British Occupational Hygiene Society

A GUIDE TO THE DESIGN AND INSTALLATION OF LABORATORY FUME CUPBOARDS

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A GUIDE TO THE DESIGN AND INSTALLATION OF LABORATORY FUME CUPBOARDS*

BRITISH OCCUPATIONAL HYGIENE SOCIETY TECHNOLOGY COMMITTEE

Working Party on Laboratory Fume Cupboards:

Chairman: S. A. Roach, Imperial Chemical Industries Ltd., Wilmslow, Cheshire
succeeded by: G. A. Hedgecock, Pilkington Bros. Ltd., St. Helens, Merseyside

H. J. Benford, B.P. Research Centre, Sunbury-on-Thames
J. Folwell, Health and Safety Executive, London
P. J. Hewitt, The University of Bradford
M. Sanders, Warren Spring Laboratory, Stevenage
G. F. Shortridge, Atomic Weapons Research Establishment, Aldermaston

Secretary: K. Everett, The University of Leeds

Abstract—After reviewing available information and carrying out appropriate tests, the Working Party has recommended that a correct aerodynamic design of fume cupboard will require an air velocity of 0·5 m/s under working conditions. Variations in air velocity across the working face should not exceed ±15%.

If it is essential that under no circumstances should transient escapes of material take place in the operator's breathing zone, a face velocity of 0·76 m/s may be necessary. Under these conditions the use of a total enclosure is preferred.

The Guide includes recommendations for the design and installation of fume cupboards to meet these criteria.

1. INTRODUCTION

1.1

The Working Party was set up to review the information available on the design of fume cupboards for use in laboratories and to carry out such tests as appropriate.

1.2

The Working Party considered that its objectives must include the following: to review briefly the history and relevant literature, to trace the source of the experimental data, to carry out such tests as it felt were necessary to fill in gaps in the record or to confirm statements made and to produce an up-to-date specification for safe and efficient fume cupboards.

2. DEFINITIONS

2.1

The Working Party found that its first task was to define clearly the meaning to be attached to the term fume cupboard, and that it would be useful to reserve the use of the term fume hood for a more limited type of fitting (see 2.3). Certain authors have graded fume cupboard design specifications according to the proposed usage, e.g. for low, medium or high toxicity work or, alternatively by the institution in which they will be used, e.g. schools, industry or university. The Working Party was conscious that such systems can lead to wrong use in practice and considered that a general purpose fume cupboard for use in chemical and associated laboratories must be capable of being used for a broad spectrum of materials and that during its expected working life both the materials used in it and the staff associated with it would be likely to change and, further, that knowledge of any limitations not visibly obvious would tend to be eroded by the passage of time. The Working Party realised during the course of its deliberations that implicit in its work was the assumption that it was limiting itself to laboratory fume cupboards.

2.2

A fume cupboard is defined as a form of partial containment consisting of an enclosed chamber, with a sash or sliding door and mechanical extract ventilation.

This definition can be compatible with that given in the *Ionising Radiations* (*Unsealed Radioactive Substances*) *Regulations*, 1968 (G.B. PARLIAMENT, 1968), viz. "fume cupboard" means a partial enclosure: (a) having mechanical means of producing at any opening between it and the workplace a flow of air into it which has a velocity (being in any event a velocity not less than 50 cm/s) and is otherwise such as to prevent the spread of radioactive substance from the enclosure to the workplace; and (b) where the said flow of air is not kept in constant operation, provided with a shutter which is kept in its closed position when the flow of air is not in operation and which is such that when the shutter is in its closed position is a total enclosure. N.B. In the American literature a fume cupboard is referred to as a laboratory hood.

2.3

A fume hood is a simple canopy, with one or more sides permanently open, the hood being provided with a flue relying either on convection currents, e.g. where furnaces are present, or on a fan to extract the fumes.

2.4 *Special safety enclosures*

Mechanically-ventilated enclosures with fixed, restricted area openings, and which may incorporate such features as microbiological filters in the extract system, are classed as special enclosures.

Enclosures incorporating sophisticated air input and extract systems are included under this heading also (see Appendix 6).

The Working Party did not include total enclosures, i.e. glove-boxes, or laminar flow work stations within its terms of reference.

2.5

Fume cupboards are required for work with materials which generate dusts, fumes, gases and vapours which must not be released into the laboratory environment. These materials may be toxic, corrosive, flammable, or socially unpleasant. Certain highly toxic materials must be worked *only* in total enclosures, e.g. plutonium and certain carcinogens.

Fume hoods as opposed to fume cupboards, as defined above, are intended for the capture and removal of dusts, fumes and vapours which are a nuisance or of low toxicity, e.g. steam and hot gases from furnaces. The design of fume hoods is dealt with in some detail in *Industrial Ventilation: A Manual of Recommended Practice* (A.C.G.I.H., 1974).

3. DESIGN PARAMETERS

3.1

The following considerations affect the design of a fume cupboard system: (i) the aerodynamics of the fume cupboard; (ii) the layout of the laboratory, with particular reference to air input and sources of disturbance of air patterns, e.g. doors, openable windows, bulky objects, personnel movements in the vicinity of the fume cupboard; (iii) the choice of materials of construction; (iv) the fume extract system; and (v) the dispersal of the fumes to atmosphere.

3.1.1. It must be emphasised that fume cupboard performance cannot be divorced from the general laboratory ventilation either in terms of air flow patterns or air change rates.

