety Devices

Safety for the hood user is primarily dependent upon the proper location and design of the hood and the proper selection of the exhaust system for the work to be done. Intelligent use of the hood is, of course, also necessary and it is partially dependent

Fig. 1. Standard laboratory fume hood types.



upon the user's background in safety training. However, there are available mechanical aids which may supplement an educational campaign:

1. A closable sash or window for each hood. Rather than being an expensive damper in the exhaust line, the sash or window should be regarded as a splash barrier and so used. Horizontally sliding windows in a vertically rising sash can allow easy access to the hood interior while still affording splash protection.

2. A static pressure gage permanently connected to the exhaust duct. Such a gage can readily indicate need for maintenance of the exhaust system.

3. A heat sensitive device inside the hood. This can be connected to an audible-visual fire alarm.

4. A screen over the interior baffle openings. This screen is to keep lightweight materials from entering the exhaust system and impairing fan performance.

5. A warning system to indicate exhaust fan failure. This might be used in addition to the static pressure gage already mentioned.

6. An explosimeter head with an audible alarm. This device might well be used if high concentrations of flammable solvents are expected.

If any or all of the above safety devices are used, their reliability should be thoroughly investigated before installation. Furthermore, periodic servicing (including performance testing) is recommended as these devices will be exposed to fume and vapor inside the hood which might well cause malfunctioning.

HOOD DESIGN AND LOCATION

The hood chosen must be of the proper size and shape to accommodate the work to be done and, if possible, future demands should be anticipated. Whether the hood is purchased from a commercial manufacturer or is constructed on the spot, one of the more or less "standard" configurations is recommended. Specialized, single-purpose hoods are occasionally necessary, but their lack of versatility may well hinder long range applications. Standard assemblies available from hood manufacturers consist of (at least) the following types (see Fig. 1):

1. Bench
2. Walk-in
3. Distillation
4. California
5. Canopy

The bench type is so called because its working surface is at bench height. The walk-in type rests on the floor; its opening often is high enough to allow entry of a man into the hood interior. The distillation type is similar to the bench, but usually has a larger vertical dimension; its work surface is normally closer to the floor of the room, and it may come equipped with a lattice rack as standard equipment.

The California type is a hooded lattice bench closed on both ends and usually equipped with horizontally sliding glass doors (access is through both sides). The canopy type is simply an enlarged exhaust opening, perhaps suspended from the ceiling with no other enclosing walls. The first three types are easily available with internal and external baffling systems; the last two are not.

The first three types are the most popular and consequently are obtainable in many variations. Each may be sub-typed as being either "conventional" or "air flow" hoods. This terminology has reference to the configuration of the face opening; i.e., the "conventional" type has essentially square front corner posts while the "air flow" type is equipped with external baffles of the "picture frame" air foil variety at the face to reduce or eliminate the formation of eddies within the hood. (Any air disturbance within the hood reduces the ability of that hood to retain air-borne materials.) There is little difference in price between the two types; generally the "air flow" type is to be preferred mainly because of the reduction of turbulence at the face of the hood associated with an external baffling system.

Bench, walk-in and distillation hoods are available with an air-inlet-by-pass arrangement if they are equipped with sashes but usually not when they have horizontally sliding doors. With the sash wide open the by-pass is inoperative. As the sash is closed, at a certain point in its descent air will be admitted to the hood over the top of the sash as well as through the face of the hood. This feature is desirable as it tends to eliminate extremely high velocities through the face as the sash approaches the closed position. High air velocities can cause papers, powders, etc., to be blown into the exhaust system.

Some manufacturers have gone "all the way" with this approach, causing the by-pass to be opened as soon as the sash is closed a few inches from its wide open position. This arrangement can be used for the "constant face velocity" type of hood. These hoods have the disadvantage that, contrary to "instinct", a higher face velocity (as may be occasionally desired by the hood user) cannot be obtained by repositioning the sash to a smaller opening. Ideally, the by-pass will become operative at a point where the sash is 4 to 8 inches above the completely closed position.

The advent in recent years of year-round air conditioning has brought with it a constant demand for fume hoods using less cooled air from the room than is feasible with regular designs. In many sections of the country the cost of supplying sufficient cooled air to laboratories (for hood exhaust) far out-weighs the expense for the same volume of heated air. Accordingly, a continuing effort has been made to design hoods using uncooled air for ever greater portions of the total exhaust volume. Such hoods are usually called "auxiliary air" or "supplied air" types by the manufacturers. In this case, the variation in design is tremendous. Auxiliary air may be added directly to the hood interior; it may be added outside and above the hood face; it may be added through the "air foil" baffles at the front of the hood face, or elsewhere. Similarly, claimed percentages of auxiliary air may vary from about 30% to about 70% of the total amount of air exhausted from the hood.

