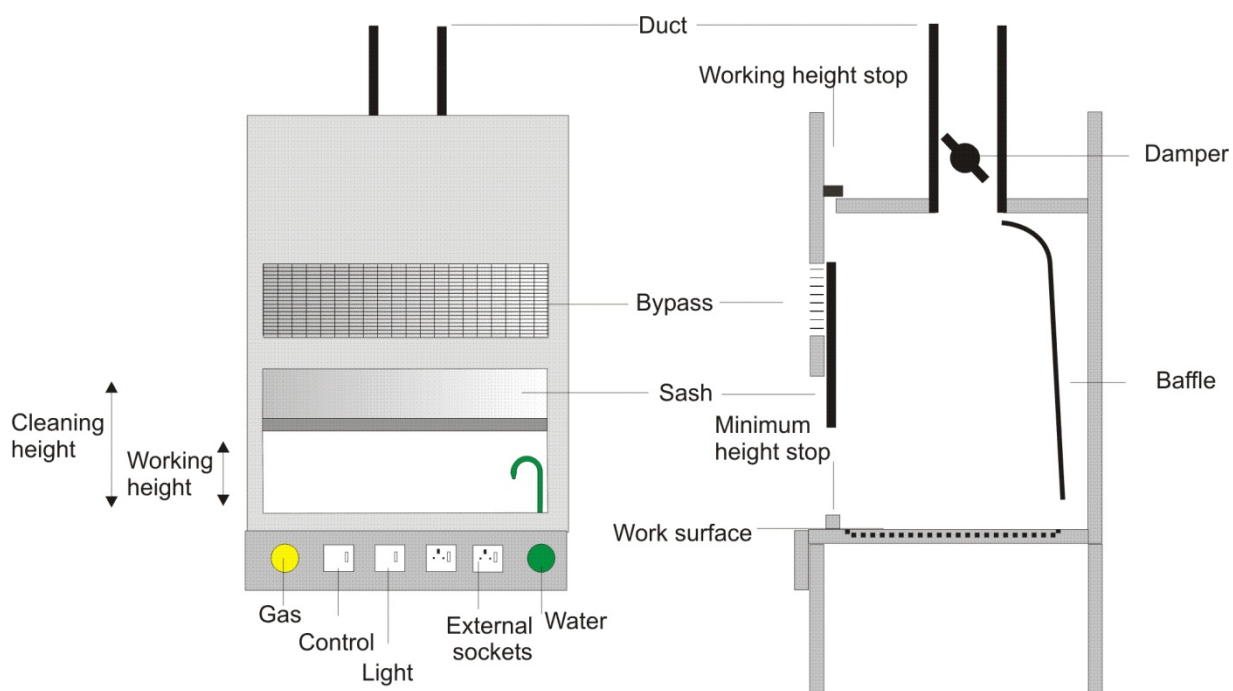


G9 Fume Cupboards in Schools

Revision of

DfEE Building Bulletin 88

November 2014



© CLEAPSS 2014

As with all CLEAPSS materials, members and associates are free to copy all or part of this guide for use in their own establishments.

Although CLEAPSS publications are normally available only to those working in local authorities, schools, colleges and other institutions which are members or associate members, given its history, this document is being made publically available as a service to science education.

CLEAPSS
Gardiner Building
Brunel Science Park
Kingston Lane
Uxbridge
UB8 3PQ
Tel: 01895 251496
Fax: 01895 814372
E-mail: science@cleapss.org.uk
Web Site: www.cleapss.org.uk

Contents

1	<i>Introduction</i>	1
1.1	Who is this guidance for?	1
1.2	Why is this guide necessary?	1
1.2.1	Existing guidance	1
1.2.2	Schools rarely buy fume cupboards	2
1.2.3	Installing, maintaining and testing fume cupboards	3
1.3	What are the main changes compared with earlier versions?	3
1.4	What is the status of this guidance?	4
2	<i>Fume cupboards explained</i>	5
2.1	General principles	5
2.1.1	How fume cupboards work	5
2.1.2	Why airflow rate is important	5
2.1.3	The sash	5
2.1.4	Face velocity	6
2.2	Ducted fume cupboards	8
2.2.1	Discharging fumes to the atmosphere	8
2.3	Recirculatory filtration fume cupboards	9
2.3.1	How filters work (and can fail)	9
2.4	Containment	11
2.4.1	Measuring containment	11
2.4.2	Variation of face velocities	11
2.4.3	Other reasons why fumes may escape into a room	12
2.4.4	Fume cupboards shared between 2 rooms	12
2.5	How to use a fume cupboard	12
2.6	Maintenance	13
3	<i>Provision, choice and siting of fume cupboards</i>	14
3.1	The number and type of fume cupboards	14
3.1.1	Provision for dedicated post-16 chemistry laboratories	14
3.1.2	Demonstration fume cupboards	14
3.1.3	Provision for science laboratories	14
3.1.4	Provision for technician services	15

3.2	Siting of the fume cupboard in a school laboratory	15
3.2.1	Design considerations	15
3.2.2	Mobile fume cupboards	16
3.2.3	Wall-mounted or free-standing?	17
3.2.4	Flexible service connections to mobile fume cupboards	17
3.2.5	Recommended distances	18
3.2.6	Fume extraction systems for ducted fume cupboards.....	20
3.3	Ducted or recirculatory filtration fume cupboards?	20
4	<i>Specification of school fume cupboards</i>	24
4.1	Relationship with the British Standard.....	24
4.2	Dimensions.....	24
4.3	Stability of mobile fume cupboards	25
4.4	Filter fitting for recirculatory filtration fume cupboards	25
4.5	Lining and construction materials.....	25
4.5.1	General	25
4.5.2	Work surfaces.....	26
4.5.3	Glazing	26
4.6	Airflow rate	27
4.6.1	Sash height and face velocity	27
4.6.2	Variation in face velocity as sash is raised and lowered	27
4.6.3	Air flow indicator	28
4.6.4	Sash suspension	28
4.7	Services	28
4.7.1	Illumination	28
4.7.2	Electrical services	29
4.7.3	Gas services	29
4.7.4	Water and drainage.....	30
4.7.5	Service connections.....	30
4.8	Noise levels	31
4.9	Information to be provided by the fume cupboard supplier	31
4.9.1	Information to be displayed on the fume cupboard	31
4.9.2	Information to be provided in accompanying documentation	32
4.10	Assumed use of school fume cupboards	32

5	<i>Duct extraction systems and filters</i>	35
5.1	Duct extraction system	35
5.1.1	Design of the system	35
5.1.2	Fans for ducted fume cupboards	36
5.1.3	Make-up air	37
5.1.4	Ductwork	38
5.1.5	Fume discharge	38
5.2	Filters for recirculatory fume cupboards	39
5.2.1	Choice of filters	39
5.2.2	Filter efficiency required	41
6	<i>Buying a new fume cupboard</i>	43
6.1	Contractors	43
6.2	Quotations	43
6.3	Installation	44
6.4	Commissioning	44
6.5	User Manual	45
7	<i>Legal requirements</i>	46
7.1	Introduction	46
7.2	Employers	46
7.3	Duties of employees	46
7.4	Non-employees including pupils	47
7.5	Standard for the school fume cupboard	47
7.6	Installation, information and training	48
7.6.1	Documentation to be provided by suppliers	48
7.6.2	Installing and commissioning fume cupboards	48
7.6.3	Training users	49
7.7	Fume cupboards in use	49
7.7.1	The need for fume cupboard maintenance, examination and testing	49
7.7.2	Who carries out maintenance and thorough examination and testing?	50
8	<i>Maintaining, examining and testing school fume cupboards</i>	52
8.1	Routine maintenance and checks	52
8.2	Statutory thorough examination and test	52
8.2.1	Additional measures for recirculatory filter fume cupboards	53
8.3	Failure to pass the thorough examination and test	55

9	<i>Procedures for examining and testing school fume cupboards</i>	57
9.1	Equipment	57
9.1.1	Anemometer	57
9.1.2	Sound meter	57
9.1.3	Smoke tubes (air current tubes) (if required)	58
9.1.4	Gas detecting apparatus	58
9.2	Carrying out a thorough examination and test	59
9.2.1	Preliminary Information	59
9.2.2	Stage 1: A thorough visual and structural examination	59
9.2.3	Stage 2: Measuring technical performance	60
9.2.4	Stage 3: Assessing control effectiveness	63
9.3	Testing the seating of the filter using polychloroethenes	65
9.3.1	When to do the test	65
9.3.2	What you need	65
9.3.3	Procedure	65
9.3.4	Interpreting the results	67
9.4	Testing the filter for saturation by acid gases	68
9.4.1	When to do the test	68
9.4.2	What you need	68
9.4.3	Procedure	69
9.4.4	Interpreting the results	70
9.5	Testing the filter for saturation by alkaline gases	71
9.5.1	When to do the test	71
9.5.2	What you need	71
9.5.3	Procedure	72
9.5.4	Interpreting the results	73
9.6	Fume cupboard thorough examination and test report (14-month) as required by the COSHH regulations	74
9.7	Fume cupboard test summary sheet	80

G9 Fume Cupboards in Schools

Revision of DfEE Building Bulletin 88

1 Introduction

1.1 Who is this guidance for?

The guidance in this document is intended for a number of different audiences, although not all will need all parts of it. Parts of the guide are relevant to those buying (or selling) new fume cupboards, but some parts are relevant to those with existing fume cupboards. Because not all readers will need to read every chapter, and because it is assumed readers will dip in to particular chapters rather than read it from cover to cover, there is some repetition between chapters. The likely audiences for this guidance include the following. The most relevant chapters for the various audiences are given in the second column.

<i>Audience</i>	<i>Most relevant chapters</i>
Science teachers and technicians in schools and colleges which may need new fume cupboards, often as part of a new laboratory development.	1, 2, 3, 4, 6
Science teachers and technicians in schools and colleges who may be concerned about the performance and/or maintenance of existing cupboards.	1, 2, 8, 9
Bursars in schools and colleges who may be commissioning architects for new or refurbished laboratories.	1, 2, 3, 4, 5, 6
Bursars and site managers in schools and colleges who may be commissioning a company to carry out maintenance or testing.	1, 2, 8, 9
Architects designing laboratories for schools and colleges which include (or should include) a requirement for fume cupboards.	1, 2, 3, 4, 5, 6
Fume cupboard manufacturers or importers which are interested in supplying the schools and colleges market.	1, 3, 4, 6
Companies offering services in maintenance or health and safety tests and inspections for the schools and colleges market	1, 2, 4, 5, 8, 9
Health and safety inspectors or advisers working for insurance companies, facilities management organisations or employed by the school or college or local authority or by the HSE.	1, 2, 4, 5, 8, 9

1.2 Why is this guide necessary?

1.2.1 Existing guidance

For many years there was a British Standard for Fume Cupboards, BS7258, now replaced by a European Standard adopted as a British Standard, BS EN 14175. Where relevant, there are direct quotations from the Standard in this guide. Note that it is important to refer to the full British European Standard as the European Standard alone will not contain the (British) National

Foreword, which is particularly relevant in the case of schools. There is a separate standard for recirculatory filtration fume cupboards, BS7989, which is likely to be replaced soon by a European Standard.

Despite the existence of British Standards, the various predecessors of the Department for Education (DfE) thought it necessary to publish guidance on fume cupboards in schools in 1982 and 1998, both of which documents were largely based on work done by, and advice from, CLEAPSS.

All new school fume cupboards should be designed to comply with relevant parts of the British Standard, but, because of changing specifications, it is very likely that older fume cupboards will not fully comply with the current Standard and there is generally no requirement to upgrade. In fact, in the UK, there is no legal requirement for even new fume cupboards to comply with the Standard, although doing so is usually seen as good practice and may help comply with relevant UK health and safety legislation (see section 7). However, the Standards are in any case relatively permissive in allowing a wide range of specifications, with details to be agreed between the supplier and purchaser.

Fume cupboard design has improved over the years but this guide considers a number of issues that have arisen. Some would not have arisen with properly designed and manufactured fume cupboards but such cupboards may already be in schools and in any case manufacturers or importers may be considering introducing new models, without understanding the pitfalls.

1.2.2 Schools rarely buy fume cupboards

For users with little experience of purchasing fume cupboards, it may be helpful for trade associations, employers' bodies or other organisations associated with a particular activity to give guidance on a suitable specification. An example would be Building Bulletin 88 from the Architects and Building branch of the Department for Education and Employment, which is currently under revision and to be published in future as G9a Fume Cupboards in Schools by CLEAPSS.

...

THE (UK) NATIONAL FOREWORD (JANUARY 2014) TO BS EN 14175

As schools or their architects rarely order new fume cupboards, they are not normally in a position to be able to supply the information specified in the British European Standard easily: for example, how would the average Head of Science know what was an appropriate flow rate? As all secondary schools have very similar requirements for fume cupboard performance, it is sensible for national bodies with specific knowledge and experience in this area, such as the DfE and its predecessors, or CLEAPSS or (in Scotland) SSERC to specify a suitable level of performance for school fume cupboards. This is the function of the specification section of this guide (section 4) which satisfies all the basic requirements of the Standard with regard to dimensions, materials and basic safety requirements. However, it goes further than BS EN 14175 and BS7989 and, for example, suggests suitable air flow rates for the type of work carried out in schools, based on assumptions made about the type of work carried out in school fume cupboards (these are given in section 4.10). As a preliminary to this, the general principles of

fume cupboards are explained in section 2 and issues around the choice and siting of fume cupboards discussed in section 3.

1.2.3 Installing, maintaining and testing fume cupboards

Again because of a lack of experience, senior management of schools rarely understand fully the problems which may arise when fume cupboard ducting and the fume cupboard itself are installed and commissioned by different companies, which in turn may be different to those who carry out maintenance or health and safety tests and inspections. Whilst compatible with the British/European Standard, this guide goes further, specifying details of duct extraction systems and filters suitable for the school situation (section 5). It also gives guidance on the process of purchasing and installing fume cupboards – quotations, commissioning etc – in section 6.

Once a fume cupboard is installed and commissioned, the exposure control measures must be maintained. The specific requirements are described in section 8 and details of what to do, including report forms to complete, are given in section 9.

1.3 What are the main changes compared with earlier versions?

This guidance is based on several previous publications. It incorporates the previous CLEAPSS guide L9b *Monitoring Fume Cupboards* (normally only available as a hand-out on the CLEAPSS training course *Fume Cupboard Testing*) and parts of CLEAPSS guide R9a *Fume Cupboard Suppliers and Repairers*. However, part of the information in R9a is now found in the CLEAPSS guidance leaflet GL123 *Fume Cupboard Buying Guide*.

However, most importantly, this guidance is the successor to *Building Bulletin 88 Fume Cupboards in Schools* (DfEE Architects & Building Branch, 1998) and its predecessor *Design Note 29 Fume Cupboards in Schools* (DES Architects & Building Group, 1982) and is derived from it, although the order of topics has been changed and much of the text rewritten. Both had been largely based on work by CLEAPSS and discussions had taken place in the late 2000s about the possibility of CLEAPSS working on a revised edition, to reflect changing needs and practices.

Much of the advice is unchanged. **However, there are some significant changes in this document with respect to re-circulatory filtration fume cupboards as compared with its predecessors:**

- **Filters, and the cupboards in which they go, must be better designed to avoid leakage around the filter;**
- **Filters should be carefully examined for flaws before installation;**
- **Testing for leakage is suggested only when doubts arise;**
- **Testing for leakage, when necessary, should use safer alternatives to trichlorethene (several are suggested depending on the circumstances);**
- **Replacing filters on a regular basis (the frequency depending on use) is suggested as an optional alternative to testing filters for saturation.**

In addition, we are proposing **more stringent noise level standards** for all fume cupboards.