3.1.2. Fume cupboards require large volumes of clean, tempered air if they are to be efficient. This means that not only is an adequate air extraction system required, but also a corresponding air supply system to the laboratory is needed.

3.1.3. The air extracted from the fume cupboard must be discharged to atmosphere in such a manner that it will be effectively dispersed and will *not* re-enter the building via air intakes, windows and doors, or collect in courtyards or on flat roofs.

4. SUMMARY AND CONCLUSIONS

The Working Party, on the basis of the information to be found in the literature, on information supplied to it, and based on the results of the tests carried out during the preparation of this report concluded that:

4.1

All the available experimental evidence shows clearly that the most important factors governing the necessary minimum air velocity through the working face are (a) the need to combat cross-draughts and turbulence caused by laboratory staff movements and (b) the design of the laboratory ventilation system.

4.2

The design of fan, duct and efflux point can help to minimize the effect of meteorological conditions by limiting the variations in face velocity under high wind conditions.

4.3

By designing the fume cupboard to produce a streamline flow of air into the cupboard, variations in measured air velocity and turbulence can be minimized resulting in more efficient retention of fumes, etc.

4.4

The provision of top and bottom take-off substantially improved the efficiency of all fume cupboards whether aerodynamic or not.

4.5

Under working conditions a correct aerodynamic design of fume cupboard will require a face velocity of 0·5 m/s (100 ft/min) to ensure that cross draughts and turbulence due to movement of staff or other processes do not cause loss of containment.

4.6

Variations in the air velocity inherent in the system are relatively transient and the re-capture of any lost material will be rapid. These variations should not exceed ±15% of the mean velocity in a *well-designed* system.

4.7

When there is a legal requirement that the face velocity must not fall below a stipulated limit, then the specification of the fume cupboard must allow for transient variations.

4.8

If it is essential that under *no* circumstances should transient escapes of material take place into the operator's breathing zone then a face velocity of 0·76 m/s (150 ft/min) may be necessary. Under these conditions the use of a total enclosure (e.g. glove-box) is preferred.

5. A RECOMMENDED SPECIFICATION FOR A GENERAL PURPOSE FUME CUPBOARD (see also appendices)

5.1

A fume cupboard which must not in any circumstances allow the escape of fumes etc., e.g. one which must meet the requirements of the *Ionising Radiations* (*Unsealed Radioactive Substances*) *Regulations* 1968 (G.B. PARLIAMENT, 1968) *must* be designed to provide a *minimum* air velocity of 0·5 m/s (100 ft/min) through the aperture at *all* settings of the sash. To achieve this an average velocity in the order of 0·76 m/s may be required. Where occasional transient escapes of vapour are acceptable the *average* air velocity should be 0·5 m/s. N.B. The Department of Employment's Code of Practice for health precautions against lead recommends a minimum air velocity of 1·0 m/sec through any part of the openings of an enclosing hood (DEPT. OF EMPLOYMENT, 1973).

If the requisite volume of air cannot be provided then the following variations are possible:

5.1.1. For preference a physical stop should limit the sash opening such that the correct air velocity is maintained.

5.1.2. An indelible mark may be placed on the fume cupboard to indicate the sash opening at which the air velocity is 0·5 m/s. A permanent and clearly-worded notice explaining the meaning of the mark should also be displayed. The minimum working aperture should not be less than 0·5 m (20 in.).

5.2

The interior of the working chamber of the fume cupboard must be designed to ensure that the working surface is swept by a current of air sufficient to entrain heavier-than-air fumes and vapours.

5.3

An air flow compensating device should be provided to ensure that, as the sash is lowered to restrict the size of the working opening, the air velocity through the opening does not rise to unacceptable levels.

5.4

The sash window should be fitted with toughened glass or equivalent material.

5.5

It is desirable that the edges of the working aperture be angled inwards to eliminate sharp edges and ensure streamline flow of the air into the chamber.

5.6

The provision of an air foil 25 mm above the front edge of the working surface is desirable to direct a smooth flow of air across the working surface.

5.7

The fume cupboard should be located away from the main circulation areas, doorways and opening windows, and should not be subject to cross-draughts other than those caused by the movements of the person(s) using the fume cupboard.

5.8

An adequate supply of clean tempered air should be provided in the laboratory. The air should be supplied through diffusers which obviate draughts and preferably at the opposite side of the laboratory to the fume cupboard.

5.9

The parts of the fume cupboard extract ducts within buildings should be under negative pressure.

5.10

The extracted air should be discharged to the atmosphere in such a manner as to ensure that the vitiated air does not re-enter the building, e.g. through air intake points, open windows and doors.

5.11

When first installed, suitable tests should be carried out to ensure that the fume cupboard meets the specification. Periodic tests should be carried out to ensure that the specified performance of the fume cupboard is maintained.

5.12

An air flow indicator should be provided. Ideally, one which indicates air flow through the working aperture.

6. RECOMMENDED AIR FLOW TEST METHOD

6.1

The following test procedure is recommended (B.S. 848: Part 1, 1963; Part 2, 1966; HEWITT, 1972, 1973; see also appendices).

(i) The aperture should be divided into imaginary squares and the velocity of the air measured at the centre of each square as described in BS.848 (1963).

(ii) A series of readings should be taken at each of the selected points in the working aperture.