Unfortunately, most of the systems for supplying unconditioned air to the hood are deficient in at least one respect. Those that supply air directly to the hood interior have the fundamental defect that they can protect the hood user only by dilution of contaminating vapors. With this type of air supply system the face velocity of the hood usually becomes far too low to give adequate protection by the *direction* of air flow. Furthermore, experimentation with several arrangements of this type has shown that they almost invariably force air out of the hood at one or more places at the hood face.

Systems supplying air to the outside of the hood have a theoretical superiority in that the supplied air does not cause a decrease in the hood face velocity. In order for that superiority to be realized, however, most (or all) of the supplied air must reach the hood face directly, it must not cause excessive turbulence at the hood face, and the system for accomplishing these objectives must have a reasonable price tag. Attainment of any one or two of these "ideals" is relatively easy; attainment of all three with adequate quantities of auxiliary air for "normal" hoods in "normal" laboratories is not. Probably most hood manufacturers have worked or are working on this problem but, while considerable progress has been made, a complete solution is still awaited. With present designs, it appears unlikely that more than 40 or 50% of the volume of air exhausted from a hood can be supplied successfully by auxiliary systems and even this may be possible only under ideal circumstances.

The best advice that can be given to prospective purchasers of air-supplied hoods is that they critically examine the various supplied air systems and then conduct their own tests to determine that their requirements are satisfied. Tests with a blanket of smoke will show whether or not a sufficient quantity of the supplied air is actually reaching the hood face, while measurements of the velocity of air at the face of the hood can be used for a calculation of the variance of face velocity data to enable a determination of whether or not the turbulence at the face of the hood is excessive.

If the user decides that supplied-air may well be the solution to his problem and if he has decided that a certain design will meet his specifications, then he must consider the economics of this type of system. Auxiliary air may need to be filtered and it should be warmed to room temperature during the cooler seasons. Cold auxiliary air has a tendency to "drop to the floor" and not be captured by the hood, while the cold air captured will cool surfaces within the hood, often causing water condensation and other problems. Hence savings which may be effected are simply from a reduction in the quantity of cooled air used; heating costs will not be changed materially. Furthermore, a secondary air supply system will be necessary and the total costs of that system (including operation and maintenance as well as the additional cost for the air-supplied hood) must be balanced against the savings possible on the cooled air system (including reduced operation and maintenance expenses).

Location of Hoods in the Laboratory

The best location for optimum hood performance is one where air disturbance at the face of the hood caused by external sources is negligible. Air disturbance at the hood face can be caused by open windows, radiators, nearby open doors, room air supply inlets, room heating or cooling units, traffic past the hood face, etc. Ideally, then, the only disturbance at the hood face should be caused by the man working at the hood (see Fig. 2).

In addition, the hood should be located in a position where there is a minimum of about 3 ft between both ends of the hood and the walls of the room. This will allow an ample flow of air across the entire hood face. An adjoining wall presents a partial obstruction that often results in decreased air flow at that end of the hood and a higher velocity at the opposite end.

Aside from these considerations, the hood must usually be located as close as possible to main piping and (if a central exhaust system is used) exhaust duct chases. If these services are located in corridor walls (as they often are) the hood may have to face a main traffic aisle and/or be in proximity to a door. Obviously this is undesirable, and a good deal of thought and planning may be necessary so as to keep air disturbance at the face of the hood to a minimum while still being as economical as possible with piping and ductwork.

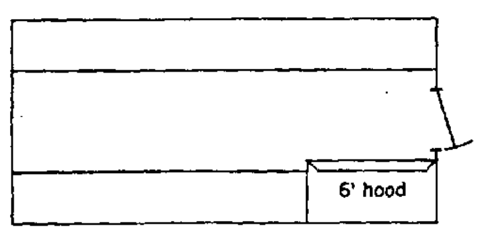
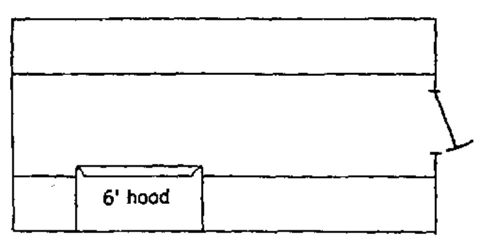


Fig. 2. While this is a common hood location in a 10 by 20 ft laboratory . . . .



. . . . this is a better hood location.

Hood Face Velocities

Laboratory hood face velocities are one of the most critical and yet controversial aspects of hood installations. Since the first hood was connected to an exhaust blower, a search has been made for a magic number suitable for all hoods under all conditions. Unfortunately, there is no such number whether it be 50, 100, 150 ft per min or greater. The variables which must be considered when selecting a face velocity are such as to completely eliminate the possibility of a single number being always appropriate.