1.4 What is the status of this guidance?

When the government decided, in 2010, that publication of guidance on fume cupboards in schools was no longer the type of activity in which it should be involved, CLEAPSS had already been working on a revision of *Building Bulletin 88* and decided that there was still a need for this sort of publication and that, given its history, it should be made publically available and not just to CLEAPSS members.

It is, as it always was, advice. Employers are free to make their own decisions as to how they should comply with the law. However, this advice is based on over 50 years of experience that CLEAPSS has with fume cupboards in schools, and the problems encountered with them.

In producing this guidance, CLEAPSS has consulted the Education Funding Agency (the successor to the DfEE Architects & Building Branch) and the CLEAPSS representative on the British Standard Institution Committee, LBI/1/1 *Laboratory Furniture and Fittings*, was able to consult with and take advice from other members of the committee, including the HSE's Health and Safety Laboratory. A number of companies manufacturing fume cupboards for the schools market or providing testing services for that market were also consulted as was the CLEAPSS sister organisation in Scotland (SSERC). However, the opinions expressed represent those of CLEAPSS alone.

2 Fume cupboards explained

2.1 General principles

2.1.1 How fume cupboards work

A fume cupboard is intended to minimise exposure to hazardous gases, vapours or dusts. Lists of those likely to be found in schools are given in section 4.10. A subsidiary function can be to act as a safety screen to protect people from minor explosions, splashes etc. It is an example of a partial enclosure and is classed as **Local Exhaust Ventilation (LEV)**. Protection is achieved by a flow of air which is designed to ensure the contaminant remains inside the fume cupboard. The cupboard sash provides a transparent physical barrier between the users' breathing zones and the contaminated air within the cupboard.

The contaminated air is then diluted and vented to the outside; this is an example of a **ducted fume cupboard** (see *Figure 2.1*). This is by far the most common type of fume cupboard in schools.

As an alternative to ducted fume cupboards, the fumes can be passed through a filter and then discharged back to the laboratory. The filters never remove 100% of the fumes and the percentage of fumes removed drops as the active sites on the filter become saturated. Fume cupboards which function in this way are referred to as **recirculatory filtration fume cupboards** (see *Figure 2.3*). Ducted fume cupboards can sometimes have a filter before the air is vented to the outside but these are never required in schools.

2.1.2 Why airflow rate is important

If the airflow rate is too low, hazardous fumes may escape, especially if the air is disturbed by cross-draughts or people moving about nearby. On the other hand, if it is too high it may destabilise Bunsen burner flames, waste energy and be noisy.

Airflow rate may depend on the fan, the ducting (unless a filtration fume cupboard), the sash height, the presence of a baffle, bypass, damper and inverter, see section 2.2.

2.1.3 The sash

On most fume cupboards, there is a **sash** (see *Figures 2.1* and *2.3*) which can be raised to help gain access and lowered to protect the operator from splashes etc. The sash reduces operator exposure to hazardous gases, etc, by breaking down the turbulent wake in front of the operator. Smoothed air entry at the edges of the cupboard minimises the creation of eddies (swirls of air) and leakage of contaminated air from the face of the fume cupboard.

The **working aperture** is the opening through which the users can put their arms. If the working height of the aperture is too small, manipulation of apparatus is restricted; if it is too large, it can be hazardous as it is harder to keep the variation in air velocity across the aperture low and to make the bypass effective (see section 2.1.4). It also requires a more powerful extraction system and there is less protection for the operator from splashes, which is particularly important if pupils who have not yet reached adult height are using the fume cupboard.

Generally speaking, the smaller the sash opening the better the containment.

The operational sash opening shall be variable in the direction of the sash movement. Its maximum position should preferably be 500 mm in the direction of sash movement and shall not exceed 600 mm. This dimension shall be clearly marked on the fume cupboard.

BS EN 14175-2:2003, SECTION 7.3.1

The **maximum working height** should be included in the specification.

For vertical sash(es), some form of stop shall be incorporated to prevent the sash being opened more than the maximum operational sash opening. It shall not be possible to override the stop more than the maximum operational sash opening without a deliberate act on the part of the operator. The design of the sash stop shall ensure that the sash stop is automatically reset when the sash is returned to a position less than the maximum operational sash opening.

An audible and visual sash alarm should also be incorporated to indicate to the operator that the sash is opened to more than the maximum operational sash opening. The audible alarm may be silenced once alarmed.

BS EN 14175-2:2003, SECTION 7.3.2

For schools, a maximum working height of 400 mm or a little more allows manipulation of apparatus in the fume cupboard but improves containment and provides some protection to the face of the user. A higher aperture increases user exposure to splashes and can reduce containment effectiveness. It also makes it more difficult to obtain an airflow rate which does not increase by too much as the sash is lowered and increases the difficulty of fitting an efficient bypass (see 2.1.4).

When tested in accordance with BS EN 14175-3:2003, a vertical sash shall be such that it cannot fall when one suspension device fails. Closing and opening the sash shall not present a danger of injury. The sash shall be capable of being stopped in any position.

Sash suspension devices shall either not be exposed to the workspace atmosphere or otherwise be appropriately protected against corrosive atmospheres.

An audible and visual sash alarm should also be incorporated to indicate to the operator that the sash is opened to more than the maximum operational sash opening. The audible alarm may be silenced once alarmed.

The size and position of the sash handle(s) shall not be a hazard to the operator by obstructing vision or by restricting the workspace available.

BS EN 14175-2:2003, SECTIONS 7.3.2. 7.3.6

2.1.4 Face velocity

The face velocity is the velocity of air at the plane of the sash set at the maximum working height. It is usually measured at 9 positions over the aperture. Measurements on school fume

cupboards¹ have shown that disturbances, eg, movements of the user or cross draughts, reduce containment more if the face velocity is lower than 0.3 m s^{-1} . On the other hand, high face velocities can cause Bunsen burner flames to be unstable and even to extinguish (an important consideration for schools) and can increase turbulence in fume cupboards of simple design. They also waste energy by requiring a more powerful fan and discharging heated laboratory air to the outside. The optimum face velocity is a compromise.

As a sash is lowered, the face velocity will increase and, for example, this increases the risk of de-stabilising a Bunsen burner flame. The purpose of a **bypass** is to minimise the variation as the sash is lowered and raised. School fume cupboards have improved considerably in recent years in this respect. Other methods of achieving the same effect are possible, but not relevant to schools.

A **baffle** helps to minimise variation in face velocity caused by eddies and hence leakage of contaminated air.

Baffles shall be constructed in such a way as to be easily cleaned and maintained. It shall not be possible to alter their position from the original design positions.

BS EN 14175-2:2003, SECTION 7.2.3

The **damper** is used when the cupboard is installed (usually during commissioning) to adjust the air flow rate, and hence the velocity. As an alternative to a damper, some fume cupboards may have an **inverter**, which is used to adjust motor speed. Whichever option is used, once set, it should be locked into position and not altered during normal use. Dampers may increase noise levels if they are used to produce a considerable reduction in velocity from an unnecessarily powerful fan.

For a ducted fume cupboard, the duct exit should be at the middle of the width of the top of the fume cupboard. This is to reduce variation of the face velocity across the working aperture. The position of the exit in relation to the front and back of the fume cupboard must be considered simultaneously with the design of the baffle. The aim is to reduce variation of the face velocity across the working aperture.

Prior to use of the fume cupboard an air flow indicator shall be incorporated to show unambiguously the correct functioning of the fume cupboard's air flow. In addition, means should be provided to easily check or self-check the correct functioning of the air flow indicator.

The airflow indicator shall be provided to monitor the amount of the extract air and, if necessary, direct make-up air and auxiliary air input necessary for correct functioning of the fume cupboard's air flow, as established in the type test results.

It shall incorporate audible and visual alarms to warn the operator of incorrect operation of the fume cupboard. The audible alarm may be silenced once alarmed.

BS EN 14175-2:2003, SECTION 8.2

Modern fume cupboards usually incorporate an **airflow indicator** with audible and visual alarms to warn the operator of incorrect operation of the fume cupboard although the former may be

¹ Unpublished research by CLEAPSS.

silenced once alarmed. Simple mechanical indicators without alarms can be fitted to existing fume cupboards.

2.2 Ducted fume cupboards

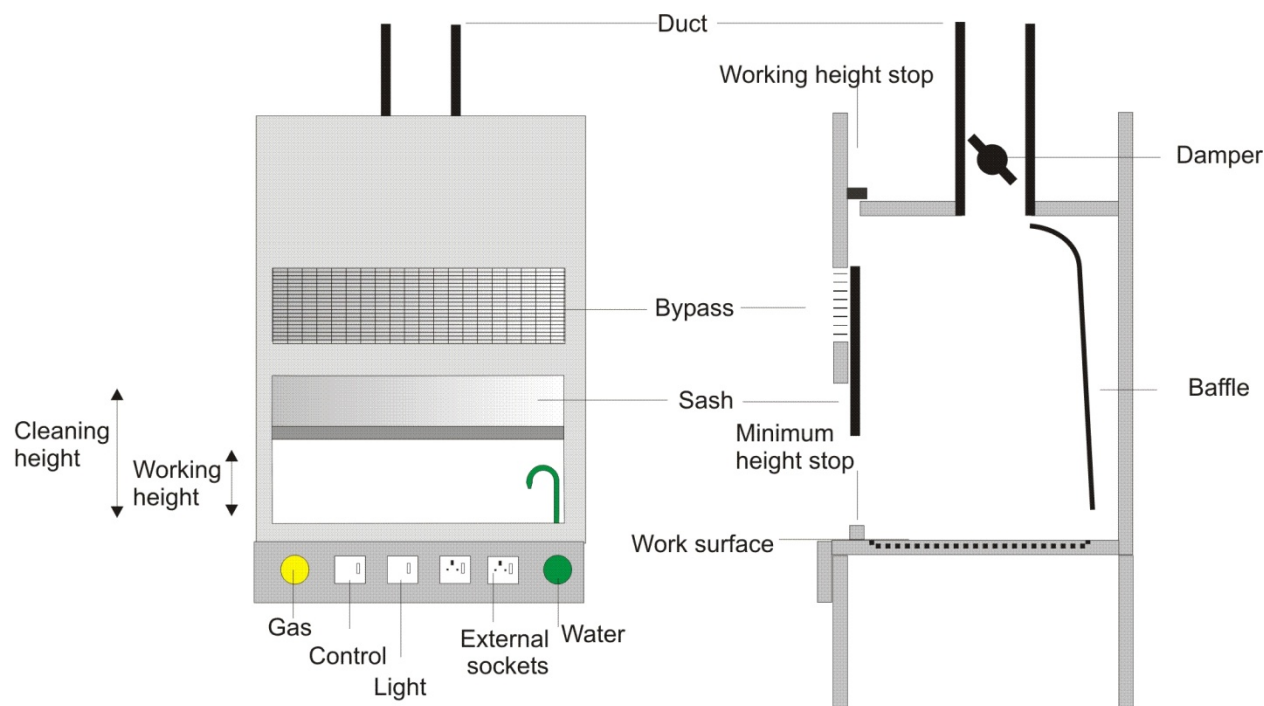


Figure 2.1: Schematic diagram of a ducted fume cupboard with by-pass

2.2.1 Discharging fumes to the atmosphere

To achieve safe dispersion into the atmosphere, the diluted airborne contaminant gas is ducted to a high point where it is released through a properly designed and sited **discharge stack**.

Figure 2.2 shows two designs of discharge stack.

The design and siting of stacks from fume cupboards is critical. This is because exposure to contaminated air can occur if the fumes from the discharge stack are re-entrained into the building eg, via windows or ventilation inlets, or flow to outdoor areas where people congregate.

Figure 2.2 shows a **centrifugal fan** mounted on the outside of the building (or in the roof space). This ensures that the LEV ducting inside the building is under negative pressure (compared to atmospheric pressure) and that any leakages are into the duct and not into the rooms through which the ducting passes. Older fume cupboards used to have axial fans mounted just above the fume cupboard. These noisy fans put the whole of the ductwork under positive pressure and thus leakage of fumes to surrounding spaces is more likely.

It is important that the stack height is sufficiently high above the building to prevent re-entrainment. Because schools are usually situated in residential areas there is sometimes opposition to (high) stacks. Designers and architects need to realise that school fume cupboards are not in operation 24 hours per day, as might be the case in research laboratories. Hence they cause much less nuisance to neighbours. Nor are they constantly pumping out chemicals to the atmosphere to affect those working (pupils and staff) and living nearby as use of fume cupboards in schools is very intermittent.