(iii) The variation about the mean at each point should not be greater than ±15% of the mean value at that point.

(iv) The face velocity through the working aperture shall be the mean of the mean values at each test point. The mean values at each test point shall be within ±15% of the overall mean.

6.2

The efficiency of containment should also be tested by a suitable method, e.g. the release of smoke in the working area and the observation of the path followed by the smoke.

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APPENDIX I

HISTORICAL BACKGROUND AND REVIEW OF THE LITERATURE

1. *Historical background*

The earliest form of laboratory ventilation appears to have been a sort of hood or canopy, based on the open fireplace or blacksmith's forge. Pictures of 19th century laboratories suggest that fume extraction was virtually non-existent. By 1905 the Pharmaceutical Society certainly had a primitive fume cupboard in its chemistry research laboratory (NUFFIELD FOUNDATION, 1961).

Fume cupboards appear to have developed by the adding of side walls and a vertically sliding sash window to a canopy hood. In use the sash was pulled down and convection currents were relied upon to dissipate the fumes. Later a gas burner in the flue was added to create a stronger convection current. A later development was the provision of a fan to extract the fumes. The flue was short and discharged to the open air at the nearest available point.

This fairly primitive state of affairs prevailed until the early 1940s, when the war-time study of radioactive materials in government financed laboratories, particularly in the U.S.A., stimulated the serious study of the design of fume cupboards. It soon became clear that existing fume cupboards were grossly inadequate and each establishment seems to have produced its own design of fume cupboard and to have decided upon the basic engineering specification of the extract system. Thought was also given to the discharge of the fumes to atmosphere.

With the end of hostilities and the easing of security restrictions, exchange of information became possible and in November 1951 a conference was held at Los Alamos under the auspices of the American Society of Architects and the U.S. Atomic Energy Commission, in the course of which there took place what appears to have been the first serious public discussion of the design of fume cupboards. The proceedings of this conference were published in May 1952 (AMERICAN INSTITUTE OF ARCHITECTS *et al.*, 1952). The September 1954 issue of the *Industrial Hygiene Quarterly* contained a paper by SCHULTE *et al.* (1954), of Los Alamos, entitled "The evaluation of laboratory fume hoods ".

These are the two seminal papers. Although many articles have appeared since in numerous journals there have been no major changes in design criteria since that date, so far as the actual fume cupboard is concerned, although several papers have been published reporting original work on fume dispersal systems.

2. *Literature review*

Since these two papers were published, many articles have appeared in a wide variety of journals drawing attention to the problems of fume cupboard design. The majority of these originated in the U.S.A.

In the U.K. the first major publication on the subject appears to be BS 3202 : 1959 *Recommendations on Laboratory Furniture and Fittings.* Although much useful information is presented, it is in the form of an uncritical review of existing types of fume cupboard. A table of recommended extract velocities through fully-opened fronts is given, but these are based as much on the institution in which they are to be installed, as to the use to which they will be put. It is understood that the Standard is presently under review.

Although it does not refer specifically to fume cupboards, some guidance is included in a booklet issued by H.M.F.I., entitled *Dust and Fumes in Factory Atmospheres* (H.M. FACTORY INSPECTORATE, 1969).

In 1966 the *Handbook on Radiological Protection in Universities* (COMMITTEE OF VICE-CHANCELLORS AND PRINCIPALS OF THE UNIVERSITIES OF THE U.K., 1966) recommended a minimum air velocity through the working aperture of a radioactive fume cupboard of 0·75 m/s (150 ft/min).

In two papers, HUGHES (1968; 1969) reviewed the requirements for radioactive laboratories in the light of the various Acts of Parliament and Codes of Practice and of experience in meeting these requirements. Many of the comments on fume cupboards trace back to and confirm the two seminal papers of 1952–54 (AMERICAN INST. OF ARCHITECTS *et al.*, 1952; SCHULTE *et al.*, 1954).

Microbiological cabinets

The literature reviewed above deals with fume cupboards for various types of chemical work. At the same time, microbiologists have been interested in the problem of containing pathogenic organisms and some of the results are relevant to fume cupboard design.

Two sources of information in the U.K. have been the Public Health Laboratory Service, Air Hygiene Laboratory, Colindale Avenue, London N.W.9 (P.H.L.S., 1970) and the Microbiological Research Establishment, Porton, Salisbury, Wilts.

WILLIAMS and LIDWELL (1957) showed that an air velocity of 0·5 m/s (100 ft/min) is required to retain spores in a cabinet. This is supported by the experience of the M.R.E. (DARLOW, 1967).

In a paper on "Precautions against tubercular infections in the animal house", REES (1961), a special hood for post mortem examination of small animals is described. The hood is in essence a fume cupboard with a specially designed screen (instead of a vertically sliding sash) and a custom-built base. A 6-in. wide opening below the glass screen admits the operators' arms. The air velocity through this opening is *not less than* 1·6 m/s (300 ft/min).

In the same paper a cabinet for the housing of small animals is also described in which the ventilation system is designed to provide a current of air of " approximately 0·5 m/s (100 ft/min) which is sufficient to carry away from the operator all small droplet nuclei and even particles of sawdust", when the cupboard is opened.

APPENDIX 2

MEASUREMENTS AND TESTS CARRIED OUT BY THE WORKING PARTY

The members of the Working Party had access to a variety of fume cupboard systems and it was decided that the performance of as many types as possible should be investigated.