In 1959, one of the authors of this article published the details of a technique for recommending face velocities for laboratory hoods; the original paper may be consulted if more information is needed.[1] Essential features of that method are presented below:

The basic feature of this method is that a face velocity is found for a "standard hood" that depends only on the nature of the materials to be handled. Then, that face velocity is modified in proportion to deviations of the actual hood from the "standard hood". These manipulations have been incorporated into an equation for calculating the recommended face velocity:

$$V_r = 0.75M\ (1.0 + E + C) + 2\sqrt{s_x^2} \qquad \text{(I)}$$

Where V_r is the recommended face velocity in fpm (linear feet per minute). Meanings of the other variables and techniques for their estimation follow:

1. M, the "Vapor Control" factor. The vapor control factor, M, is the face velocity that would be assigned to the standard hood. Its magnitude varies from 50 to 100 and is dependent upon the vapor pressure, molecular weight, and the "control concentration" appropriate for the material(s) to be handled in the hood. If the hood is to be used for handling materials with a high or unknown vapor inhalation hazard, this factor should be given a value of 100. Under other circumstances it may be lower (but with a minimum of 50). The materials to be handled within the hood should be listed along with their molecular weights, vapor pressures at the normal temperature of handling, and their "control concentrations". The control concentration used for any particular material will usually be the Threshold Limit as specified by the American Conference of Governmental Industrial Hygienists, or the Maximum Acceptable Concentration as published by the American Standards Association, etc. Choice of the figure to be used will depend to a certain extent on the expected frequency and duration of possible exposures and on the consequences of overexposure.

A number, "R", should then be calculated for each material by multiplying the vapor pressure (in millimeters of mercury, using 760 where the material is a gas) by the molecular weight and dividing by the control concentration (in ppm, parts per million by volume in air). These values of "R" should then be used in conjunction with Fig. 3 to determine the value to be assigned to the vapor control factor, M. In cases where a number of different materials are to be handled in the hood, the highest value of "M" so found is usually used. If the hood is to be used for work with radioisotopes or infectious organisms (in cases where a hood rather than a glove box is appropriate) a value of 100 is usually assigned to M.

2. E, the "Environment" factor. Values assigned to the environment factor depend upon the amount of air disturbance expected at, or near, the hood face. Normally, hoods should be placed in locations where there will be little or no external air disturbance (the location specified for the "standard hood") and this factor will have a value of "0". Where this cannot be done, values of the environment factor listed in Table 1 can be used.

In addition to air disturbance at the face of the hood caused by external sources, air disturbance may also be created by sources within the hood. For example, if the hood is overcrowded with equipment, if it is used for housing sources of large amounts of heat (for instance a number of Bunsen burners or hot plates) if air stirrers are used or if spraying is to be done within the hood then the environment factor must be increased. Actual values to be used under these circumstances have not yet been determined, except that a value of 1.0 may be used when the hood functions as a spray booth.

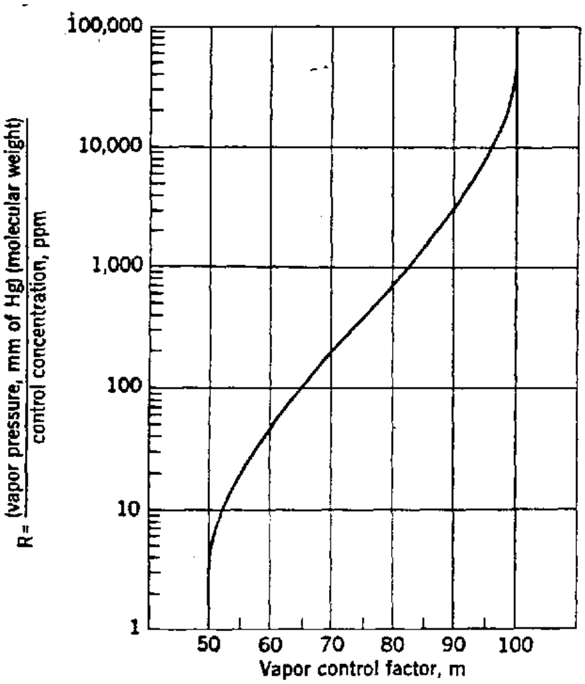


Fig. 3. Vapor control factor for laboratory hoods.