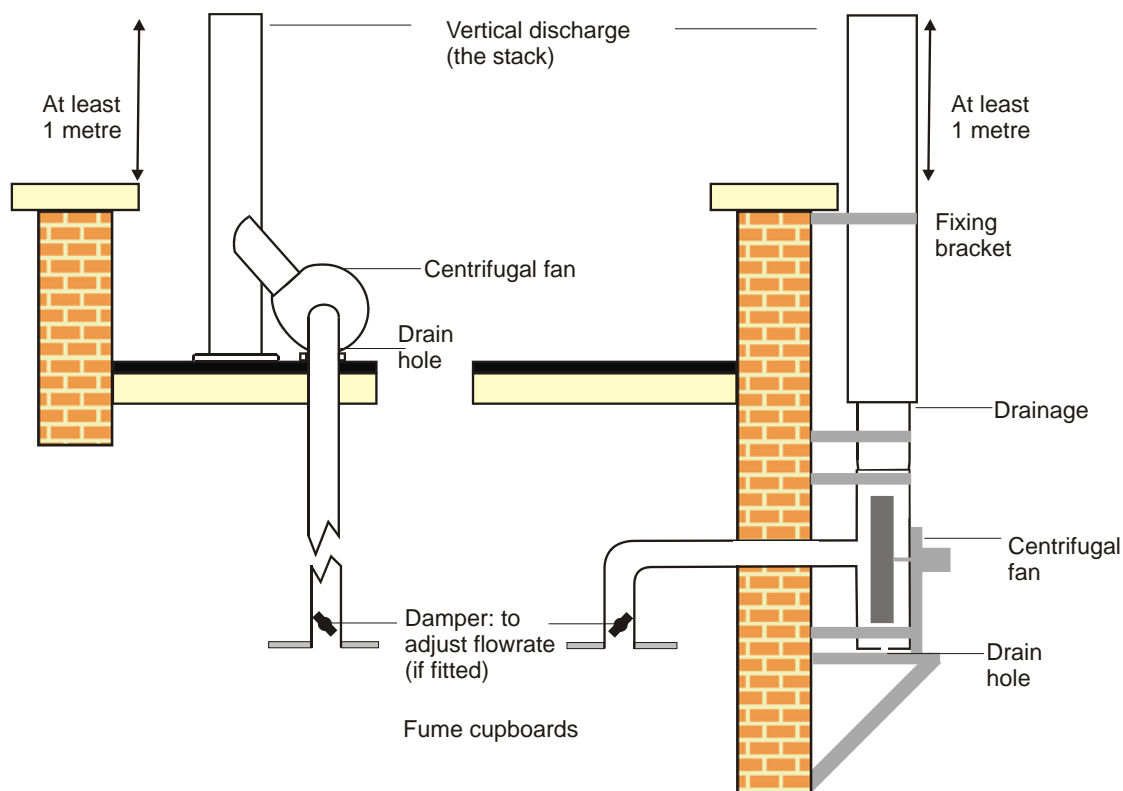


Figure 2.2: Discharge stacks

2.3 Recirculatory filtration fume cupboards

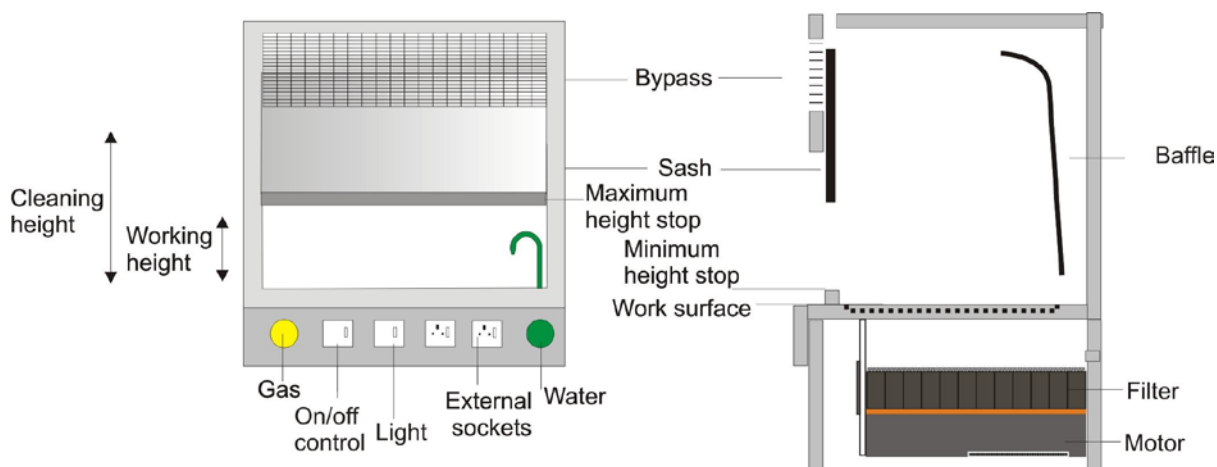


Figure 2.3: A recirculatory filtration fume cupboard

2.3.1 How filters work (and can fail)

Fume cupboards can be found with the filters above the workspace but almost all of those used in schools in the past have the filters below the working surface (as shown in *Figure 2.3*). This minimises manual handling issues when changing the filters, which can weigh over 20 kg. It also reduces the height and lowers the centre of gravity. However, because of the direction the air flows in, tests show that generally better containment is achieved with a high level fan and filter. There may also be some risk to a low level filter if there is spillage of a liquid onto the worktop. The fan, driven by a motor, draws contaminated air from the fume cupboard through the filters, passing first through a pre-filter (*Figure 2.4*). The pre-filter is usually made of compressed paper

and removes large dust particles. It has been known for sparks from chemical reactions such as the 'howling jelly baby', to ignite the pre-filter (and then the carbon filter) which is why these procedures should **not** be performed in filtration fume cupboards.

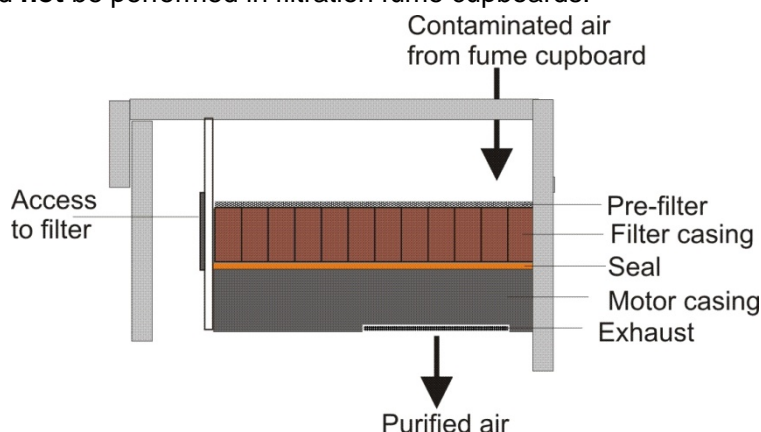


Figure 2.4: Details of filters in fume cupboard

The main filter is made of activated carbon which adsorbs vapours and gases. 1 g of activated carbon has a surface area of over 500 m². The picture in *Figure 2.5* was taken with an electron microscope and shows the “honey comb” structure upon which the organic chemicals adsorb (using van der Waals forces or London dispersion forces). However, corrosive gases, such as hydrogen chloride, sulfur dioxide and ammonia, are **not** adsorbed. The filter is treated with chemicals such as sodium hydroxide and phosphoric acid to neutralise and absorb these gases. Once the neutralisation has taken place then that site is lost forever and the filter becomes less efficient. Note, also, that low-density, neutral gases, such as methane (EXTREMELY FLAMMABLE) and carbon monoxide (TOXIC) are not adsorbed at all and neither is elemental mercury vapour (unless the filter is specially treated) and thus recirculatory filtration fume cupboards are **unsuitable and unsafe** for use with these substances.

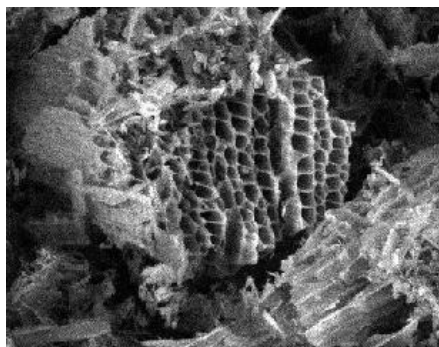


Figure 2.5: Nanopores on an activated carbon sample, seen at the electron microscope (Air-n-water Inc.)

The integrity of the seal around the filter is critical. Any gap, no matter how small, will allow hazardous gases to bypass the filter and exit into the laboratory so great care has to be taken when replacing a filter to not to break the seal or damage the filter. In some models, it is necessary to slide the filter into place, which can lead to the seal rucking and hence leaking. In other models, the filter is dropped into place, sometimes in a drawer which can be pulled out. If there is no sideways sliding movement, rucking is much less likely to be a problem and CLEAPSS considers such designs to be inherently safer. The heavy filters may require two people or equipment to assist removal or installation.

Some filter seals are not made to a sufficiently high standard. Where the seals along two edges join at a corner, there is sometimes a gap of 1 or 2 mm (in the worst cases, CLEAPSS has seen even more). Such faults will cause unacceptable leaks.

2.4 Containment

2.4.1 Measuring containment

Containment is a measure of the efficiency of a fume cupboard. A crude measure of the containment of a fume cupboard is given by:

$$R/C$$

where **R** is the rate of release of the hazardous gas inside the fume cupboard, and **C** is its concentration just outside the fume cupboard. (Obviously, with recirculatory filtration fume cupboards, any hazardous gas that leaks out of the working aperture of the fume cupboard will be augmented by any of the gas passing through the filter).

C can be compared with the Workplace Exposure Limits established by legislation (see section 7.2) and decisions made as to which operations can be safely performed in the fume cupboard. The bigger the ratio, the more successful the fume cupboard is in protecting people outside. The recommendations in this guidance are based on containment tests conducted on school fume cupboards, using values of **R** measured and estimated for a wide range of school activities². Although the original research was carried out some time ago, in preparing this document CLEAPSS reviewed its methodology in the light of current practice in schools, changing health & safety legislation and the accumulated experience of issues arising from the use of fume cupboards in schools and concluded that its approach was still valid.

Because carrying out containment tests requires relatively sophisticated equipment and is time-consuming, alternative tests are recommended in this guide for commissioning and subsequent monitoring. They are tests of **minimum face velocity** and **variation in face velocity**. For recirculatory filter fume cupboards, it is also necessary to **examine closely the integrity of the seal** around the filter; if there are doubts, it may be necessary to carry out a **filter challenge test**.

Tests in which smoke is released around the perimeter of the sash opening or in a fume cupboard and its route through the cupboard observed (**smoke tests**), if carefully used, can give a qualitative indication of any significant containment failures but they should not form part of any contract with a fume cupboard testing company, if used, as their interpretation is too subjective.

2.4.2 Variation of face velocities

The variation in face velocities is the spread in values of the face velocity measured across the working aperture; the greater the variation, the greater the likelihood of significant escapes caused by eddies. A simple measure of the variation is the percentage differences of the maximum and minimum values from the average value. This should not vary excessively. At one time HSE stated that this should not be greater than 20%, and in CLEAPSS experience this is easily achievable, but HSE now simply state the variation should not be excessive. The distribution of deviation is also important: if, for example, all the low velocities were at one side of

² *School fume cupboards*, J R Crellin, *Education in Chemistry*, **12** (6), November 1984 p 185-8.

the opening this would increase the risk of leakage as compared with a random distribution. Eddies can carry some of the gases out of the fume cupboard. The effect is found most commonly to occur close to edges, eg, to the sides of the working aperture. Even if a fume cupboard has aerodynamically-shaped surfaces, some escapes must be expected. However, research by CLEAPSS has shown that, with the low releases of gases during school use, the exposure levels resulting from fume cupboards meeting the recommendations on air flow in this document are well below Workplace Exposure Limits.

2.4.3 Other reasons why fumes may escape into a room

Other than poor ducting or filters not working efficiently, escapes of toxic gases into a room can occur as a result of rapid arm movements, someone rapidly moving in front of the fume cupboard, rapid sash movements or a very rapid release of gas.

The siting of fume cupboards is important. They should be positioned away from draughts, whether draughts generated by opening windows or doors or caused by inlet air supplied to the laboratory, eg in air conditioning systems. In one school a recirculatory filtration fume cupboard was sandwiched between a fridge freezer and a wooden cupboard. The exhaust air had nowhere to go except towards the front - and thus towards the user. This powerful draught caused unsatisfactory containment of the toxic gases. In smaller rooms such as prep rooms, mechanical ventilation of the room to the outside by a powerful fan in the wall can pull air down the stack of a ducted fume cupboard, even though the fume cupboard is on and supposedly extracting.

2.4.4 Fume cupboards shared between 2 rooms

Fume cupboards with two openings fitted between two rooms, should **not** be installed. Such double-sashed fume cupboards were common in the past, but they reduce security and fire resistance and, above all, do not provide adequate containment. It is impossible to comply with the minimum height stop requirement and still prevent cross-draughts. The face velocity under one sash will be affected by the position of the other. It is much safer to have two separate fume cupboards, with separate extraction systems.

These fume cupboards fitted between two rooms should not be confused with another type, also sometimes called a double sash, which have a hinged sash. These hinged sash cupboards can be useful where there is a restricted floor to ceiling height, although sliding sashes are always preferred. They are more common in filtration fume cupboards designs because these are often moved from room to room through a door! There are also combination sash cupboards but these are not normally found in schools.

2.5 How to use a fume cupboard

Teachers, technicians and pupils will need training in how to use any particular fume cupboard but the following are general principles that will almost always apply.

- Carry out a quick visual check of the fume cupboard. Look for
 - Signs of damage to any ducting, especially if flexible;
 - Signs of any damage to the services;
 - Ease of movement of the sash;
 - Signs of damage to the cupboard itself.

- If there is a sink in the fume cupboard, check that there is water in the U-bend or trap so that fumes cannot leak out.
- Switch on the extraction system.
 - Does the sensor, if fitted, indicate a satisfactory air flow?
 - If a sensor is not fitted, unless the fume cupboard has been used recently, use a simple hand-held device to check for satisfactory air flow (see section 8.1 and footnote 21).
 - Does the extraction system make any unusual noises?
- Place any apparatus in the fume cupboard, raising the sash as necessary, perhaps even raising it above the maximum working height stop.
- Lower the sash as far down as possible, but in any case below the maximum working height stop, to improve containment.
- Keep the sash as far down as possible throughout the procedure, raising it briefly as necessary to manipulate apparatus or chemicals, but never higher than the maximum working height stop.
- When the procedure is complete keep the extraction system running until you are sure that there are no hazardous contaminants being generated and those generated have been removed.
- Clear away and, where necessary, safely dispose of any chemicals.
- Clear away the equipment.
- Check whether the glazing, especially inside, has become obscured by deposits and needs to be wiped clean.
- Leave the fume cupboard ready for immediate use by somebody else.

2.6 Maintenance

The inside glazing of fume cupboards needs to be cleaned regularly to remove powdery deposits which can result from many processes commonly carried out in schools.

Water should be kept in sink traps in order to prevent leakage of fumes.

All fume cupboards need to be given simple **regular checks** to see that they are functioning correctly. In addition, all LEV must be given a **thorough examination and test**, at least every 14 months. See section 8 for details.

3 Provision, choice and siting of fume cupboards

3.1 The number and type of fume cupboards

3.1.1 Provision for dedicated post-16 chemistry laboratories

Each dedicated chemistry laboratory in a school or college that is used for teaching post-16 chemistry (GCE A-level or equivalent) should have at least two fume cupboards, one of which should be suitable for demonstration use. A third will be useful for larger classes of fifteen or more. Commonly, in higher education and research, reactions such as organic preparations, are routinely considered to require a fume cupboard and this will increasingly be an expectation in schools and colleges for much post-16 work. This could mean that each pair of students would need to use a fume cupboard for such work.

3.1.2 Demonstration fume cupboards

For all age ranges within a secondary school, there is often a need for the teacher to demonstrate reactions which it would be inappropriate for the students to carry out themselves. A demonstration fume cupboard needs to be glazed all round and positioned so that the demonstrator can stand at the aperture, with 30 observers around the other three sides. This is usually achieved by having a fume cupboard with some degree of mobility, ie, the ability to pull it out from the wall, although this of course raises questions about how the services are to be provided. It is difficult for 30 pupils to see a demonstration in a fixed fume cupboard with a width of 1000 mm (the common size).

3.1.3 Provision for science laboratories

Schools and colleges may have laboratories which are designed for the teaching of all sciences. Ideally, there should be a fume cupboard in every such laboratory but financial constraints will limit this. Demonstration fume cupboards are commonly required but pupils below the age of 16 will rarely need personal access to a fume cupboard except to dispense a hazardous or unpleasant chemical.

- If the room is used for A-Level chemistry or equivalent then this determines the number of fume cupboards (see section 3.1.1).
- A demonstration fume cupboard (see 3.1.2) should be installed in at least one third of the laboratories; classes then move to such a laboratory when a risk assessment requires the use of a fume cupboard.
- Mobile fume cupboards (see section 3.2.2) can be moved to a laboratory when a risk assessment requires its use and connected via a docking system to the services but in practice many schools find the demands on technician time are too great for this to be practicable most of the time. Hence if mobile (usually recirculatory filter fume cupboards) are used they need to be installed in about one third of laboratories; contrary to expectations, in the experience of CLEAPSS, one will usually **not** suffice for the whole department.
- Schools teaching only up to about age 13 would have less use of a fume cupboard and only one, demonstration-type cupboard, may be necessary in the suite of teaching laboratories.

3.1.4 Provision for technician services

Technicians servicing classes using chemicals need access to an efficient single-sashed fume cupboard for the dispensing of toxic, volatile substances or highly flammable liquids, for preparations involving these and for temporarily storing apparatus awaiting dismantling. It is important that this fume cupboard should be in the preparation room. If in a teaching laboratory, it will be inaccessible to technicians for much of the time and they may be tempted to carry out hazardous procedures without its protection. Fume cupboards in prep rooms can be located next to benches as they are not normally used for demonstration and so do not require visibility from three sides.