The basic parameter to be measured was the air velocity through the working aperture and this parameter related to the retention/capture effectiveness of the fume cupboard.

Of the three methods of assessing retention: smoke retention, manipulation of innocuous bacterial spores (WILLIAMS and LIDWELL, 1957) and manipulation of fluorescent powders (ROBOTHAM *et al.*, 1966), only the visual method using smoke was used.

Standard methods of measuring air velocity were agreed. Three types of instrument were available to the Working Party for this purpose: (i) velometer; (ii) vane-anemometer, with electro-magnetic pick-up; (iii) thermo-anemometer.

These three types of instrument have widely differing speeds of response. The thermo-anemometer (iii) is particularly sensitive to transient peaks and very local air currents, e.g. within vortices. Thus, this instrument is sensitive to very rapid changes in air velocity and where the range is substantial the average recorded is subjectively influenced by the judgement of the operator. If the sensing head is located in a vortex then the velocity measured will be that within the vortex rather than the general velocity of the air stream. Should the vortices be moving past the fixed sensing head, then very rapid fluctuations in the indicated air velocity will be noted.

The two other types of anemometer have lower speeds of response and tend to flatten transient peaks due to their mechanical inertia. They are also less sensitive to low air velocities.

It was clear that two important variations of air velocity had to be considered: (i) the variation of velocity with time at a given point in space; and (ii) the variation of velocity between specified points at a given time. Experiments showed that these variations could amount to $\pm 25\%$ of the mean velocity and the following major factors were identified to account for them: (a) movement of laboratory personnel in the vicinity of the fume cupboard and factors inherent in the layout and design of the laboratory; (b) outdoor wind conditions affecting fan performance (CLARKE, 1965); (c) turbulence due, either to apparatus in the fume cupboard or to the design of the fume cupboard.

One of the most striking pieces of evidence produced consisted of a continuous recorder chart showing the air velocity at a fixed point in the working aperture of a fume cupboard. Concurrently an anemometer out of doors was coupled to the recorder to register the wind velocity. During the test, conditions were flat calm so that any variations (in the air velocity into the fume cupboard) could be attributed to laboratory effects or variable fan performance only. During the period in which the fume cupboard was in use major fluctuations were recorded but when the laboratory staff were absent the air velocity was constant within narrow limits. The undisturbed air velocity was 0·5 m/s (100 ft/min), the variations being approximately ±25% about this value, when staff were present.

This experiment strikingly confirmed the statement by SCHULTE *et al.* (1954) that the minimum face velocity is set by the need to counter the air disturbances set up by laboratory staff working at or near the fume cupboard. N.B. A person wearing a laboratory coat sweeps out an area in the order of 1 m^2. Moving at a speed of 2–3 km/h (35–50 m/min) a volume of between 33 and 50 m^3/min is displaced. This is of the same order of magnitude as the extract rate of the fume cupboard.

Tests carried out by a member of the Working Party to ascertain the variation in air velocity at fixed points on the face as measured under controlled conditions showed that random variations about the mean exist (HEWITT, 1972; 1973).

Readings in a range of ±15% of the mean, which is considerably less than the effect of turbulence due to movements of staff in the area of the fume cupboard (up to ±25%) were recorded.

Although these quite substantial variations were noted in the measured air velocity, they were transient, the average time between successive maxima (and minima) being approximately 1 min.

The factors, which can affect the magnitude of the variations, as indicated earlier, include fan performance and meteorological conditions as well as turbulence due to the design details of the cupboard.

No long-term variation in the average velocity was noted.

APPENDIX 3

SOME RELEVANT TESTS REPORTED IN THE LITERATURE

WILLIAMS and LIDWELL (1957) carried out tests on a design of protective cabinet for handling infective material in the laboratory. The efficiency of retention of bacterial spores was measured under varying circumstances at two rates of air flow through the working face: 0·5 m/s (100 ft/min) and 0·3 m/s (60 ft/min). The tests did not take into account air disturbances due to cross-draughts but did include the effects of the operator carrying out the normal arm movements associated with bacteriological work. The conclusions reached were that: (i) under the test conditions the higher velocity gave a slightly better retention; (ii) the concentration of test material outside the cabinet was about 2% of that with an unventilated cabinet. The authors also concluded that to provide a reasonable margin of safety the higher velocity (0·5 m/s) should be recommended.

ROBOTHAM *et al.* (1966) reported tests carrying out standardised manipulations of fluorescent powders in two types of fume cupboard. These were: (i) a small wooden cupboard (length 2 ft 9 in, depth 2 ft 6 in., height 4 ft) with a single slot exhaust on the back face about 1 ft from the floor of the cupboard; (ii) A Kiwanee (aerodynamic) fume cupboard (length 5 ft 7 in., depth 2 ft 6 in., height 3 ft 9 in.).

In all the tests the sash was raised to give a 1 ft high opening. Tests were made with extract velocities of 0·6 m/s (120 ft/min) and 0·3 m/s (60 ft/min) and with cross draughts (controlled) up to 1·6 m/s (300 ft/min). Air samples were taken to the left and right of the fume cupboard and with a personal air sampler worn by the operator.