TABLE 1—ENVIRONMENT FACTOR GUIDE

Classification of Air Disturbance	"E" Factor
Minor air disturbance. The hood is located away from foot traffic, drafts from open doors or windows, air circulating fans.	0 to 0.15
Moderate air disturbance. The hood is located where persons occasionally walk by, near an inside door which is usually closed, etc.	0.15 to 0.45
Severe air disturbance. The hood is located where persons frequently pass, near an inside door usually open, etc.	0.45 to 0.75
Very severe air disturbance. The hood is located near an outside door or window which may be opened; air from a fan or heater impinges on the hood face.	0.75 and up

3. C, the "Hood Characteristic" factor. The hood characteristic factor depends upon the size and shape of the normal opening at the face of the hood and the presence or absence of external baffles. Values assigned to this factor may be either positive or negative depending upon how the hood differs from the "standard hood" which is equipped with external baffles, and has a square face opening with an area of ten square feet. Experience has shown that most laboratory hoods are operated wide open when in use, and therefore the opening to be used when calculating V_r will usually be the maximum face area of the hood. However, under some circumstances and with some hood users a smaller face opening may be more appropriate. Only after investigation and consultation with prospective users should a smaller-than-maximum opening be used for this calculation.

Values for the face area (in square feet) and for the "side ratio" ("r", the shorter dimension of the face opening divided by the longer) are necessary for each hood. If the hood is to be equipped with external baffles (i.e. "picture-frame" or air foil type) Figure 4 should be used to find values for C. If the hood is not to have an external baffling system, then Figure 5 should be used.

4. s_x^2, the variance of face velocity data. The variance is the square of the standard deviation of measurements made (in this case, of hood face velocities). Obviously such measurements cannot be made for a hood that is still in the planning stages and therefore some other method of assigning values to this variable must be used. The first choice of methods is to determine, by measurement, values of the variance for existing hoods of the same type with similar amounts of external and internal air disturbance. If this cannot be done, the expected variance may be estimated by reference to Table 2.

Values in this table were determined for cases where the external air disturbance was negligible ($\leq$25 fpm lateral air velocity) and where the hoods were in use but not overcrowded with equipment. In all cases, the actual face velocity of the hoods from which these data were gathered was greater than 50 fpm. (Above that velocity the variance is relatively independent of the actual velocity.) Values in the table were derived from experience with bench hoods; that experience has also shown that the variance is not influenced by the size and shape of the face opening.

[redacted]. After values have been assigned to all of the variables, Equation (I) is used to calculate the recommended face velocity for each hood. The value found should be rounded to the nearest 5 fpm and this should be the actual velocity recommended. Furthermore, when that velocity is used to calculate the recommended volumetric flow rate for the hood, further rounding to at least the nearest 10 cfm should be followed.

As an example, assume that a hood for handling benzene at room temperature is necessary. After consideration of a number of factors a bench hood has been chosen. The hood is to be equipped with internal and external baffles and is to have an open face area five feet wide and 30 inches high. It is to be located in an area where some foot traffic may be expected but where other sources of air disturbance are absent. What face velocity should be recommended?

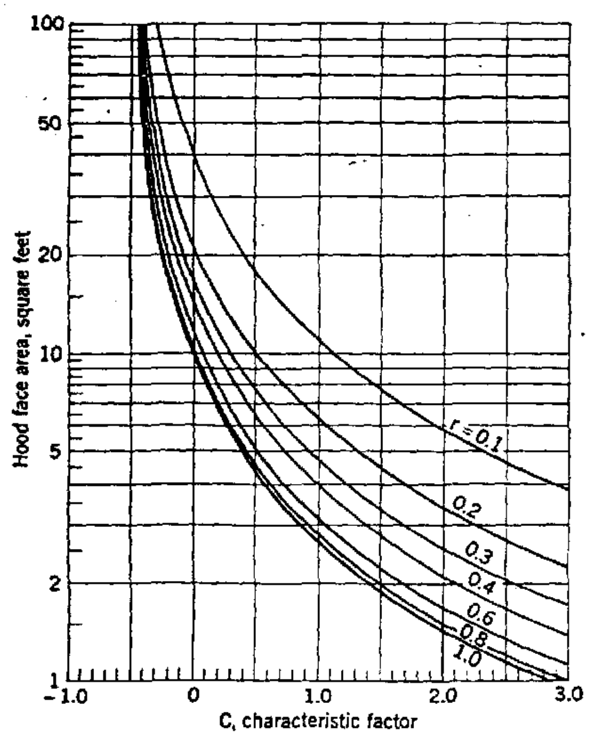


Fig. 4. Hood characteristic for laboratory hoods with external baffles. The side radio, "r" is the shorter dimension of the face opening divided by the longer.