Whilst, in principle, recirculatory filtration fume cupboards could be used in preparation rooms, in practice they present various problems. There is no need for the mobility that such fume cupboards can provide. Generally, fume cupboards are used in prep rooms far more frequently than those in teaching laboratories, hence the filters will need replacing more often. If a prep room fume cupboard is out of action whilst waiting for a new filter, this will seriously limit the preparation work which can be carried out and hence the curriculum. Prep rooms are generally much smaller in volume than teaching laboratories, hence the fumes which do inevitably pass through the filter are much more noticeable, reaching higher concentrations more quickly. As prep rooms tend to be occupied continuously by the same person, that person will be at greater risk of exposure to hazardous fumes, especially if a problem develops. Filter fume cupboards tend to be fitted with drip cups rather than sinks but these are unsuitable for prep room use as technicians often need to pour away more than test tube volumes of solutions.

3.2 Siting of the fume cupboard in a school laboratory

3.2.1 Design considerations

The siting of a fume cupboard should be considered at an early stage in the design of a laboratory. The location should be approved by the engineer designing the whole fume cupboard system (and indeed the whole school ventilation system). Because of the space limitations of school laboratories, it is seldom possible to meet all the requirements suggested below. Compromise is often necessary. All the laboratory designs in *BB80 Science Accommodation in Secondary Schools*³ include fume cupboards.

Occasionally it is suggested that what is, in effect, the top part of a fume cupboard should be mounted on an existing laboratory bench at the side of the room. This is rarely satisfactory, for example because the bench may be higher than the normal work surface height of a fume cupboard, with the result that users get little protection even when the sash is lowered, and it may be difficult to fit relevant services onto an existing bench.

³ *Building Bulletin 80, Science Accommodation in Secondary Schools, a Design Guide*, Schools Building and Design Unit, DfES, 2004; http://www.teachernet.gov.uk/_doc/6152/BB%2080_19.pdf. Now archived but still available.

3.2.2 Mobile fume cupboards

It is important for architects and engineers to appreciate that a fume cupboard is required for demonstrations so that pupils gather round to observe experiments. Ideally, demonstration fume cupboards should be capable of being moved away from the wall to facilitate this.

Sometimes, when people refer to a mobile fume cupboard they mean a re-circulatory filtration fume cupboard. However, ducted fume cupboards can also be mobile if they are connected via a docking system to the services, including a ducting system.

A mobile fume cupboard (ducted or filtration) will usually be mounted on wheels and moved away from the wall. It should not be an obstruction to normal laboratory work. Mobility allows visibility from all sides so that pupils can see what is occurring in the fume cupboard (see *Figure 3.1*). The teacher can both watch the experiment and the pupils.

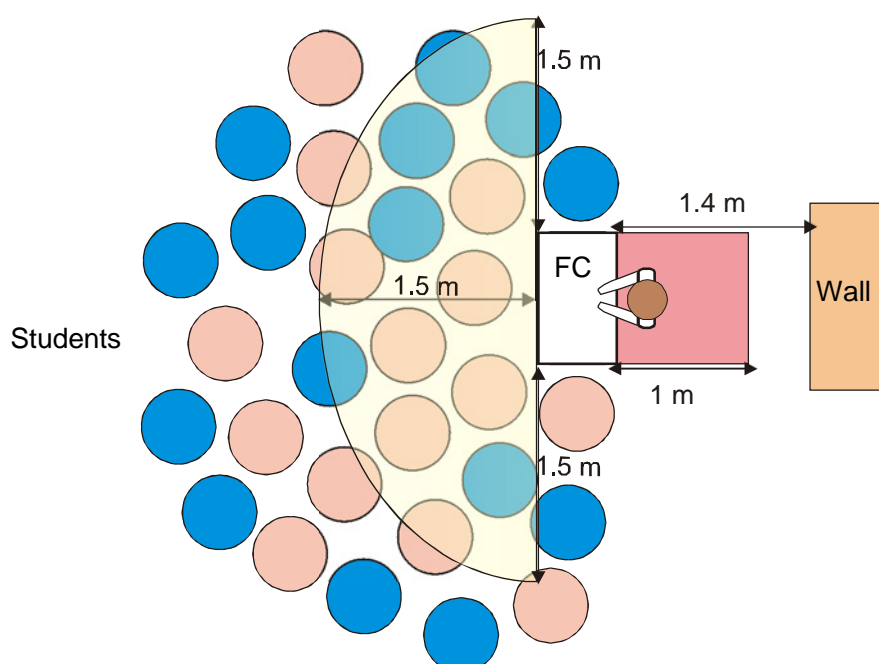


Figure 3.1: Pupils around a demonstration fume cupboard

However, the extent that the fume cupboard can be moved will vary from just being pulled out from a wall to being moved from room to room. Factors which decide the degree of mobility of a fume cupboard are:

- whether it has a filter or a flexible duct;
- the availability of sites for the fume cupboard where there are no significant cross-draughts or no adjacent doors or windows and some architectural features all of which can cause a fume cupboard to leak due to a non-uniform velocity profile at the plane of the sash opening;
- the provision, in different locations, of fixed ducts leading to extraction systems to which the flexible ducting can be connected and the ease of connection and disconnection;
- the provision of gas supply, as the distance is limited to 1.4 m from the bayonet link;
- the provision for the disposal of waste water;
- whether doors are sufficiently high and/or wide to allow unimpeded movement of the fume cupboard into other rooms;

- whether there are steps or other barriers to the free movement of the cupboard between rooms;
- the amount of technician support for moving stools out of the way, holding doors open, etc.

3.2.3 Wall-mounted or free-standing?

A fume cupboard mounted against the wall is easy to install as mains services will normally be around the perimeter of the laboratory. It is also not an obstruction to normal laboratory work. However, there is limited visibility so that even if glazed on the sides, it is difficult for 30 pupils to see what is happening. Also teachers have to think very carefully about control of the class as they may be working with their backs to the class during certain manipulations.

A free standing fume cupboard sited in the middle of a laboratory allows visibility from all sides and pupils can more easily see what is occurring in the fume cupboard. Furthermore, the teacher is not working with his/her back to the pupils. However it may be an obstruction to movement and line of sight to a whiteboard. It may also be expensive/difficult to install the extra ductwork and services.

3.2.4 Flexible service connections to mobile fume cupboards

If a fume cupboard is intended to be mobile, thought must be given as to how the services are to be provided. The preferred option is to have special outlets fitted for attaching flexible armoured hoses at the same locations as the capped drainage points (*Figure 3.2*). These supply hoses, the drainage hose and any flexible fume extraction duct (*Figure 3.3*) need protection from strain by a cable limiting movement of the fume cupboard. With an arrangement in which the gas is controlled by a tap on the fume cupboard, it is important that the gas supply is shut off before the gas hose is disconnected. There are bayonet connections which cut off the supply as disconnection is made.



Figure 3.2: Docking station for services



Figure 3.3: Docking station for extraction system

A less satisfactory alternative is to have no gas and water outlets on the fume cupboard; without a water outlet, no drip cup and drain are needed. If the use of a Bunsen burner is required, the mobile fume cupboard can be stationed **close** to a gas outlet on a bollard, bench, etc, and the burner connected to it and controlled from it in the normal way; care must obviously be taken that the hose does not form a hazard. If water is needed, perhaps for a condenser, it can be fed from a water outlet on a bollard, etc, and returned to a laboratory sink. Alternatively, a condenser can be fed with cold water from a washing up bowl, using a small submerged pump. Water from the top of the condenser is then cycled back to the bowl.

The provision of electricity presents fewer problems although flexible cables, plugs and sockets must be maintained to a high standard. As a portable appliance, a mobile fume cupboard will need to be subject to regular PAT-testing, although that is not considered further in this document.

Special docking stations as in *Figure 3.2*, particularly drainage points, are expensive to install and in the rushed environment of most science departments, technicians often do not have the time to make the connections required, particularly if there is a drainage hose which needs to be thoroughly flushed out before disconnection and a flexible ventilation duct to be connected. In practice, therefore, fume cupboards which are designed to be moved from one position to another tend to stay in one position but they can still be moved 1.4 m away from the wall, allowing the teacher to stand at the aperture and pupils to be on the other three sides, as in *Figure 3.1*.

The siting of docking stations needs particular care because they determine where the fume cupboard can be used, hence the issues about distances in the next section are relevant. Often they are sited next to a teacher demonstration bench, but given the size of the cupboard this may not always be the best position.

3.2.5 Recommended distances

Except where national regulations indicate otherwise, the following spaces should be allowed between fume cupboards and building elements or other equipment.

All dimensions given are for guidance. Alternatives may be appropriate, although their effectiveness should be objectively verified, preferably by the test methods described in EN 14175-4 ...

BS EN 14175-5:2006 SECTION 4

The following minimum distances, largely taken from BS EN 14175-5: 2006, *Fume cupboards – Part 5: Recommendations for installation and maintenance*, should apply to all school or college fume cupboards.

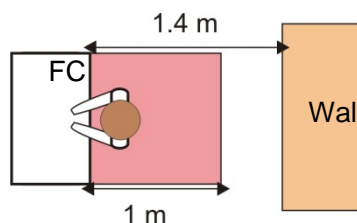


Figure 3.4 Minimum distances

- The minimum distance from the sash to any part of the laboratory frequently used by other personnel in moving from one part of the laboratory to another should be at least 1 m (see *Figure 3.4*).
- A fume cupboard should be sited away from circulation routes. Passers-by create eddies, which may cause a release from the fume cupboard. During the brief period a demonstration is likely to take, this may not be a significant risk but passers-by can also distract or even knock into its user.
- It is important to bear in mind the need for a clear area in front of a fume cupboard when sitting one in a preparation room.
- There should be no opposing wall or other opposing obstruction likely to affect air flow within 1.4 m of the sash (see *Figure 3.4*).
- The distance between the sash and the bench opposite should be at least 1.4 m (see *Figure 3.4*). If more than one operator uses the same bench opposite, this distance may need to be greater.
- For demonstration purposes an unobstructed working zone of radius 2 m from the centre of the fume cupboard is recommended (see *Figure 3.1*). This zone would accommodate 15 to 20 pupils with some sitting and others standing. In practice 2 m is difficult to achieve even with moveable furniture and the minimum radius of 1.5 m is more realistic.
- Even if a fume cupboard is not required for demonstration to the whole class, a minimum working zone of radius of 1.5 m is recommended to allow for pupils watching or waiting to use it.
- No doorway frequently used by personnel should be within 1 m of the sash or within 0.3 m (ideally 1 m) of the side of the fume cupboard, see *Figure 3.5*. (This does not apply to doorways exclusively used as emergency exit.) The provision of the minimum working zone of 1.5 m will generally ensure that the minimum distances from walls and doors quoted above are satisfied.

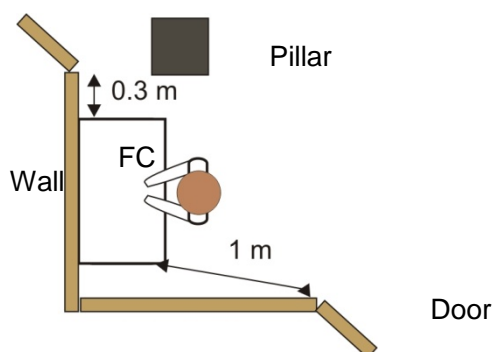


Figure 3.5 Location of doors, pillars, etc

- Fume cupboards should preferably be located away from exit doors, particularly if there is only one exit from a room. If an accident occurs in a fume cupboard or if its extraction

system fails, it may be necessary to evacuate the room which may be made harder if it is sited near to an exit.

- Large isolated obstructions, eg columns, pillars, tall cupboards, etc, at the side of the fume cupboard and projecting beyond the plane of the sash can influence the containment of the fume cupboard.
- A ceiling height of 3 m is recommended and a height of 2.7 m should be the minimum (any less than this and the fume cupboard may not be able to perform in accordance with the British European Standard against which it was tested).
- The impact of air inlets on the performance of the fume cupboard should be carefully considered. Room air flow should not exceed 0.2 m s^{-1} at a zone 400 mm from the sash. See BS EN 14175-4:2004, section 5.8 for details.
- Increasing the distance from doors and windows minimises the effects of disturbing draughts caused by doors movement and fluctuations in the wind. If a fume cupboard has to be near a door, draughts caused by its opening and shutting can be reduced by fitting an air transfer grille and a suitable door closer.

3.2.6 Fume extraction systems for ducted fume cupboards

It is important to stress that the protection of fume cupboard users depends as much on the design of the extraction system and its installation as on the fume cupboard itself. It should be possible to operate a fume cupboard independently of the general laboratory ventilation system. The design of all extraction systems for fume cupboards should be by, or receive the approval of, a suitably qualified ventilation engineer and this is discussed in more detail in section 5.1.

3.3 Ducted or recirculatory filtration fume cupboards?

The advantages and disadvantages of ducted and recirculatory filtration fume cupboards, mobile or fixed, with or without services, are summarised in *Table 3.1*.

Table 3.1

	<i>Ducted fume cupboard</i>	<i>Recirculatory filtration fume cupboard</i>
Health & safety	Inherently safe, because hazardous gases are pumped to the outside.	There is always an uncertainty about the current condition of the filter (and seal). Schools are sometimes tempted to save money by not replacing a filter or staff changes may result in nobody realising it is necessary to do so.
Building work	Requires ductwork, a fan and a stack discharging well above the roof line and so is difficult and expensive to install, particularly in an existing building. Provision for make-up air is also required.	No building work required but purchasers should check if the fume cupboard is assembled for them on delivery. Great care is necessary to ensure the filter is properly seated – an initial test may be needed. Make sure the cupboard can fit through a doorway and that there are no steps if it is to be mobile!
Services	The installation of services (ie, electricity, gas, water and drainage) for both fixed ducted and filtration fume cupboards is similar. With mobile fume cupboards docking points are required.	

	<i>Ducted fume cupboard</i>	<i>Recirculatory filtration fume cupboard</i>
Mobility	Mobile ducted fume cupboards are available but are an expensive option whereas mobile filter cupboards are common. Semi-mobile ducted cupboards are cheaper and allow better visibility than fixed. CLEAPSS has had a number of reports about flexible connectors (for drainage or fume extraction) splitting or seals failing. Mobility of both ducted and filter fume cupboards is limited by the provision of services, suitable door height, the absence of steps and the availability of technician time to move them around and connect up services.	
Glazing	Glazing material is toughened or laminated glass.	Glazing materials are sometimes polycarbonate or acrylic, or toughened or laminated glass. Plastic glazing gets marked by hot particles. Polycarbonate glazing is usually not found in a sash arrangement but a permanently open trapezium-shaped aperture.
Visibility	This depends on whether there is all-round glazing and where the fume cupboard is sited, not on whether the fume cupboard is ducted or recirculatory.	
Construction	The main construction is mild steel or anodised aluminium. If mobile, continual movement can shorten the life of the fume cupboard.	
Noise levels	Modern ducted cupboards tend to be quieter because the fan is remote from the laboratory (on or near the roof), but if the fan is over-powered and a damper just above the cupboard is used to reduce air speed, this can raise noise levels.	As the fan is in the cupboard, and has to overcome the resistance of the filter, these tend to be noisier. Quieter motors are available but at significant extra cost.
Commissioning (‘Initial appraisal’ or ‘Intended operating performance’)	Commissioning the fume cupboard is essential. It will involve a visual check and a quantitative test that the performance is at least as good as the minimum laid down in this specification. Handing over of relevant documentation and training of school staff is usually best done at the same time.	Commissioning the fume cupboard is essential. It will involve a visual check and a quantitative test that the performance is at least as good as the minimum laid down in this specification. In the experience of CLEAPSS, filters sometimes become dislodged from seating during transport or the seal becomes damaged when being inserted. Some filter seals are not made to a sufficiently high standard. It may be necessary to carry out a challenge test at this stage. Handing over of relevant documentation and training of school staff is usually best done at the same time.
Control of substances hazardous to health	Will protect adequately against normal releases of all hazardous gases generated or used in school science, but not, for example, against the use of <i>cylinders</i> of chlorine gas.	Providing the filter is not saturated and is properly seated, will protect adequately against normal releases of all hazardous gases used in school science except hydrogen, methane and carbon monoxide and (unless specially treated) mercury vapour. If the filter fails the fume cupboard <i>fails to danger</i> as contaminants will be released back into the classroom or prep room.
Heat losses	It is sometimes claimed that recirculatory filtration fume cupboards offer significant savings because they do not extract warmed air from the building. However, most school fume cupboards are run for only a small proportion of the time so that the loss is not significant, perhaps £30/year.	