The results were expressed in terms of a protection factor P defined as:

$$P = \frac{\text{amount of material handled in the fume cupboard (g)}}{\text{airborne concentration outside the fume cupboard (g/m}^3\text{)}}.$$

Two facts emerged: (a) P values for the aerodynamic cupboard were in the range (20 to 300) $\times 10^6$ compared with (5 to 30) $\times 10^6$ for the simple cupboard, i.e. from 4 to 10 times greater efficiency; (b) A cross-draught approximating to the linear flow rate into the cupboard did not significantly affect the protection factor, but that cross-draughts of 2–3 times the flow rate produced a significant increase of contamination in the breathing zone. The authors point out that it is unlikely that cross draughts in excess of 1·2 m/s will be present, *unless there is an open window* very close to the cupboard, although a person walking past at 1·2 m/s (4·3 km/h) may well cause a momentary release of contamination from the cupboard.

It was noted that some rather low (0·3 m/s) air intake velocities had been cited as adequate by some authors, but on investigation it was found that the test conditions had been idealized, e.g. no external disturbances, no apparatus in the cupboard.

APPENDIX 4

1. *Lining materials*

There is no ideal material of construction for fume cupboards in general and the final choice will be a compromise dictated by the known or probable use to which the fume cupboard will be put.

Plastic materials of construction have attractions from the point of view of chemical resistance but attention is drawn to the fact that in fire *all* plastics decompose thermally and create large volumes of smoke and, in the case of PVC, very corrosive decomposition products, such as hydrogen chloride, which dissolves in any water present to give hydrochloric acid. Consequential losses considerably greater than the primary damage loss can occur, especially when electronic equipment is present.

Asbestos is absorbent unless the surface is sealed, e.g. with epoxy based compounds. Acid-resistant tiles can be difficult to joint satisfactorily but may be advantageous in special circumstances, e.g. perchloric acid fume cupboards.

Aluminium can be used inside fume cupboards, untreated in some circumstances, or painted with a chemically-resistant paint.

Stainless steel, although expensive, is a very good material so long as it is realised that there are several varieties of stainless steel with differing degrees of chemical resistance. The term "stainless" is a misnomer, "non-oxidizable" being a more accurate description.

2. *The sash*

The glass should *never* be ordinary window glass.

For *fire protection*, wired glass is the only material having any substantial resistance to fire. The glass has normal (poor) thermal resistance but the wire mesh holds the cracked glass in position. The wire would also corrode at the edges in time, causing venting of the glass.

For *explosion protection*, laminated and toughened glasses are the two acceptable materials. Of the two, laminated is slightly the better under normal temperature conditions, since on fracture it remains as a complete sheet more readily than does toughened. It has a poorer thermal shock resistance than toughened and in the presence of organic vapours can break down due to attack on the plastics interlayer.

Toughened glass is still the manufacturers' recommendation for fume cupboards even though a large explosion can cause the ejection of glass fragments.

Certain transparent plastic sheets are available having a higher impact resistance than glass; they are chemically resistant to hydrogen fluoride, but their temperature resistance and surface durability are much inferior to glass.

A toughened, laminated anti-explosion glass is available but is very expensive.

Miscellaneous considerations

Most vapours produced in fume cupboards are heavier than air. Consequently, it is necessary to induce a current of air which will continuously sweep the bottom of the fume cupboard at a sufficient velocity to entrain these vapours.

Tests on various types of fume cupboard showed that some form of low level take-off designed to give a continuous sweep of air across the working surface capable of entraining these heavy vapours is necessary.

The air flow characteristics are considerably improved when there is top and bottom take-off. A baffle at the back of the hood gives a substantial improvement, whilst a further improvement is obtained by the fitting of an air foil over the front edge of the working face. In the absence of these features the air follows the path of least resistance leaving a dead space at the back of the cupboard. (These points are illustrated diagrammatically in Figs 1–3).

Smoke tests also showed that the use of an angled "lead-in" assisted in the production of a more streamlined flow of air with less tendency to form vortices at the edges of the working aperture than when a sharp edge exists (see paragraph 3.2).

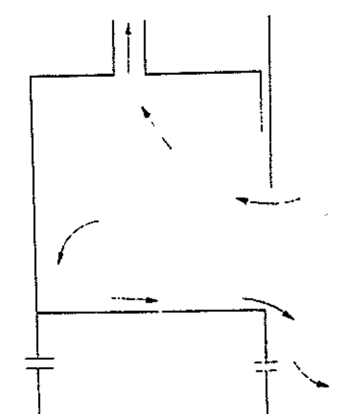

Fig. 1. Air currents in the absence of a baffle.

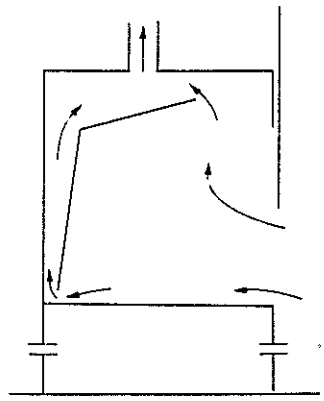

FIG. 2. Air currents with baffle fitted.

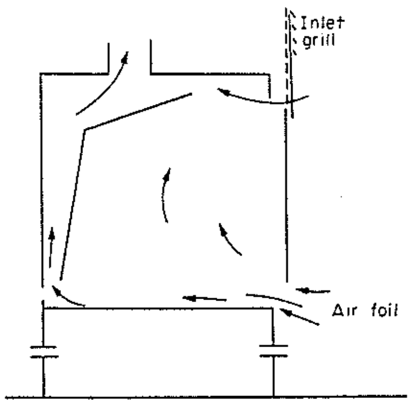

Fig. 3. Air currents with baffle and air-foil fitted and by-pass operating with the sash down.