TABLE 2—VARIANCE SUMMARY

Hood Type	Variance, s_x^2	
	Average	Range
Bench		
Internal and external baffles	130	26 to 265
Internal baffles only	217	26 to 756
No baffles	714	138 to 2812

Data

Item	Value
Vapor pressure at 25°C:	95.2 mm of Hg
Molecular weight:	78.0
Control concentration (Threshold Limit):	25 ppm
Hood face area:	12.5 ft²
Hood side ratio, "r":	0.5

Calculations

$$R = \frac{(V.P.)(M.W.)}{C.C.} = \frac{(95.2)(78.0)}{25} = 297$$

From Figure 3, $M = 72$

From Table 1, $E = 0.15$

From Figure 4, $C = 0$

From Table 2, expected $s_x^2 = 130$

$$Vr = 0.75\,(M)(1.0 + E + C) + 2\sqrt{s_x^2}$$
$$= (0.75)(72)(1.0 + 0.15 + 0) + 22.8$$
$$= 62.9 + 22.8 = 85.7 \text{ fpm}$$

The face velocity recommended for this hood would be 85 fpm; the volumetric flow rate would be:

$$85 \text{ fpm} \times 12.5 \text{ ft}^2 \cong 1060 \text{ cfm}$$

Values of the recommended face velocity calculated by this technique can vary quite widely. When the recommended face velocity is found to be in excess of about 250 fpm (for a normal laboratory hood) examination will usually show that one of the variables can be modified to reduce the recommended velocity to a more acceptable value. That is, unacceptably high recommended face velocities are usually the result of a high value for the external air disturbance factor, or of a high value for the variance of face velocity data. Where the external air disturbance factor is high, the hood (or sources of air disturbance) could be relocated and/or external baffles could be used. Where the variance is unacceptably high, the use of internal and/or external baffles should be seriously considered.

EXHAUST HOOD SYSTEM COMPONENTS

When new laboratories are designed, one of the first steps toward the development of the heating, cooling and air moving system is a calculation of the total air volume needed for exhausting the hoods. With this at hand, an integration of the air volume into the overall building ventilation system is necessary.

In essence, hood exhaust systems will either be centralized or each hood will be equipped with a separate blower. Both of these arrangements have advantages and in some cases a mixture of the two may be necessary. Absolute control of the building ventilation system is most easily achieved with centralized supply and centralized exhaust systems. However, in many cases some degree of control can be profitably exchanged for the flexibility and simplicity of an individual blower and exhaust duct for each hood.

Well engineered systems using either a centralized exhaust or individual blowers for each hood should be designed so that:

1. Hoods serve as room exhausters obviating the need for other exhaust fans in the laboratories.
2. The direction of air flow in the building is from the offices and corridors to the laboratories. With offices at higher static pressures and laboratories at lower static pressures laboratory odors are usually eliminated from corridor and office areas and cross-contamination between laboratories is reduced.
3. Exhaust air from hoods is never recirculated.
4. Even though the laboratories are at lower static pressures than offices, they are at a slightly positive pressure with respect to the atmosphere. This will prevent drafts and will also tend to keep dust and other external air pollutants outside of the building.

Hoods are absolutely dependent upon an adequate air supply to the room. Under nearly all circumstances a positive air supply system will be necessary and this system may also heat, cool or simply filter the air that it is supplying. An insufficient supply of air for a laboratory will "starve" the hoods which otherwise might function very well. The method of introducing air to the laboratory room should be one which minimizes the amount of turbulence and cross-drafts, especially at the hood's face. *A major "trouble shooting" solution to poor hood performance is found to be correction of an inadequate or improperly located air supply system.*

Exhaust Ducts

Materials for hood exhaust ducts vary widely, as do methods of making joints; i.e. flange, slip, welded, etc. Selection of the material to be used for ducting will be influenced by economic and other considerations. Following are examples of commonly used materials and their applications:

1. Stainless steel for radioisotope, bacteriological and perchloric acid used. Type 316 stainless is preferred for perchloric acid.
2. Asbestos-cement pipe for general chemical use.
3. Carbon steel (black or galvanized) with an acid resistant coating is sometimes appropriate for general chemical use.
4. Vitrified clay pipe with mastic joints for main runs is resistant to a variety of acids (except hydrofluoric) as well as to alkaline and plating solutions.
5. Thermoplastic materials, such as polyvinyl chloride, and thermosetting plastics, such as glass-fiber-reinforced polyester resin, may be suitable where neither high solvent vapor concentrations nor potent oxidizers will be handled.