	<i>Ducted fume cupboard</i>	<i>Recirculatory filtration fume cupboard</i>
Maintenance and repairs	<p>Little maintenance is needed. Some repairs can be done by local companies.</p> <p>Some specialist companies do not charge for an initial visit.</p>	<p>Pre-filters and filters need to be replaced periodically and schools find them expensive and often have to paid for from science department budgets. In future, used filters may have to be disposed of as hazardous waste. The manufacturer is usually needed for any repair and call-out charges may be high.</p>
Life expectancy (depends on use)	<p>Some ducted fume cupboard installed many years ago are still working effectively.</p>	<p>The first generation of recirculatory filtration fume cupboards lasted about 15 to 20 years. Constant moving from room to room, misuse, and clouding plastic windows were partly to blame for the deterioration. Filtration fume cupboards made more recently are more robust.</p>
14-monthly 'Thorough Examination and Test '	<p>Ducts should be inspected for leaks and discharge points for blockage.</p> <p>The examination and test is relatively straightforward and will include face velocity measurements.</p> <p>There is no reason why the test cannot be carried out in-house by school technicians.</p> <p>The cost of work by an outside contractor will depend on the total number of fume cupboards in the school, although travelling time is the main factor.</p>	<p>The examination and test is similar to that for ducted fume cupboards but in addition the saturation of filters may need to be checked, unless a decision is taken to replace the filter at a shorter interval than its likely working life. Obviously, replacing filters which still have some life in them may be expensive.</p> <p>Saturation testing of the filter can be done by suitably trained school technicians.</p> <p>If outside contractors do test the filter saturation, the cost of a full service is usually more than for ducted cupboards although this depends on the policy of the contractor. It will depend on the number of filtration fume cupboards in the school, although travelling time is the main factor.</p> <p>Electronic filter-saturation alarms are not yet available for the range of chemicals used in schools.</p>
Number of cupboards required	<p>See section 3.1 but typically prep room + $\frac{1}{3}$ of laboratories.</p>	<p>As filtration fume cupboards can be moved around, in principl, one would suffice for a department. However ducted cupboards are more suitable for prep room use. Experience also shows that because schools don't have sufficient technician time, they rarely move them between laboratories and hence filtration cupboards are also best provided in about $\frac{1}{3}$ of laboratories.</p>

	<i>Ducted fume cupboard</i>	<i>Recirculatory filtration fume cupboard</i>
Costs: initial	Costs per cupboard will include: <ul style="list-style-type: none"> • The fume cupboard • Ducting & associated building works • Fan • Provision for make-up air • Installation • Services (including a docking system if it is mobile) • Commissioning test 	Costs per cupboard will include: <ul style="list-style-type: none"> • The fume cupboard with suitable carbon filter & pre-filter • Docking system / services • Commissioning test
Costs: on-going (depends on use)	<ul style="list-style-type: none"> • Annual thorough examination and test. 	<ul style="list-style-type: none"> • Annual thorough examination and test. • Replacement pre-filters (at least 1 every 4 years and it may be much more depending on use, could be one every 6 months) • Replacement filters (if a decision is taken to replace the filter at a shorter interval than its likely working life, at least one every 2 years for cupboards in the prep room and at least one every 3 or 4 years for those used in teaching rooms). • Possibly in future disposal of used filters as hazardous waste (not generally considered necessary at present.)
	<p>The costs of ducted fume cupboards are largely front-loaded, with low on-going costs but the reverse is true for recirculatory filtration fume cupboards. However, whilst the capital cost of a ducted fume cupboard is high, the total cost of a filtration fume cupboard over a period of time may be comparable.</p> <p>The situation is complicated by the fact that the initial cost and the on-going costs may well come from different budgets.</p> <p>Costs obviously depend on the number of cupboards required but it is a mistake to assume that because filtration fume cupboards are mobile they will actually be moved around frequently in schools. Technician time is rarely built into the calculation. Health & safety and/or the curriculum both benefit from having a similar number, irrespective of type.</p>	

4 Specification of school fume cupboards

4.1 Relationship with the British Standard

This section of the guide specifies the construction and performance expected of school and college fume cupboards. Extracts from BS EN 14175:2 *Fume cupboards – Part 2: Safety and performance requirements* are quoted in a number of information boxes. However, the Standard is relatively permissive, in that in some cases the specification is to be agreed between the customer and the supplier, within limits. This is particularly emphasised in the National Foreword to the Standard, which is why it is important to ensure that you – and your supplier – use the British Standard **BS** EN 14175, rather than the European Standard EN 14175. This specification for school and college fume cupboards makes firm recommendations, within those permissible limits, about what is most suitable for schools and colleges. It focuses on those aspects known to be important for safe use of school and college fume cupboards.

4.2 Dimensions

The overall width of fume cupboards shall be a multiple of 100 mm with preferable dimensions of 1200 mm and 1500 mm.

The overall depth of fume cupboards shall be between 600 mm and 1200 mm.

The height of the working surface shall not exceed 900 mm.

Other dimensions may be agreed between customer and manufacturer.

Tolerances shall be specified by the manufacturer.

BS EN 14175-2:2003, SECTION 4

- It is assumed that the fume cupboard will be rectangular.
- A width of 1000 mm is recommended because there is rarely room for anything larger in most schools, although 1200 mm (or even 1500 mm) is preferable in prep rooms. A 1000 mm width fume cupboard will have an internal width of only 900 mm (or possibly as little as 600 mm with some double skinned designs, although these are not generally used in schools). Even 900 mm allows only one procedure to be carried out in the fume cupboard at a time. A narrower cupboard gives an insufficient area of work surface clear of service fittings.
- An internal depth of 500 mm is recommended. If a fume cupboard is much deeper, users will find it difficult to reach the back through the normal working aperture (ie, they will have to put their head inside the fume cupboard!) and may be tempted to use it for storage, which is **not** recommended. A shallower cupboard gives insufficient area of work surface clear of service fittings.
- The minimum internal height for a fume cupboard is 750mm, preferably 900 mm. 750 mm is required for the tallest apparatus likely to be used.
- The **maximum working height** should be 400 mm, or perhaps a little more, with a sash stop at the maximum working height which can be over-ridden for cleaning purposes.
- It should not be possible to close the aperture completely because this could prevent the flow of air and thus be unsafe.

- As pupils younger than 16 will not normally be using the fume cupboard, lower work surfaces than 850 - 900 mm are not required. It would be uncomfortable for adults to work at lower heights.

4.3 Stability of mobile fume cupboards

It should be possible to prevent a mobile fume cupboard moving during use. One method of achieving this is to fit two wheels with locking devices which are easy to apply and release.

4.4 Filter fitting for recirculatory filtration fume cupboards

The design of the recirculatory filtration fume cupboard shall facilitate:

- a) Access to the filter housing and any filter test ports;*
- b) Filter replacement without jeopardising the integrity of the seals;*
- c) Filter handling*

BS 7989:2001, SECTION 4.4.8

Filters are inevitably heavy – 20 kg is typical. It is therefore vital that the cupboard is designed in such a way as to minimise the problems when handling the filters. Cupboards can be found with the filters either above or below the work space. Changing a filter for the former is likely to involve lifting heavy objects, possibly above head height. Some modern designs of high level filter can overcome this problem but this is not necessarily the case with all models. Some manufacturers recommend that filters are only replaced by their own trained personnel.

When inserting a filter, this large and heavy object has to be moved horizontally into a relatively small opening, without damaging the seal. CLEAPSS has encountered a number of examples where the seal has been damaged because of the difficulty of sliding the filter into place. Fume cupboards for use in schools should be designed such that it is not necessary to slide the filter into place, for example by lowering into a tray, which is then slid into place on runners or some equivalent design.

4.5 Lining and construction materials

Fume cupboards shall be made of materials which withstand the anticipated mechanical, chemical and thermal stresses during expected use and shall not be easily combustible.

The materials of construction of those parts of the fume cupboard (excluding services) that are likely to come into contact with the fumes shall be selected to suit the nature of the process carried out within the fume cupboard.

BS EN 14175-2:2003, SECTION 6.1

4.5.1 General

Materials should be resistant to fire and to chemicals and be non-absorbent. Safety glass, acrylic, polycarbonate, compact laminate (eg, melamine) and epoxy-coated or stove-enamelled aluminium or steel are suitable.

Wood, plywood, suitably veneered and treated block board, chipboard or medium density fibre board can be suitable if treated with flame retardant and chemical resistant coatings or finishes but are generally not preferred. Solid grade laminate has good resistance to flame spread.

4.5.2 Work surfaces

Suitable work surface materials include compact laminate, filled acrylics, solid epoxy, solid grade laminates, moulded glass-reinforced epoxy laminate, polypropylene, suitably-grouted ceramic tiles or possibly grade 316 stainless steel.

However, compact laminates are severely marked by red-hot objects such as crucibles and tongs. It is important that plastic materials are dark coloured as the stains produced by hot objects and most chemical stains tend to be orange-brown.

Stainless steel can be blackened, pitted and even holed by solutions containing chloride ions, eg, hydrochloric acid or bleach, particularly in the presence of particles of metal. It may even go rusty. If it is used, it should be grade 316 rather than the grade 304 used for domestic purposes.

The work surface of bench type and low level fume cupboards shall be flat with a raised edge at the front. Preferably, the raised edge should surround the work surface at all sides.

BS EN 14175-2:2003, SECTION 7.2.2

The work surface should be dished or its front should have a lip to prevent spilt liquids running out of the front of the cupboard; the lip should be shaped for easy cleaning. If the work surface is flat with a lip at the front, it should be sealed round its other edges with a suitable material, for example, silicone rubber mastic. The work surface should be approximately level with other work surfaces in the laboratory, which are usually about 850 mm above the floor.

4.5.3 Glazing

The sash shall be transparent. It shall be made from materials to give optimal physical protection from the accidental emission of substances.

Toughened or laminated glass in accordance with EN 12600, type 2B or type 2C or in accordance with EN ISO 12543-1 or suitable plastics materials shall be used for the sash between the operator and the workspace.

BS EN 14175-2:2003, SECTION 7.2.2

The sash of a fume cupboard must be glazed and, if used for demonstration, the fume cupboard should have a glazed back and sides. Protective glazing must be used: toughened glass or laminated glass at least 5mm thick; or acrylic, or polycarbonate. Toughened or laminated glass refers to impact resistance. Protective glazing is necessary because there is a risk of pupils running into a fume cupboard and, also, a very slight risk of an explosion inside. Acrylic is less strong than polycarbonate. Georgian wired glass is not a safety glass.

If a fume cupboard is to be illuminated by general room lighting, then it must be glazed elsewhere besides the sash.

4.6 Airflow rate

4.6.1 Sash height and face velocity

A working height of 400 mm allows manipulation of apparatus in the fume cupboard but improves containment and provides some protection to the face of the user. As some users in schools will be pupils and many of the staff are women with a lower average height than men, better protection is provided by a working height of 400 mm rather than 500 mm preferred by the British Standard. Thus we recommend that the height of the bottom edge of the sash or its frame above the lip or raised edge of the work surface at the full working aperture should be **400 mm**.

A sash stop should be fitted to prevent the sash being raised above 400 mm in normal use. The stop should be of such a design that it can be over-ridden, eg with a key, to give a larger aperture for assembling equipment or cleaning. Although the British Standard suggests the incorporation of an automatic alarm to warn the user that the maximum working height has been exceeded, the use of a stop that is difficult to over-ride, a clear maximum height label and clear written procedures would normally suffice in schools.

It should not be possible, during normal use, to raise the sash so that the face velocity falls below **0.3 m s^{-1}** .

The working height of **400 mm** and minimum face velocity of **0.3 m s^{-1}** has been established over many years as providing adequate protection for operations (see section 4.10) carried out in schools and colleges teaching up to GCE to A-level or equivalent⁴.

A minimum height stop should prevent the sash closing completely as this restricts airflow through the fume cupboard; in its lowest position, the gap under it should be not less than **50 mm**.

Some recirculatory filtration fume cupboards do not have sashes that can be continuously varied, but an arrangement of hinged flaps. This implies an aperture with a fixed working height, for although the flaps can be raised to assist experimental set-up, when in use the flaps should be lowered so that the face velocity will be adequate. The top and sides of the working aperture are usually determined by a cut-out in a flap; the bottom is determined by the work surface.

It may be difficult with a filtration fume cupboard to achieve a working aperture height of 400 mm. In this case those manufacturing fume cupboards for school use should aim for a height of at least 360 mm. It is also acceptable to restrict the width of the aperture. Users would need to consult the manufacturer's instructions regarding the recommended working height for their cupboard.

4.6.2 Variation in face velocity as sash is raised and lowered

A fume cupboard with a movable sash should be fitted with a **bypass** (also called a **secondary air inlet**) whose purpose is to prevent much increase in face velocity as the sash is lowered and to maintain a stable air flow. A recirculatory cupboard can have a variable volume system so that constant in-flow velocity is achieved independent of the sash position.

Care must be taken to ensure that the face velocity at full working aperture is not too high (ie, not in excess of 0.65 m s^{-1}). Otherwise, even with a by-pass, lowering the sash may increase the face velocity sufficiently to blow out Bunsen burner flames.

⁴ Unpublished research by CLEAPSS.

It is recommended that **each** school fume cupboard should have its own extraction system and, with this, the bypass should be designed to keep the **face velocity** reasonably constant and so remove any risk of Bunsen burner flames being affected as the sash is lowered. However, 2 adjacent ducted fume cupboards, eg in the same 6th form laboratory, could share a single duct. It is recommended that a bypass should not allow the face velocity to rise by more than 50% (preferably much less) when the sash is lowered from its position at full working height (usually 400 mm) to 200mm. Lowering the sash of a modern ducted fume cupboard with a well-designed bypass will not affect containment significantly.

The variation in face velocity across the aperture should not exceed $\pm 20\%$. In the experience of CLEAPSS, this is easily achievable for new school fume cupboards. A baffle can be added as a means of achieving this.

If a baffle is fitted, it must be such that it can be easily removed for cleaning and replaced in the correct position. It is essential on a demonstration fume cupboard that the baffle is transparent and kept clean.

4.6.3 Air flow indicator

The British European Standard suggests that fume cupboards should incorporate an air flow indicator to show unambiguously the correct functioning of the fume cupboard's air flow. It should include audible and visual alarms to warn the operator of incorrect operation of the fume cupboard. The audible alarm may be silenced once alarmed. However, if the working height is clearly marked on the cupboard, there is a reliable visual indication of the air flow rate (ie an air velocity meter) and there are clear operating procedures it is questionable whether schools really need an automatic alarm.