It will be noted that if the air velocity is specified for the maximum working aperture, then as the sash is lowered the air velocity will increase to unacceptable levels unless some form of compensating device is provided, e.g. an air by-pass which allows an increasing proportion of the air to be drawn into the cupboard over the top of the sash rather than through the working opening (Figs. 6 and 7).

Laboratory layout relative to the fume cupboard

An efficient fume cupboard requires a substantial air supply, e.g. a working aperture 1 × 0·67 m with an air velocity of 0·5 m/s requires 20 m^3/min of air. In a small laboratory, say 6 × 6 × 3 m, this is approximately 10 air changes per hour.

This air cannot be obtained by "natural" ventilation in an acceptable manner. The control of the temperature of the incoming air and of its dirt load requires that the bulk of the incoming air should be both filtered and warmed, at least at the point of its entry to the building. Some air will inevitably be drawn from corridors through the doorway. Dirt can enter through unsealed windows and is brought in on footwear.

Cross draughts adversely affect fume cupboard performance, and input air to the laboratory should be supplied at locations as far as possible from the fume cupboard

(Fig. 4) because otherwise: (a) the rest of the laboratory may remain unpurged (Fig. 5) and a valuable source of general laboratory ventilation lost; (b) unfavourable air currents may be set up near the fume cupboard (Fig. 5).

Doorways should be as far from the fume cupboard as possible, firstly because movement of personnel is concentrated near doorways, secondly because the opening and closing of doors sets up major air disturbances and thirdly because a fume cupboard is a possible major hazard area and should be as far from the line of exit as possible. The first two points are closely linked with the need to maintain a face velocity of 0·5 m/s to overcome cross draughts.

Fume cupboards are often associated with such bulky items as gas cylinders and it is preferable to have these away from busy circulation areas.

When dangerous liquids are used in fume cupboards then the fume cupboard should be fitted with a spillage trough or tray of sufficient capacity to contain all the liquids used.

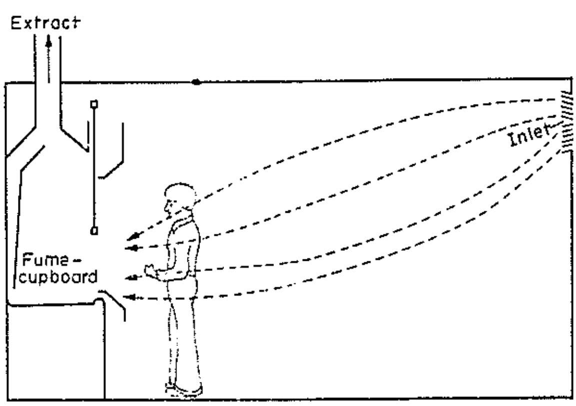

FIG. 4. A room air inlet positioned to ensure that the air velocity near the operator's head is not excessive and that most of the room is ventilated (EVERETT and HUGHES, 1975).

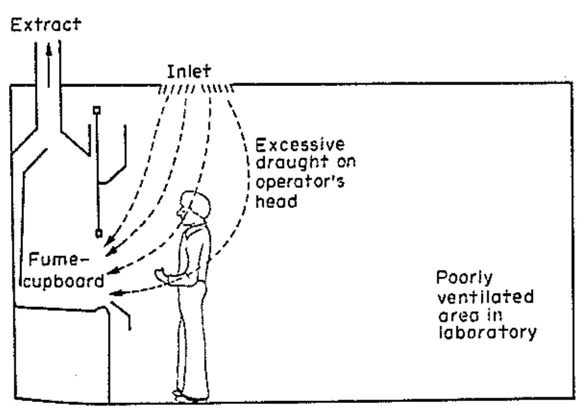

FIG. 5. A badly placed air inlet causing excessive down-draughts and providing little general ventilation in the room (EVERETT and HUGHES, 1975).

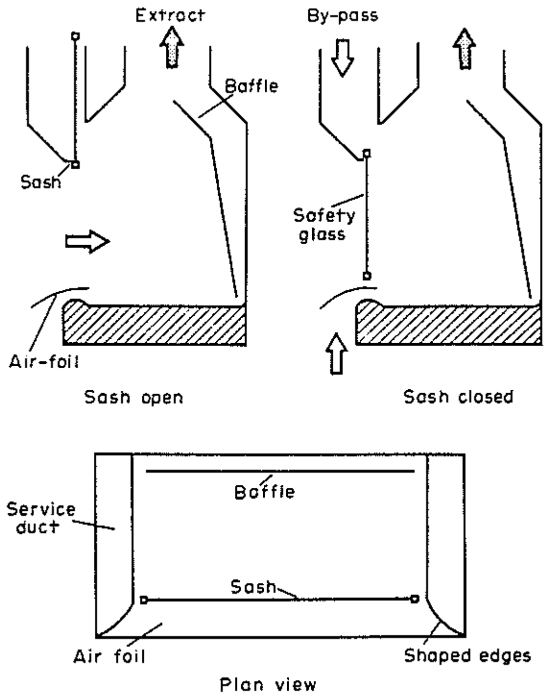

FIG. 6. An aerodynamic fume cupboard with back baffle, air-foil, shaped edges and simple by-pass, which prevents excessive air velocities when the sash is lowered (EVERETT and HUGHES, 1975).