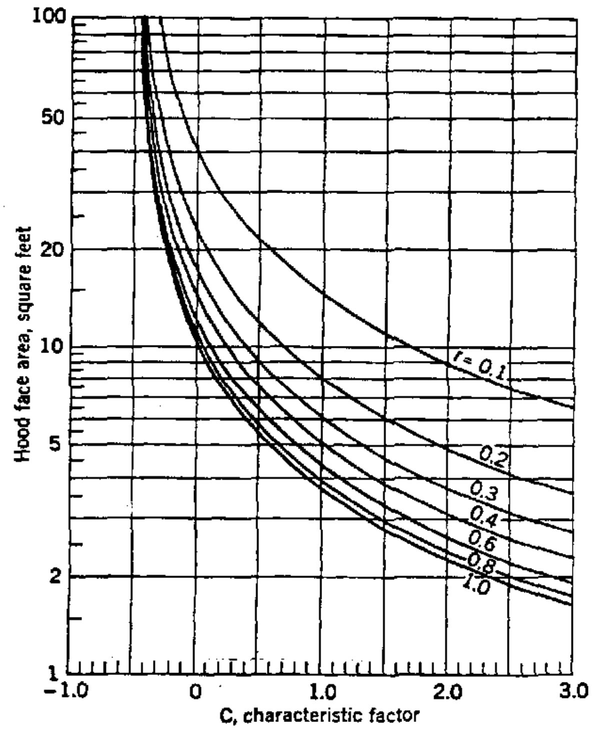


Fig. 5. Hood characteristic for laboratory hoods without external baffles. The side ratio, "r" is the shorter dimension of the face opening divided by the longer.

The choice of duct material should be a considered one, with thought given to available space, cost, accessibility for installation and maintenance, as well as to compatibility with the materials handled in the hoods. No one material is appropriate for all conditions. In any case, joints should be leak-tight and cleanout and inspection ports should be provided.

Exhaust Blowers

Exhaust blowers are available in either of two main types, axial or centrifugal. Each of these main types can be further divided into a number of subtypes. Centrifugal blowers are normally used to exhaust hoods as this type of blower is generally best suited for the pressure drops encountered. However, some axial types have been used with success.

Some foreward-curved roof exhausters (with the "squirrel cage" horizontal and air discharging around the entire periphery of the fan) will exhaust at 50-60% of their capacity when run backward. The simple installation of a reversing switch can, therefore, result in the equivalent of a two-speed fan. With proper and thorough indoctrination of hood users (plus constant attention) use of this technique can result in an appreciable savings of conditioned air.

Blower manufacturer's literature and recommendations should be carefully consulted; information about the following factors will be necessary before a wise choice can be made.

Materials to be Handled in the Hood. Corrosion resistant, oxidizer resistant and non-sparking fan wheels are available from most manufacturers. As fans are likely to receive less-than-excellent maintenance, quality should *never* be sacrificed for economy.

When several hoods are connected to a central exhaust system, attention must be given to the materials handled in each of the hoods. Problems of incompatibility might well be experienced; the ductwork and blower are poor locations for experimental reactions.

Exhaust Rate. Exhaust systems decrease in efficiency with use as the fan blades deteriorate, as resistance in the duct and blower increases (because of accumulated dirt and waste) and as fan belts begin to slip. From 10 to 20% additional exhaust capacity is recommended for each blower to compensate for these losses.

Elevated operating temperatures and operation at altitudes appreciably higher than sea level may require a further increase in blower capacity as blower ratings are based on "standard" air at 70F and 29.92 inches of mercury pressure.

Static Pressure. The necessary static pressure capability of the blower at the desired air flow rate is determined by pressure losses occurring throughout the exhaust system served by the blower. Data on static losses are available from many sources and the calculations required are not difficult;[2,3] guesses are unnecessary, inefficient, and may lead to future trouble. If filters are used in the system, allowance should be made for increased resistance as they collect dust. Good engineering of exhaust systems will include some flexibility and some means for future balancing, should that become necessary, if more than one hood is served by one fan.

Location and Orientation of Blowers. Roof or penthouse blower locations offer advantages for both individual and central exhaust systems. At such locations, the distractions of noise and blower maintenance are removed from the laboratory. Of greater importance for safety reasons, blowers located outside the building cause the exhaust duct to be under negative pressure and if leaks develop, fumes are not forced out from the duct into the building. Weatherproof blowers or blowers with weatherproof housings are available from most blower manufacturers.

When ordering a centrifugal blower, the orientation of that piece of equipment should be specified unless the blower is of the "low-silhouette roof exhauster" type, in which case orientation is not a variable. "Orientation" refers to the relative positions of the inlet and outlet ports of the blower. In most cases, a little study will show that one orientation will be much preferred over the others. The preferred orientation should result in air being discharged in such a manner as to minimize (completely eliminate, if possible) "short-circuiting" to the intake system by taking advantage of elevation, the direction of locally prevailing winds, etc. All blowers, of course, must be in accessible locations for maintenance and servicing.

5. Motor Voltage—Motor sizes up to and including one horsepower are usually wired for 110-220 volt single phase service; larger motors are often wired for three phase operation at higher voltages. Motor overload protection is recommended. Voltage and phase characteristics of the motor can normally be obtained to conform with the existing power supply.