4.6.4 Sash suspension

A movable sash should be supported by a counterbalance or spring system to enable it to remain at any position where the user puts it. It should not be difficult to gain access to this system for inspection and repair. Any counterbalance system should jam if a cable or cord breaks and not allow the sash to fall. The cable or cord supporting any counterweight should be inspected annually.

4.7 Services

4.7.1 Illumination

Good illumination aids safety and is essential for demonstrations. A maintained illuminance of at least 300 lux on the work surface is required. One or more suitable lamps should be built into the fume cupboard unless the fume cupboard is extensively glazed and to be used in an area already very well illuminated.

Light fittings must prevent ingress of gases released within the fume cupboard to reduce the slight risk of igniting flammable vapours and to avoid corrosion.

4.7.2 Electrical services

Whenever possible electrical sockets should be located on the outer surface of the fume cupboard and not within the workspace. If they are located outside on a low level fascia, below the work surface, they shall be protected against liquid spillage and shall have a minimum protection level of IP44 in accordance with BS EN 60529.

If the location of the electrical sockets within the workspace is unavoidable, they shall have a minimum protection level of IP44 and shall be unambiguously and separately switched from outside the workspace. In case of multisocket blocks, the blocks may be unambiguously and separately switched from outside the workspace.

BS EN 14175-2:2003, SECTION 9.3

Unless it is a mobile cupboard, the wiring to a fume cupboard should be permanent.

The extract system should **not** be wired from a Residual Current Device (RCD) which also protects socket outlets or other equipment. A fault on one of the sockets or other equipment could trip the RCD and cause the extract system to switch off and allow fumes to escape.

A switched double-socket outlet, with integral indicator lights and protected by an RCD, is needed and should be placed on the front of the cupboard close to the work surface and near to one side. If necessary, it should be protected from drips by an anti-drip groove below the edge of the work surface which should protrude sufficiently.

4.7.3 Gas services

The outlets shall be located in the workspace of the fume cupboard and should be easily accessible. The operating devices for all the services shall be located on the outer surface of the fume cupboard. The operating device shall be unambiguously associated with its outlet, and positioned in such a way as to minimise interference with airflow.

Operating devices for fuel gases shall be protected against accidental opening.

NOTE Fuel gases include natural gas, propane, butane or mixtures thereof. Other gases, such as acetylene or hydrogen, are not included (see BS EN 14056).

BS EN 14175-2:2003, SECTION 9.1

One gas supply point is needed, and a double one is desirable, placed on or just above the work surface near to the front and to one side of the cupboard.

The controls should be outside the cupboard, on the front and below the work surface. The gas tap should be manufactured to BS1552 so that the “on” and “off” positions can be readily identified. It should not be possible to turn the gas tap on by accident.

Systems common in older fume cupboards, in which the control knob and valve are connected through rods, should be avoided. They can be hazardous as pupils do not understand the play inherent in them and may damage them with excessive force. Panel-mounted valves are more reliable.

For mobile fume cupboards, flexible steel appliance connections shall not be more than 1.4 m long, not be located in a rising duct, be connected to the fixed gas installations with self sealing and swivel plug/socket end connections, and be protected by stainless steel restraint cables⁵.

4.7.4 Water and drainage

Fixed fume cupboards need a water supply, on or just above the work surface near to the front and close to the side. The controls should be outside, on the front and as direct and simple as possible.

Systems common in older fume cupboards, in which the control knob and valve are connected through rods can be damaged and should be avoided. Panel mounted valves are more reliable. There should be a drip cup, fitted into the work surface without any lip, below the water outlet and connected to the main drain via a bottle trap. Its purpose is to receive water from the tap, the outflow from condensers and to aid the clear-up of spills. Some drip cups are too small for practical use. A small sink is sometimes requested instead of a drip cup. **This is not recommended** except in a prep room because it reduces the working area inside the fume cupboard and encourages the tipping of hazardous chemicals into the drainage system. **They must be diluted and/or neutralised first.** If a sink is fitted in a prep room fume cupboard, a wider fume cupboard (ideally 1.5 m) is needed but there is rarely room for this in most prep rooms so 1.2 m is a common compromise.

If the service outlets and drip cup are too far back, users are tempted to put their heads inside the fume cupboard to use them. They must be near to the side to leave a clear area of the work surface for apparatus.

When a drip cup is fitted it should be coupled with proper fittings to a drain and not to a container underneath the cupboard. Leading the waste from the drip cup to a container can present hazards if noxious liquids are poured or spilt into it.

A bottle trap should be adequate to protect the drains from the chemicals used in schools; a dilution trap should not be needed.

Fittings should be made from chemically resistant polypropylene, such as 'Vulcathene'.

If there is no water outlet on the fume cupboard (and no drip cup etc) and water is needed for a condenser, it can be supplied via hoses from a nearby sink. For this purpose, it may be useful to have two short metal tubes passing through the side of the cupboard at low level, to which the hoses can be attached.

4.7.5 Service connections

Care must be taken to ensure that cables and hoses bringing services to a mobile fume cupboard do not present any hazard. In particular, the gas supply to an **outlet with a control** on the fume cupboard must be properly plumbed; any hose should be reinforced or armoured and securely attached to rigid fittings at either end. To prevent hazards it should not be possible to disconnect the gas hose without the supply being cut off first or simultaneously at the fixed outlet.

⁵ *Gas Installations for Educational Establishments*, IGEM/UP/11 Edition 2, 2010, ISBN 9781905903191, para. 5.9.

4.8 Noise levels

A noisy fume cupboard is hazardous. Students working at a cupboard, or watching a demonstration taking place in one, need to be able to hear the teacher. If a cupboard is too noisy, there will be a strong temptation to switch it off or students may mis-hear instructions. In the past, some school fume cupboards + associated extraction systems have been much too noisy. Quiet cupboards/systems can be provided but this adds to the cost so a compromise has to be made. In (draft) guidance from the Education Funding Agency on acoustic levels in schools, the limit for science labs is set at 40 dB(A). The accompanying guidance is likely to suggest that fume cupboards should be limited to 50 dB(A), measured at a height of 1500 mm above the floor and 1500 mm from the face of the fume cupboard, with the sash set at a height of 200 mm. This seems reasonable and some existing cupboards meet this standard, although cupboards installed in the past 10 years tend to be much better than some older ones. A lower level of 45 dB(A) for fume cupboard noise would provide better acoustic conditions.

4.9 Information to be provided by the fume cupboard supplier

The front wall shall be marked, preferably on the sash, with a sign "Keep sash closed whenever possible". ...

A durable identification plate shall be fitted marked with

The name and/or trade mark of the manufacturer and/or supplier;

The type designation including the year of production.

...

All marking on the sash shall not significantly restrict the visibility through the sash.

BS EN 14175-2:2003 SECTION 11

4.9.1 Information to be displayed on the fume cupboard

The following information should be displayed prominently on the casing of the fume cupboard.

- The manufacturer's and installer's names and addresses.
- The model, serial number and dates of supply and installation.
- Any relevant CE marking.
- An indication of the sash positions, or of the arrangements of a folding flap-type front, which are necessary to ensure that working aperture height and minimum face velocity requirements are met.
- A permanent label should indicate the highest safe working position of the sash and make it clear that, if the maximum working height stop is released so that the sash can be raised further, it is only for setting up apparatus etc, not for handling chemicals, etc.
- For filtration (recirculatory) fume cupboards with a fixed sash with hinged flaps to allow cleaning access, a notice to ensure the fume cupboard is used with hinged flaps down.
- A warning that there is a legal obligation to carry out a thorough examination and test of the fume cupboard at least every fourteen months.
- A warning to check the fume cupboard visually to see that it is working before each use.
- Warnings that the face velocity needs regular checks and where instructions for such checks can be found.

- On filtration (recirculatory) fume cupboards, warnings of either the need to check filter saturation or replace the filters regularly. The need for setting and checking any filter saturation detectors must be prominently displayed.
- On filtration (recirculatory) fume cupboards, lists of the hazardous gases commonly released in school science which the filter will and will not absorb adequately.

4.9.2 Information to be provided in accompanying documentation

The following documentation should be provided by the supplier.

- The user manual (including instructions for users).
- A log book to record results of thorough examination and tests.
- The results of the commissioning tests.

4.10 Assumed use of school fume cupboards

Obviously, we have had to make assumptions about what fume cupboards will be used for. There is little point in looking just at current curricula, as these will change many times during the expected life of a fume cupboard. The following is a list of substances which, in the quantities usual in school experiments, can be released safely in a fume cupboard meeting the recommendations of this guide. This claim is based on containment tests. It is inevitably an incomplete list. Absence from the list does not necessarily imply that the gas or vapour is too toxic to be handled in such a fume cupboard or can be handled safely in the open laboratory. Inclusion in the list does not necessarily imply that the gas or vapour cannot be handled safely in the open laboratory if quantities are sufficiently small.

<i>Inorganic</i>		
aluminium chloride and bromide	hydrogen chloride	phosphorus (white)
ammonia	hydrogen sulfide	phosphorus chlorides and bromides
ammonium chloride fumes	iodine	phosphorus oxides
bromine	iodine chlorides	silicon tetrachloride
carbon monoxide [<i>NOT in filter fume cupboards</i>]	lead fumes	sulphur chlorides
chlorine	lead bromide fumes	sulphur dioxide
chromium(VI) dichloride dioxide (chromyl chloride)	mercury and its compounds [<i>NOT in filter fume cupboards</i>]	thionyl chloride
hydrochloric acid vapour	nitric acid vapour	tin(IV) chloride
hydrogen	nitrogen oxides	titanium tetrachloride
	phosphine	zinc chloride fumes

Organic acid amides acid anhydrides acid chlorides alcohols aldehydes aliphatic amines and their salts	aliphatic hydrocarbons [<i>methane NOT in filter fume cupboards</i>] aromatic amines and their salts aromatic hydrocarbons aromatic nitro compounds carboxylic acids esters	ethers ketones nitriles organohalogens phenols pyridine
Dust, etc dyes	enzymes	smoke

The following is a list of processes which, in the quantities usual in school experiments, can be carried out safely in a fume cupboard meeting the recommendations of this guide. Absence from the list does not necessarily imply that the procedure is too hazardous to be handled in a fume cupboard meeting the recommendations of this guide or can be handled safely in the open laboratory. Inclusion in the list does not necessarily imply that the procedure cannot be handled safely in the open laboratory if quantities are sufficiently small.

Alkali metals reacting with water Aluminium chloride (anhydrous) preparation Aluminium reacting with iodine Aluminium with mercury salt solutions Ammonia: catalytic oxidation Ammonia: dispensing of '880' Ammonia preparation Ammonia reacting with hydrogen chloride Ammonium chloride heating Ammonium dichromate decomposition (volcano experiment) Aromatic amine preparation Benzoyl chloride: dispensing and reactions Bromination of alkenes (eg cyclohexene, styrene) Bromine diffusion experiments Bromine/hydrocarbon reactions Bromine reacting with iron Burning plastics Butylamine to illustrate reactions of aliphatic amines Cannizzaro's reaction using benzaldehyde Carbon disulphide handling Carbon monoxide preparation [<i>Not in a filter fume cupboard</i>]	Hydrogen burning in chlorine Hydrogen chloride dissolving in methylbenzene Hydrogen chloride gas preparation Hydrogen sulfide: preparation and reactions Iodine: action of heat (sublimation) Iodine reactions with metals other than aluminium Iron(III) chloride preparation Mercury(II) solutions dispensing Mercury heating to form oxide [<i>Not in a filter fume cupboard</i>] Mercury oxide heating [<i>Not in a filter fume cupboard</i>] Mercury reacting with iodine [<i>Not in a filter fume cupboard</i>] Mercury used as an electrical contact [<i>Not in a filter fume cupboard</i>] Methanal for use as a preservative, fixative or to kill microbes Methanol oxidation using a copper spiral Methyl methacrylate polymerisation Naphthalene cooling curve demonstration Nickel carbonate decomposition Ninhydrin spraying of chromatograms Nitric acid preparation Nitric acid reacting with copper
---	--

<p>Carbon monoxide reducing metal oxides <i>[Not in a filter fume cupboard]</i></p> <p>Cellulose dissolving in strong ammonia solution</p> <p>Chlorine preparation</p> <p>Chlorine reacting with metals</p> <p>Cholesteryl benzoate preparation using pyridine as a solvent</p> <p>Chromatography using organic solvents</p> <p>Chromyl chloride preparation</p> <p>Contact process demonstration</p> <p>Copper pyrites heating</p> <p>1,4 - dichlorobenzene to pre-treat root tips to arrest metaphase</p> <p>Dichloromethane extractions (eg caffeine from tea)</p> <p>Dissolving alloys in aqua regia or concentrated nitric acid for analysis</p> <p>Electrolysis of molten lead bromide</p> <p>Electrolysis of molten sodium hydroxide</p> <p>Electrolysis of molten zinc chloride</p> <p>Ethanal: reactions and dispensing</p> <p>Ethanoic acid: reactions and dispensing</p> <p>Ethanoic anhydride: reactions and dispensing</p> <p>Ethanoyl chloride: reactions and dispensing</p> <p>Fountain experiments with ammonia, hydrogen chloride or sulfur dioxide</p> <p>Friedel-Craft reactions</p> <p>Galena (lead sulfide) heating</p> <p>Halides with concentrated sulfuric acid</p> <p>Halogenoalkane solvent dispensing</p> <p>Harlow's solution for macerating woody tissue</p> <p>Hoffman bromination reaction</p> <p>Hydrocarbon solvent dispensing</p>	<p>Nitric acid reaction with sawdust</p> <p>Nitrogen dioxide preparation</p> <p>Nitrogen monoxide preparation</p> <p>Organic acid anhydride preparation</p> <p>Organic acid chloride preparation</p> <p>Organic solvent warming</p> <p>Perspex depolymerisation</p> <p>Phenol dispensing</p> <p>Phenol/methanal resin preparation</p> <p>Phenylamine reactions illustrating aromatic amines</p> <p>Phenylethene polymerisation</p> <p>Phosphine preparation</p> <p>Phosphorus allotropy</p> <p>Phosphorus burning in air/oxygen</p> <p>Phosphorus burning in chlorine</p> <p>Phosphorus chloride reactions</p> <p>Silicon tetrachloride reactions</p> <p>Sugar reacting with concentrated sulphuric acid</p> <p>Sulfide precipitations (using ammonium sulfide or hydrogen sulfide solution)</p> <p>Sulfur burning</p> <p>Sulfur dioxide handling</p> <p>Tetrachloromethane: dispensing and use</p> <p>Thermal decomposition of nitrates</p> <p>Thermal decomposition of potassium iodate</p> <p>Thermite reaction</p> <p>Tin(IV) chloride preparation</p> <p>Tin(IV) iodide preparation</p> <p>Trichloromethane: dispensing and use</p> <p>Urea/formaldehyde (methanal) resin preparation</p> <p>Zinc reacting with sulfur</p>
<p>Any procedures a technician is likely to carry out in supporting normal activities in school science, including those not explicitly mentioned above, can be carried out in a fume cupboard meeting this specification, although of course many such activities will not require a fume cupboard.</p>	

5 Duct extraction systems and filters

5.1 Duct extraction system

5.1.1 Design of the system

CLEAPSS has received a number of reports over the years of inadequate systems being installed, of inadequate up-grades and of systems being made inadequate by building alterations. Aesthetic considerations, the need for planning approval etc, may make a solution difficult to find but it must be safe. Take special care if a building is altered after a fume cupboard has been installed.

As the protection of fume cupboard users depends as much on the design of the extraction system and its installation as on the fume cupboard itself, the cupboard plus extraction system should be thought of as one, integrated unit, which should be designed and installed by the same company. The design of all extraction systems for fume cupboards should be by, or receive the approval of, a suitably qualified engineer.