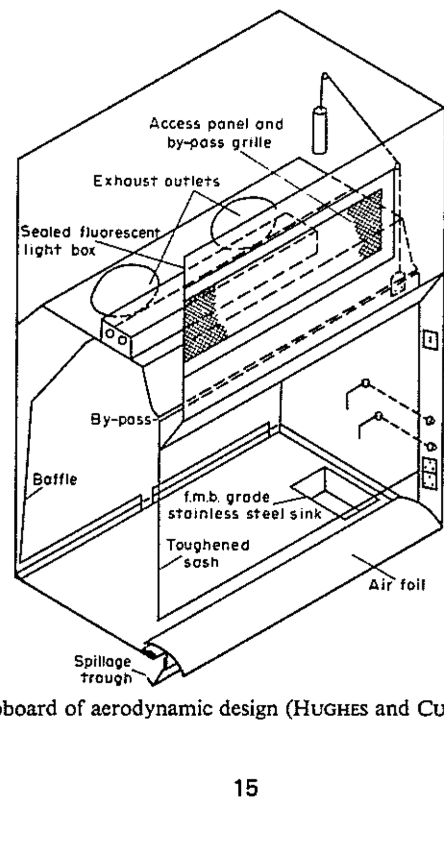

FIG. 7. Fume cupboard of aerodynamic design (HUGHES and CULLINGWORTH, 1971).

B

APPENDIX 5

Fume cupboard exhaust systems

Basically, a fume cupboard exhaust system consists of an extract duct, a fan and a discharge stack.

In special cases filters may be required. These will be bulky and should be placed:

(a) as near to the fume cupboard as possible, to avoid contamination of the duct work; (b) and be easily changed under "clean" conditions. These requirements may not be compatible.

Extract fans should be sited to ensure that any ducting inside the building, or on a roof to which there is access, is under negative pressure. This ensures that all leaks are into the duct. N.B. Rain water can be drawn in through faulty flange gaskets.

The Working Party favoured the use of centrifugal fans rather than axial flow fans because: (i) the fan motor and drive are outside the duct and therefore more readily accessible for maintenance; (ii) only the fan impeller is actually exposed to the fumes being conveyed; (iii) a centrifugal fan is less sensitive to pressure variations in the duct system and is less susceptible to meteorological conditions, e.g. high winds.

The Working Party noted that the location of the discharge nozzles in relation to the building air intakes is of great importance, as is the general dispersal of fumes from the stack but this problem was outside its terms of reference (CLARKE, 1965; HUGHES, 1972; EVERETT and HUGHES, 1975).

Duct materials

When fume cupboards are to be used for perchloric acid digestions great care is required in the choice of material; the use of untreated metal is to be avoided at all costs (SCHUMACHER, 1960; EVERETT and GRAF, 1971; appendix 6).

The choice of duct materials for general purpose fume cupboards is a matter upon which opinions are divided.

Metal ducts are more likely to survive in a fire, although very hot fires can result in metal ducts buckling. A further problem is that a very hot metal duct is capable of radiating substantial amounts of heat to its surroundings.

It is essential that the inside of metal ducts should be given an epoxy resin coating or other chemically-resistant treatment; experience suggests that the ducts should be treated by a firm specialising in this type of work (HUGHES, 1968; 1969).

It is important that the exterior of the duct is also adequately protected, e.g. where the duct is exposed to the weather the external surface and seams must be proof against corrosion due to rainwater.

Plastic ducts are chemically-resistant but suffer from several drawbacks: (i) plain plastic ducts collapse or distort at very low temperatures (90–150°C); (ii) polypropylene and polythene are flammable; (iii) PVC decomposes to form a very corrosive smoke which can damage reinforced concrete or laboratory apparatus.

It is reported that PVC backed with glass reinforced plastic does not collapse at low temperatures and that there is much less condensation in ducts of this material.

Asbestos-based materials have been extensively used for ducting and the comments made under lining materials apply here.

Noise

The large air-flow rates required can result in unacceptable noise levels associated with fume cupboard systems. The noise can be in three general locations: (i) the laboratory containing the fume cupboard; (ii) rooms through which the extract duct passes; (iii) outside the building.

The noise level in the laboratory should not be obtrusive. It is suggested that the noise produced by the fume cupboard should not add appreciably to the general laboratory background noise.

A well-designed system should not produce noise levels when measured in accordance with B.S. 4196 (1967) in excess of ISO noise rating curve 55 (60 dBA).

If the duct passes through offices then adequate sound insulation will be required to ensure that an acceptably low noise level is achieved (DEPT. OF EMPLOYMENT, 1972).

Noise from fans and exhaust nozzles must be limited in both quantity and quality to a level acceptable to the neighbourhood. If the fans are to be run 24 hours/day stringent control will be necessary. The actual noise levels will depend on whether the location is adjacent to residential or other "quiet" areas and the local authority should be consulted as to acceptable noise levels (B.S. 4142, 1967).

Exhaust system

The system illustrated in Fig. 8 shows all the principal features which might be required in a fume cupboard exhaust system. In practice, and depending upon local conditions, some of these features might be unnecessary, e.g. automatic fire extinguisher, filter, automatic damper, fire damper, silencer (HUGHES, 1974).