INSPECTION AND BALANCING OF NEW INSTALLATIONS

Before the new hood is put into service, all plumbing, mechanical and electrical facilities and accessories as well as the exhaust system will normally be inspected and tested to assure proper functioning. Almost as often as not, newly installed valves on hood service fixtures for air, gas, hot water, cold water and steam are found to leak. In most instances these leaks are caused by metal chips from piping which has been poorly de-burred or cleaned and not by a defective valve. If the piping has been improperly cleaned, chips imbed themselves in valve discs or seats after the valve has been opened and closed a few times, resulting in a leak.

The actual hood face velocity and volumetric flow rate as well as the velocity and flow rate at all air supply outlets should be determined by measurements made prior to use. Similarly, the current drawn by each fan motor may be determined and compared with name-plate specifications. After any deviations from specifications have been corrected a permanent record should be made of all final values. Once adjusted, dampers and baffles in the hood and ductwork should be semi-permanently locked in position and/or sealed to be made as tamper-proof as possible. A large portion of a central supply or a central exhaust system can be unbalanced by one fume hood taking more (or less) than its designed volume of air.

After the central exhaust system has been balanced (or after each individual hood exhaust system has been checked and found to be working properly) static pressure readings can be made in the ductwork close to each hood and permanently recorded.

In the future when the question arises (as it will) about whether or not any particular hood is still functioning properly, a repeat static pressure measurement can answer the question easily and well. These measurements are much easier to make than are measurements of face velocity and are just as adequate for a "yes or no" answer; therefore, permanently installed static pressure gages are recommended, especially for critical locations.

Operating Instructions

Observation indicates that most chemists have only a very vague idea of what makes a good hood work well and, perhaps unfortunately, chemists are the main users of hoods. Their lack of knowledge is shared, no doubt, by biologists, bacteriologists, pharmacologists, and others of many scientific persuasions and their technicians. The proper use of hoods should probably be taught in our already overburdened schools, but as such instruction is presently rare it must be undertaken by others.

Safety meetings are a relatively common way of imparting knowledge in industry and they are an excellent means of acquainting hood users with hoods and for periodically emphasizing good technique. However, day-to-day reminders may also be helpful. Following is a series of "do's" and "don'ts" that might be reproduced on a metal plate and fixed permanently to each hood in an easily visible location:

Do	Don't
Make sure the hood fan is on.	*Block the baffle openings.*
Use the sash (door).	*Put your head in the hood.*
Keep work away from the front edge.	*Disturb dampers or baffles.*
Distribute heat loads.	*Use the hood for storage.*
Limit quantities of materials.	*Be a poor housekeeper.*
Report malfunctions.	*Take chances.*

PREVENTIVE MAINTENANCE

The benefits derived from proper care of laboratory hood facilities are, without doubt, a most handsome return on the investment of time and money devoted to that purpose. However, to accomplish a regularly scheduled program of preventive maintenance (rather than corrective repair) plant policy must be established defining the need and providing the means for following that policy, and a specific group or person with suitable talents must be designated to routinely inspect all laboratory hoods, supervise their repair and set up routine preventive maintenance schedules.

Instruments for determining air velocity, static pressure, and the amperage drawn by fan motors must be purchased and then used properly. Instruments for determining air velocity are available from several manufacturers, many of whom have a program for periodic maintenance and calibration of those instruments as they *do* lose calibration. Air velocities can be determined by any of the available instruments that are capable of accurate determinations in the range of 35 fpm and above; meters that measure the cooling effect of an air stream on a heated element have been quite satisfactory for this purpose. Instruments for determining static pressure and motor amperage generally do not require as much care and maintenance as do instruments for determining air velocities; their choice is not critical.

Preventive Maintenance Tips

1. Hoods should not be used for the storage of chemicals and materials not in daily use. Ventilated storage cabinets, easily accessible by laboratory personnel, are recommended for the storage of chemicals that the chemist would otherwise leave in the hood.

2. The hood interior should be thoroughly cleaned periodically and the exposed surfaces inspected for evidence of deterioration. The use of protective coatings may be evaluated at that time.

3. Wax, or other coatings may be desirable to maintain the finish and appearance of the hood.

4. Periodic inspection of any accessible dampers or adjustable baffles will assure that settings have not been altered by unauthorized personnel.

5. Velocity determinations and/or static pressure determinations made periodically and checked with previously recorded values will show if all exhaust and supply systems are functioning properly.

6. The rear (interior) baffle of each hood should be removed occasionally and the area behind it cleaned.

7. Accessible exhaust ducts should be inspected occasionally through cleanout or inspection openings provided with removable cover plates. Supply ducts generally require much less maintenance, but they too should be inspected occasionally.