The total system resistance should be calculated from CIBSE data⁶, taking account of the resistance offered by the fume cupboard, ductwork and any dampers.

Each fume cupboard should have its own extraction system. If an extraction system is shared, then all the fume cupboards on the system will need to be on or off simultaneously with an indicator light by each fume cupboard to show when the system is on or off. A shared system also needs a damper fitted to each fume cupboard and an effective bypass. With a shared system, there is a risk that it may be switched off when fume cupboards are in use. Having to run all fume cupboards when only one is needed increases heat losses and is environmentally unfriendly through wasting energy. Further, while the noise of a fume cupboard in a particular laboratory is tolerated if it is being used by occupants of that laboratory, it will not be tolerated if it has to be switched on because a fume cupboard needs to be used elsewhere. However, these objections may be less significant when all the fume cupboards are side by side in the same laboratory, as is sometimes the case in 6th form laboratories and it may then even be possible to fit sensors which automatically adjust the fan velocity.

Fume cupboards should be able to be operated independently of general laboratory ventilation systems.

If a mobile fume cupboard has some flexible ducting, the extraction fan **must never** be fitted on top of the cupboard but to the fixed ducting so that the interior of the flexible ducting is at negative pressure. A centrifugal fan (which is preferred in any case) would automatically achieve this, see section 5.1.2. With the flexible ducting at negative pressure, any defects in it will lead to leaks into the system rather than out of it.

Flexible ducting should be designed so that there are no low points where condensation can settle when the fume cupboard is either in its working or parked position. The movement of a mobile fume cupboard must be limited with a cable to ensure that its duct connections cannot be strained or wrenched off.

⁶ Flow of Fluids in Pipes and Ducts, Section 4, Guide C: Reference data, 2007 ISBN: 9781903287804, <http://www.cibse.org/index.cfm?go=publications.view&item=3>

5.1.2 Fans for ducted fume cupboards



Figure 5.1 Example of centrifugal fan

A **centrifugal fan** should be sited outside the building (or possibly in the roof space) and as near as possible to the discharge point of the extraction system. Where this is not practicable, any ductwork under positive pressure should be rigid and particular attention paid to ensuring that joints are, and remain, airtight.

A fan at or near the end of the ductwork means that most of the system is under negative pressure, ensuring that, if there are any failures of integrity, air leaks inwards. It is particularly important that any parts of the system inside the building are under negative pressure.

If the siting of the fan near the discharge point cannot be achieved, then it is essential that the number of joints in any ductwork that unavoidably pass through voids or other unventilated spaces be kept to an absolute minimum.



Figure 5.2 Example of an axial fan

Axial fans sited above the fume cupboard should not be used for new fume cupboards. These should be fitted only for up-grades where other fans are impracticable

To achieve the required face velocity, each fume cupboard should be fitted with an air flow control device or **damper**. This is usually fitted above the fume cupboard where the duct attaches to the cupboard. However, it should be used for minor adjustments only – using a damper to effect significant air velocity reduction for an over-powered fan will waste energy and increase noise. Where the damper control is in an easily accessible position, it must be fitted with some locking device to prevent unauthorised interference. If the 14-monthly monitoring required by COSHH is to be valid, it is essential that the damper setting can be locked or at least requires a tool to change it. An inverter, which adjusts the motor speed, can be used as an alternative to a damper but the points about locking it are equally applicable.

It is important that the fan and ducting are correctly sized to give the required face velocity, without requiring major adjustment by a damper or inverter. While a damper should be fitted, it should not be required to do more than make small adjustments to the air flow. Fitting an over-

powerful fan and using the damper to reduce the air flow to an acceptable level is a waste of money.

All parts of any fan in the airstream should be resistant to the airborne contaminants which may be present. While it is unlikely that a fan manufacturer would be prepared to guarantee resistance to every chemical, a claim that a fan is 'acid proof' is very likely to be adequate.

Centrifugal fans with either backward-curved or forward-curved blades should be used. Directly-coupled ones, correctly sized, are most satisfactory.

Belt-driven fans have the advantage that their speeds are adjustable but they are very unlikely to receive the maintenance which they require and so should not normally be used. If the belt breaks, it may not be immediately obvious that there is a fault.

For quiet operation, outlet velocities should be between 5.5 m s^{-1} and 7.5 m s^{-1} and impeller tip speeds in the range 10 m s^{-1} to 15 m s^{-1} .

Fans must be accessible for cleaning and provision should be made to pipe away any condensate or rain collecting in the fan scroll.

Anti-vibration fan mountings should be used, to ensure that vibrations are not transmitted from the fan to the building or to the duct.

If the **fan wiring** is protected by an RCD, this should not also protect other devices or socket outlets because the other devices might cause a cut-out when the fan was in use.

The **fan motor** should be protected with a thermal overload device.

An on-off switch, fitted with an indicator lamp, sited close to the fume cupboard, should be used, not a manual speed regulator which would make it impossible to be sure that the face velocity is maintained at its optimum value.

5.1.3 Make-up air

If the air flow through the face of the fume cupboard is to be satisfactory, there must be adequate provision for make-up air, ie, for air to enter the room to replace that extracted by the fume cupboard and by other devices also extracting.

It is important that the flow through a fume cupboard is not significantly affected by other fume cupboards and extraction fans, either through some switching arrangement or because of a lack of make-up air.

Sometimes, perhaps because there is inadequate make-up air, systems are electrically connected so that general ventilation and fume cupboard extraction cannot function simultaneously. This is not satisfactory and can lead to gases being drawn out of the fume cupboard when it is switched off and the general ventilation switched on.

When a fume cupboard is running, it makes a significant contribution to the ventilation of the room. In a modern building, windows are much better sealed than in the past so that they can no longer be regarded as providing make-up air. Doors may also be better sealed but air entering through the gaps around two doors is probably sufficient for one fume cupboard but this is not ideal, as air velocity would need to be of the order of 1 m s^{-1} . If a room is fitted with several fume cupboards and with extraction fans, the performance of all these devices will be adversely affected unless there are vents or grilles kept permanently open which allow air to enter. The risk of hazardous gases released in a fume cupboard escaping into the room is increased greatly if make-up air is inadequate.

Some new schools have been fitted with a type of air conditioning and the fume cupboard designed to work in conjunction with this. If, however, the air-conditioning is switched off, because the school is unable to afford to run it, the fume cupboard may no longer work as intended.

5.1.4 Ductwork

Ductwork should have a circular cross-section. The diameter should be chosen so that the air velocity in the duct passing through any teaching room does not exceed 5 m s^{-1} . Higher velocities increase noise levels and require greater fan power.

The route followed by ductwork should be as direct as possible, with horizontal runs kept to a minimum. These should have no adverse falls where condensate might collect. Bends and offsets should have the largest possible radii. Silencers, fire dampers and guide vanes should be avoided unless absolutely essential. The number of joints in ductwork that unavoidably passes through voids or other unventilated spaces must be kept to an absolute minimum.

The materials of construction of ductwork, both ducting and seals, should be resistant to the gases they are likely to come in contact with including vapours of solvents. Rigid PVC is suitable. It should meet relevant British Standard requirements⁷ for the 'self-extinguishing' and 'very low flammability' classification.

Ductwork, both horizontal and vertical, should be adequately supported but supports must allow thermal movement. Flexible joints should be provided where necessary to accommodate this and to reduce transmission of fan vibrations. If a duct is under negative pressure and its diameter is less than 500 mm, socket and spigot joints with an appropriate sealant are satisfactory.

The passage of ductwork through walls and floors should not be allowed to reduce the fire compartmentation of the building. Fire dampers should be avoided and protection obtained by compartmentation of the ductwork or by running it outside the building. Where fire dampers cannot be avoided, the preferred option is the intumescent type that sit on the outside of the duct. When heat is detected they expand and crush the duct. They do not require maintenance and are not sited in the contaminated air flow.

5.1.5 Fume discharge

Fumes should be discharged in a vertical direction at a minimum of 1 metre above the highest point of the building. This avoids the effects on fume cupboard performance of wind variations and eddies, eg, at the edges of parapet roofs. See *Figure 2.2* on page 8.

Ideally, the point of discharge should be at a height of $1.25 \times$ the height of the building or 3 m above the highest point of the building, whichever is the higher. **Where this is not practicable, designers should use their discretion and possibly seek advice: discharge must be as high as possible and the siting of the discharge stack relative to building protrusions is critical.** An additional advantage of having the discharge at least 1 m above the highest point is that it is much less likely to become obstructed by footballs, vegetation, etc. The discharge velocity must be vertical and normally not less than 7 m s^{-1} . A **reducer** can be used to accelerate flow away from the building.

⁷ For example, BS 476: Part 7: 1997 *Fire tests on building materials and structures*, BS 2782: Part 1: Method 140D: 1997 *Methods of testing Plastics: part 1 Thermal properties Method 140D* and BS 2782: Part 1: Method 140E: 1997 *Methods of testing Plastics: part 1 Thermal properties Method 140E*.

It should be noted that school fume cupboards, unlike those in industry and research, do not operate continually so the nuisance to neighbours is very limited. Use is very sporadic, and the amounts of hazardous material expelled are very small.

The discharge stack must be sited so that prevailing winds, natural down-draughts, eddies caused by building protrusions etc, do not cause the entrainment of fumes in any fresh air entering the building.

Attention must be paid to the position of windows and ventilation inlets, particularly any on higher buildings close to the laboratory building and also to any air inlets on the roof on which the stack is mounted.

Figure 2.2 shows that with centrifugal fans any rain entering the discharge stack will be discharged through a drain hole. However, in the rare cases when an axial fan or a bifurcated fan has to be fitted, then measures need to be taken to prevent any rain entering the fume cupboard. Generally, nothing but a reducer should be fitted over the end of the stack but if a gauze or grid is fitted it must have a wide mesh. This prevents birds, etc, entering the system but does not become significantly clogged with dust. 'Coolie' hats are not suitable.

5.2 Filters for recirculatory fume cupboards

5.2.1 Choice of filters

Recirculatory filtration fume cupboards have been used in schools since the early 1980s. There is no evidence to suggest that they are unsafe if they are used properly, providing their filters meet the specification in *Table 5.1*, there are no leaks around the filters and they are regularly monitored for air flow and either monitored for filter saturation or the filters changed sufficiently frequently. However, these conditions are not always met in schools.

Suppliers of filtration cupboards, like all suppliers, have a duty to ensure that their products are safe if used in accordance with their instructions. By law, it is the duty of the supplier to ensure that the fume cupboard operates safely. In particular, the supplier must be sure that there are no significant risks of:

- desorption of adsorbed gases or of dangerous reactions occurring within the filter between substances adsorbed at different times;
- fire or explosion from the fan, lighting equipment or Bunsen burner flames during work with flammable gases or vapours or involving any possible escape of flammable vapours or gases, perhaps when a filter becomes saturated;
- a fire involving the fume cupboard either causing explosion risks from a substantial amount of flammable substances previously absorbed in the filter or danger from the desorption of toxic gases.

The absorption efficiencies of the filter should conform to those specified in *Table 5.1*.

Ideally, there should be a means of detecting when a filter is approaching saturation, reliable over the life of the filter which, in a school, could be as much as 5 years. Any automatic detector should give a reliable and unambiguous warning for **all** acid gases used in school science without requiring frequent adjustment by the user. At the time of writing, CLEAPSS is not aware of any detector which satisfies this requirement. It would normally be checked as part of the annual thorough examination and test.

A hazardous component gas in the air passing through the filter will become attached to the activated carbon. However, some will be expelled through the exhaust, the relative amounts determined by a ratio which depends on the gas, the particular activated carbon, the previous history of the filter, etc. This means that, although a very high percentage of the gas will be absorbed (eg, 99.9%), some will **always** pass through, not sufficient to present a hazard but enough sometimes to be detected by smell.

The **seal between the fume cupboard and the filter** must be intact. Where filter seals along two edges join at a corner it is essential that there is no gap, not even 1 mm. Otherwise hazardous gases may by-pass the filter and exit the fume cupboard around the seal and into the laboratory. The materials and any glue should be resistant to the chemicals used. The filters are very heavy and inserting the filter in the fume cupboard can rupture the seal. It is better if the design allows the filters to be dropped into place (possibly in a drawer arrangement) rather than slid sideways. The filters must be inserted with great care and detailed instructions should be given in carrying out this work.

To prevent the main filter from becoming clogged with dust, the contaminated air first passes through a **pre-filter** which resembles a thin layer of wadding. The pre-filter will also extract smoke particles whose size is 0.5×10^{-6} m (0.5 μ m) or above; finer particles will pass through.

Activated carbon filters will remove organic chemicals. If a filtration fume cupboard is to be used in a school, the filter has to be specially treated to remove hazardous gases and vapours such as the halogens (ie, chlorine, bromine and iodine), acid gases (eg, hydrogen chloride, nitrogen dioxide, sulfur dioxide), alkali gases, (eg, ammonia and some amines), and hydrogen sulfide. No filter will remove small, neutral molecules such as hydrogen, carbon monoxide and methane nor (unless specially treated) elemental mercury vapour, hence filtration fume cupboards are **unsafe** for work with such substances.

Schools should buy filters intended to absorb all the gases likely to be encountered in school science and which have been verified to do so by an organisation independent of the supplier: see *Table 5.1* for a suitable specification. Note that filters used in other industries may have quite different absorption characteristics, eg only be capable of removing organic solvent vapours, hence the supplier chosen must be familiar with schools' requirements. Second-hand fume cupboards, gifted to local schools by a company trying to be helpful, may well be fitted with inappropriate filters.

The rate at which the gas-contaminated air passes through the filter is critical. If it is too fast, the time the air spends inside the filter is too short for adequate absorption. If it is too slow, the face velocity may become too low for adequate containment.

If the pre-filter becomes coated with dust or black carbon particles from smoke, the pressure drop increases and this may result in a lower face velocity. A new pre-filter may be required. (It may also indicate that the fume cupboard is not being used correctly!) The pre-filter will be examined during the annual thorough examination and test but earlier suspicions of any significant deterioration should result in a check. This involves simply examining the pre-filter without removing the filter and comparing its appearance with an unused pre-filter. Pre-filters should be available from the supplier who should supply small packs (fewer than 10) for the schools market.

As hazardous gases enter the filter, they encounter chemicals in the carbon filter which react with the gas and render it inactive. As these sites become increasingly populated, the efficiency of the filter decreases.

COSHH Regulation 9(2) requires that fume cupboards are tested every 14 months (usually taken as annually). Paragraph 168 of the ACOP⁸ states that

In all cases, engineering control measures provided to control exposure, for example those mentioned in paragraph 98(a), (b) and (d), must be thoroughly examined and tested at suitable or specified intervals.

This implies that filters should be tested as well as air flow. However, an alternative may be to replace the filters on a regular basis based on the amount of use of the cupboard.

In some cases, it is possible to use electronic sensors to monitor continuously filter saturation. Indeed this may become a requirement of the British European Standard, currently under development. However, whilst these sensors are satisfactory for most organic chemicals there is currently no reliable sensor for the range of inorganic chemicals likely to be used in schools.

5.2.2 Filter efficiency required

The filter efficiencies recommended by CLEAPSS for school fume cupboards are shown in *Table 5.1*. The figures shown in this Table are slightly different in some cases from those in its predecessor publication, *Building Bulletin 88: Fume Cupboards in Schools* (DfEE, 1998). Partly, this is because we have changed the assumed activity to reflect changing practices in schools. Also the Workplace Exposure Limit (Short-term Exposure Limit) (WEL (STEL)) for some substances has been lowered, hence the required efficiency has increased. It is now set at 99% for all the acidic gases used in school science. In addition, the HSE no longer lists WELs for nitrogen dioxide and sulfur dioxide as it considers that no safe level can be recommended. In this case we have used figures used in Germany.