APPENDIX 6

Fume cupboards for perchloric acid work

The use of fume cupboards for perchloric acid digestion of specimens entails special hazards. Materials such as wood become highly flammable after impregnation by the vapours produced during perchloric acid digestions. Many materials are attacked by perchloric acid vapour to form crystals of metal perchlorates, which are extremely shock sensitive and violently explosive. Many serious fires, explosions and fatal accidents are recorded in the literature (SCHUMACHER, 1960; EVERETT and GRAF, 1971).

By careful choice of materials most of these hazards can be avoided.

The most important safeguard is to avoid, as far as possible, the use of metal for surfaces exposed to the vapour. This is a case where the disadvantages of PVC as a duct material are outweighed by its chemical resistance and non-metallic character.

One design (used by a member of the Working Party) consists of a working chamber constructed of brickwork and faced with either smooth concrete or tiles, a duct system and extract fan of PVC, and an aerodynamic fascia of conventional materials fitted to the front of the working chamber. The back baffle is of a heat resistant non-metal, in this instance a sheet of glass, held in position by plastic-coated lugs.

Attention is drawn to a design of fume scrubber which can be used to entrain perchloric acid vapour and spray (SILVERMAN and FIRST, 1962).

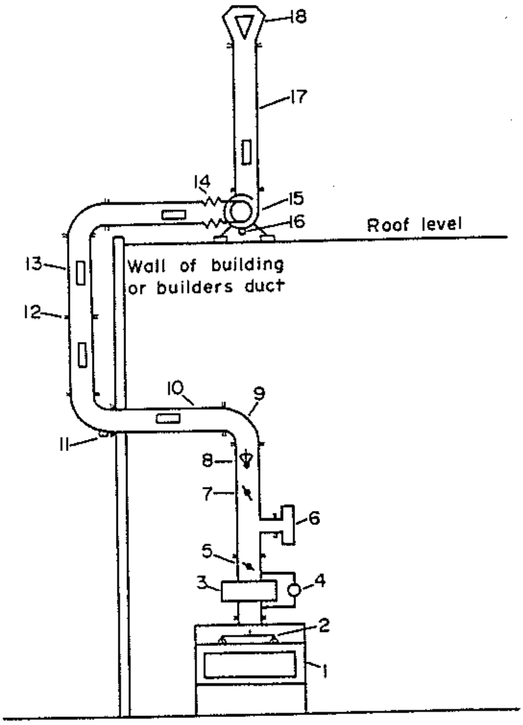

FIG. 8. A schematic diagram of a fume cupboard extract system showing all the various elements which might be incorporated, depending on the intended use (EVERETT and HUGHES, 1975). 1, fume-cupboard; 2, automatic fire extinguisher; 3, filter; 4, manometer; 5, automatic damper to compensate for changing resistance of filter; 6, air-flow sensor; 7, fire-damper with approved manual override; 8, manual setting-up damper with locking screw; 9, generously radiused bends; 10, minimum of horizontal ductwork; 11, drain connection; 12, ductwork, at negative pressure, with air- and water-tight gaskets at joints; 13, notices stating hazard and if permit to work is required; 14, flexible coupling in ductwork; 15, centrifugal fan; 16, drain connection; 17, tall discharge stack fitted with silencer if necessary; 18, high-velocity discharge nozzle.

Special enclosures

(i) "*Walk-in*" *fume cupboards.* It is recommended that, because of the very large air demand at full opening, they should be located in large laboratories, or that they should be modified to be operative only as "restricted-opening" enclosures, the maximum opening being used only for the assembly of apparatus.

(ii) *Auxilliary air supply chambers.* Some designs of fume extract chamber attempt to reduce the amount of air drawn from the laboratory by blowing an auxilliary supply of untreated air into the chamber, through slots around the working aperture. The majority of the Working Party were unable to recommend this system. The main objections were:

(a) A dangerous situation would result should the extract fan fail or become less efficient than the input fan, because in this event air could be blown from the fume chamber into the laboratory. It was felt that because the extract fans are exposed to more arduous conditions than the input fans, much more frequent maintenance checking would be needed to ensure that the balance was *always* correct.

(b) In many (urban) districts there are high dust loads in the atmosphere, especially where there are building operations in progress. To maintain acceptable standards of cleanliness the auxiliary air would need to be filtered, particularly where micro- and semi-micro scale work was being carried out. The filters would need to be large and, depending on the locality, fairly frequent changes might be anticipated.

(c) In winter the auxiliary air, about half the total air passing through the cupboard, will on many occasions be extremely cold, causing the operator's hands to become unbearably cold. It was also reported that certain types of reflux experiment cannot be carried out due to the excessively cold air flowing through the chamber. If this occurs there is the danger that operators will seal off the inlet slots and seriously unbalance the system.

(d) The provision of an inlet fan and ducting was noted as an increased capital cost on the installation. Filtering of the inlet air would be a further expense.

(e) If the fume cupboard is required for radioactive work a face velocity of 0·5 m/s will be required to meet the statutory requirements (G.B. PARLIAMENT, 1968).

The experience of some members of the Working Party suggested that fears expressed about the need for extra laboratory heat when high efficiency fume cupboards are installed were exaggerated. Generally speaking, chemistry laboratories are under-ventilated and there seems to be a greater generation of waste heat than is normally assumed, with the result that there is rarely need to provide extra heat to compensate for the effect of the fume cupboard.

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