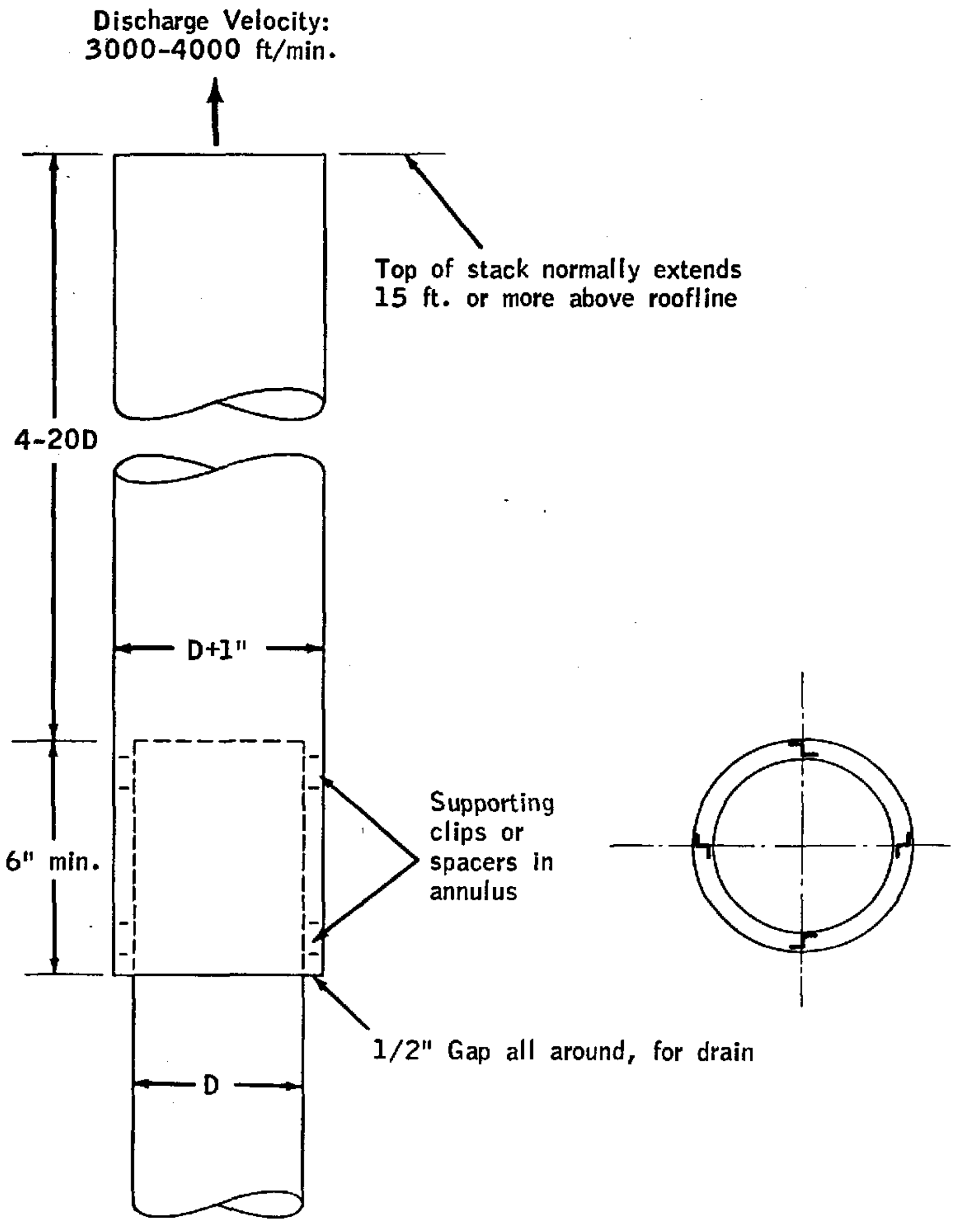
8. Lubrication of bearings and pillow blocks associated with fans and blowers should be on a periodic schedule that is adhered to religiously. Occasionally, the amperage drawn by the motors should be determined and recorded. Similarly, if the fans are belt-driven, the belts may be checked for slippage and deterioration.

9. The fan blades and the interior of the blower housings should be inspected occasionally for deterioration and/or fouling.

BIBLIOGRAPHY

1. Peterson, J. E.: An Approach to a Rational Method of Recommending Face Velocities for Laboratory hoods. *Amer. Ind. Hyg. Assoc. J. 24:* 259 (Aug. 1959).
2. *Industrial Ventilation*, 7th Ed., Am. Conf. of Governmental Ind. Hygienists, P.O. Box 453, Lansing, Michigan (1962).
3. Hemeon, W. C. L.: *Plant and Process Ventilation.* The Industrial Press, New York 13, N. Y. (1955).

Figure 2
CONCENTRIC DUCT TYPE OF SELF-DRAINING STACK



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