In drawing up this Table, the concentration of gas (in ppm) in the room has been estimated using the formula

$$C = \frac{RK(1 - e^{-nt})}{Vn}$$

R = the release rate into the room, in $\text{cm}^3 \text{s}^{-1}$.

V = volume of room. This has been taken as 250 m^3 .

t = duration of release, in s.

n = rate of air change. We have assumed 5 air changes per hour, which is $1.34 \times 10^{-3} \text{ s}^{-1}$.

K = factor to allow for uneven mixing. With a localised activity and 2 air changes per hour it could be as high as 10, but with fumes being exhausted from a recirculatory fume cupboard into a room with 5 air changes per hour we have assumed a factor of 2.

The final column shows the concentration which would arise if the activity (preparation, pouring, boiling) were to take place continuously for 30 minutes in a room of volume 250 m^3 . 30 minutes is highly implausible as in most cases the activity would take only a few minutes or even a few seconds, so in fact the estimated concentration is very much a worst case scenario. It will be seen that with the assumed level of efficiency the WEL (STEL) is not exceeded except (slightly) for chlorine. As a result, chlorine cylinders could not be used in a school fume cupboard but in practice chlorine is invariably generated on a small scale when required so that the actual release rate is likely to be $\frac{1}{4}$ of the assumed figure or even less.

⁸ L5, *The Control of Substances Hazardous to Health Regulations 2002 (as amended), 2005. Approved Code of Practice and guidance*, ISBN 978 0 7176 2981 7, <http://www.hse.gov.uk/pubns/priced/l5.pdf>

Table 5.1 Filter efficiencies required

<i>Substance</i>	<i>Workplace Exposure Limit (STEL) / ppm</i>	<i>Assumed activity</i>	<i>Estimated rate of release of gas in fume cupboard / cm³ s⁻¹</i>	<i>Assumed % efficiency</i>	<i>Rate of release of gas into room / cm³ s⁻¹</i>	<i>Concentration of gas within 250 m³ room after 30 min / ppm</i>
Ammonia	35	Preparation	100	96.5	3.5	18.5
Bromine	0.2	Pouring	2	99.0	0.02	0.1
Chlorine	0.5	Preparation	12	99.0	0.12	0.6
Nitrogen dioxide	(0.95)	Preparation from copper + concentrated nitric acid	7	99.0	0.07	0.4
Sulfur dioxide	(1.0)	Burning sulfur	10	99.0	0.1	0.5
* 1,1,2-trichloroethene (trichloroethylene)	150	Boiling	50	97.0	1.5	8.0
* tetrachloroethene (tetrachloroethylene)	100	Boiling	50	97.0	1.5	8.0
* Methanol	250	Boiling	50	97.0	1.5	8.0
* Methylbenzene (toluene)	384	Boiling	50	97.0	1.5	8.0
* Propan-2-ol (iso-propyl alcohol, IPA)	1250	Boiling	50	97.0	1.5	8.0

* From a point of view of the toxicity of the organics, such as tetrachloroethene, 1,1,2-trichloroethene or methanol, it would be acceptable to have an efficiency as low as 90%. However, in schools, one use of these might be to check whether the filter is properly seated. As any leakage of more toxic gases would be unacceptable a much higher efficiency needs to be achieved if these are used in a leak test.

6 Buying a new fume cupboard

This section should be read in conjunction with the HSE guidance INDG 408 *A simple guide to buying and using local exhaust ventilation (LEV)*⁹.

... prior to purchasing a fume cupboard, a risk assessment should be performed to assess the risks associated with the substances that are to be manipulated ...

...

THE (UK) NATIONAL FOREWORD (JANUARY 2014) TO BS EN 14175

The advice here is specifically aimed at the chemicals likely to be used in school science and is based on extensive CLEAPSS experience, over many years, usually after problems have arisen.

6.1 Contractors

Ideally, the same company should supply and install the fume cupboard, including its associated ductwork; if two or more contractors are involved, it is often difficult to decide which is responsible for a particular task. As the recommendations in this publication and the British Standard allow the customer choice in a number of matters, a clear agreement should be reached and recorded before work begins.

6.2 Quotations

When purchasing a new fume cupboard, especially a ducted one, schools should obtain at least three quotations. Schools could ask the fume cupboard supplier for the names of schools in which any of their models have been installed in recent years and then contact the staff in those schools for their opinion. If local, a visit may be possible. Remember that cheapest is not necessarily best value for money if the cupboard is expected to last for 25 years.

In any case, the company that produces the cheapest fume cupboard may well not be the cheapest when the cost of extras such as docking systems, ducting, fan and installation are taken into account but these costs will vary from site to site, especially ducting, which may or may not need scaffolding for installation. The overall price is likely to be two, three or even four times the cost of the cupboard, although typically it is about double.

Members of CLEAPSS (or, in Scotland, SSERC) can contact those organisations for information about suppliers who make models that comply with this publication (but beware that models can change). Schools, builders, architects, civil engineers or others involved in buying fume cupboards for schools and colleges are encouraged to contact CLEAPSS (or SSERC) to discuss any issues that arise.

If the person involved in ordering a fume cupboard is not a chemist and perhaps not even a scientist, then that individual may not understand the factors involved in choosing, and using, a fume cupboard. In the experience of CLEAPSS the most successful building schemes have always involved the senior chemistry teachers and technicians from the outset.

⁹ Available for free download from <http://www.hse.gov.uk/pubns/indg408.pdf>

Written specifications should be agreed upon before building work begins. Ideally, the school/employer/local authority which is purchasing the fume cupboard should prepare a specification, probably with help from this publication or from CLEAPSS (or SSERC in Scotland) and choose the successful contractor based on their initial quotation. The successful contractor then provides a detailed quotation and during installation and commissioning the cupboard is tested against and held to the quotation. However in practice CLEAPSS has found that schools often do not obtain multiple quotations and commonly the building contractor has a direct relationship with the fume cupboard manufacturer. Schools should insist on being informed of alterations to the specification. It is important to define the responsibilities of each of the contractors in the process.

6.3 Installation

The process of installation will introduce health and safety considerations for the installers, such as working at heights, manual handling, vehicle movement, electrical hazards and the possible encounter with hazardous materials such as asbestos. The installers should work safely, in cooperation with the school. Special care will be needed if the work is done during term time, when pupils are around.

Schools need to check that what was specified in the plans and discussions and included in the contractor's quotation matches what has been installed.

6.4 Commissioning

When a fume cupboard has been installed, it must be commissioned, ie, the supplier should test it and provide a report which shows that it performs according to the specification or the agreed quotation. Commissioning includes checking the effectiveness of the new cupboard and in the past this has sometimes been called 'initial appraisal' or 'intended operating performance (IOP)'. Staff from the Health & Safety Executive have reported concerns that commissioning is frequently inadequate and that many problems they encounter should have been spotted at commissioning. It is therefore essential that commissioning takes place **when members of the science staff are present** and that they are given full instructions of how the fume cupboard works and a copy of the tests and test results carried out at commissioning. If it is not possible for staff to be present (since work is often carried out during school holidays) the contractor should provide training soon afterwards, as an essential part of the contract.

Further guidance on LEV commissioning is now provided in *Controlling Airborne Contaminants at Work*¹⁰ (HSG258).

Commissioning should cover the details outlined in the customer's specification and included in the contractor's agreed detailed quotation. Those commissioning the fume cupboard should carry out a visual check and a quantitative test that the performance is at least as good as the minimum laid down in this specification. This should include a test on the filter for filtration fume cupboards. In the experience of CLEAPSS, filters sometimes become dislodged from seating during transport. Also, the seal can be damaged when the filter is inserted and some seals are of poor quality, with small gaps (1 mm) through which leaks can occur.

10 *Controlling Airborne Contaminants at Work*, HSG258 (2nd edition), 2011, Health & Safety Executive, ISBN, 978 0 7176 6415 3.

A commissioning report needs to be provided to the school and copies retained by all the interested parties such as the school finance department and the science department. It should contain diagrams of the system and the results of the initial tests. **This is important, as it is the standard against which future thorough examinations and tests will be compared.** The report should include:

- diagrams and a description of the LEV, including test points;
- details of the LEV performance specification;
- results, such as pressures, velocities at stated points, and noise levels;
- calculations;
- written descriptions of the commissioning, including the name of the person who made the checks and the company s/he was employed by, the date, the tests undertaken, and the outcome;
- a description of how operators should use the system so it works effectively.

It is important that science staff and any others using the fume cupboard in lessons and preparation are taught how to use the fume cupboard and understand any possible limitations. For example, users should switch on the fume cupboard before carrying the procedure, to ensure the fume cupboard is actually working! Either the performance of any filters should be checked or the filters replaced regularly. If odours are detected then action should be taken to correct the issue.

6.5 User Manual

The contractor commissioning the fume cupboard should supply the school with a User Manual or equivalent. The following should be included in the User Manual.

- The telephone and FAX numbers, e-mail, website and addresses of the supplier, installer, maintenance contractor, and the supplier of any test equipment, etc.
- A description of the system with diagrams.
- A set of instructions for users.
- (For recirculatory filtration fume cupboards, a list of which gases can/cannot be safely used).
- Performance information from commissioning including the name of the person who made these checks.
- A description of checks and maintenance and replacement schedules, including frequency.
- A list of replaceable parts (and part numbers).
- A detailed description of the specific statutory 'thorough examination and test' requirements and exposure targets.
- Signs of wear and control failure;
- A description of how operators should use the system so it works effectively.

There should also be a Log Book (which may be a part of the User Manual). This is to assist the 'responsible person' in the school manage the maintenance etc of the fume cupboard.

The following should be included in the Log Book.

- schedules for regular checks and maintenance;
- space for records of regular checks, maintenance, replacements and repairs;
- checks of compliance with the correct way of working with the LEV system, eg annual test record forms and instructions for completing them.

The log book should **not** detail who uses the fume cupboard and when it is used.

7 Legal requirements

7.1 Introduction

This section attempts to summarise the legal background surrounding the provision, use and testing of fume cupboards in schools. Most readers will not need this but it is written to explain to those unfamiliar with fume cupboard design, use and testing why various requirements are included in this document.

7.2 Employers

Employers¹¹, which may be local authorities, chains of academies or governing bodies depending upon a school's status, have a duty under health and safety legislation to ensure that the fume cupboards they provide adequately protect employees (ie, teachers and technicians) and others (eg, pupils) from health risks arising from exposure to hazardous substances, including airborne contaminants, a duty which is further defined by the COSHH Regulations.¹² School science involves the handling and use of substances which are hazardous to health. The COSHH Regulation 6 requires that

- (1) *An employer shall not carry out any work which is liable to expose any employees to any substance hazardous to health unless he has:*
- (a) *Made a suitable and sufficient assessment of the risk created by that work to the health of those employees and of the steps that need to be taken to meet the requirements of these Regulations.*

In school science, by handling materials and undertaking the relevant activities within a fume cupboard, exposure to airborne contaminants can be minimised and, in many cases, more or less prevented. Model risk assessments, such as those in publications from CLEAPSS¹³, SSERC¹⁴ (in Scotland), ASE¹⁵, and procedures in books and online websites¹⁶ which have been rigorously risk assessed specify when a fume cupboard should be used.

7.3 Duties of employees

The employer's safety policy should make it clear who has the function of seeing that these risk assessments are followed. It is likely to be the head of science or someone to whom the function has been specifically delegated.

¹¹ Legally, the employer is the body with whom an employee has a contract of employment.

¹² *The Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved code of practice and guidance*, Health & Safety Executive, 2005, ISBN 9780717629817. Available for free download at <http://www.hse.gov.uk/pubns/books/l5.htm>

¹³ *Hazcards*, (and other publications) available to members of CLEAPSS. CLEAPSS, The Gardiner Building, Brunel Science Park, Kingston Lane, Uxbridge, UB8 3PQ; Tel: 01895 251496; Fax: 0185 814372; E-mail: science@cleapss.org.uk; Web site: www.cleapss.org.uk.

¹⁴ <http://www.sserc.org.uk/>

¹⁵ *Topics in Safety*, 3rd edition 2001, ASE, ISBN 9780863573163. Association for Science Education, College Lane Hatfield, Hertfordshire, AL10 9AA; Tel: 01707 267411; Fax: 01707 266532; E-mail: in fo@ase.org.uk; Web site: www.ase.org.uk. There is a rolling programme of up-dating *Topics* from the 2001 edition and posting these on the members' part of the web site <http://www.ase.org.uk/resources/health-and-safety-resources/revised-topics-in-safety/>

¹⁶ For example, www.practicalchemistry.org.

As well as the general obligation of school staff to follow their employer's safety guidance, employees have a specific duty under COSHH Regulation 8(2) to use control measures, including fume cupboards as instructed when risk assessments require it and to report any defects which may arise.

7.4 Non-employees including pupils

Under section 3 of the Health & Safety at Work etc Act, employers have a duty to ensure that persons not in their employment (such as pupils) are not exposed to risks to their health and safety. There is a similar duty under regulation 3 of the COSHH Regulations. School employers' risk assessments must consider the risks to pupils and include suitable control measures. Pupils must adopt all relevant control measures specified in the risk assessments, including the use of fume cupboards. To ensure compliance, pupils, however senior, should normally only be allowed to carry out practical work under the supervision of a suitably qualified or trained employee.

7.5 Standard for the school fume cupboard

The standard for fume cupboards is covered by the European Standard EN 14175, which was adopted as the British Standard BS EN 14175 in 2003 replacing the previous BS 7258. However, this is a very wide standard, under which many designs would be permitted. There are advantages in specifying, within the limits of BS EN 14175, a more precise standard for school fume cupboards, which closely matches the type of work carried out in them. For example, some fume cupboards compliant with the BS EN 14175 have airflow rates which cause instability of Bunsen burner flames, and may extinguish them. Hence they are unsuitable for school use.

A detailed study¹⁷ was carried out on the rate of release of fumes and gases from almost all known school operations involving hazardous vapours and gases, and certainly all the common ones. To produce a margin of safety, the quantities used in the tests were significantly in excess of those that schools normally use. In preparing this document, the original research was reviewed in the light of changing practices in schools, changing legislation and CLEAPSS experience in dealing with fume cupboards over many years. The recommendations in this publication on average face velocity and variation in face velocities, the sash heights, filter efficiency, siting of the fume cupboard, etc are based on the results of those tests in conjunction with the British Standard. They are sufficient to give adequate containment to satisfy the requirements of the risk assessment.

Fume cupboards shall be designed such that:

- *hazardous concentrations or quantities of airborne contaminants are prevented from escaping from the fume cupboard into the room;*
- *fumes are removed efficiently to reduce the susceptibility to an explosive or hazardous atmosphere inside the workspace;*
- *the user is protected by a front sash against splashes of substances and flying particles.*

BS EN 14175-2:2003, SECTION 5

¹⁷ 'School Fume Cupboards', J R Crellin, *Education in Chemistry* 21 (6), November 1984, pp 185-8 and later unpublished work carried out by CLEAPSS.

A fume cupboard conforming to this publication is suitable for school use in that

- it will contain hazardous gases and not allow the operator to be exposed to them, and
- it will reduce the risk of Bunsen burner flames being extinguished by the incoming air.

In 2011, the Health & Safety Executive published the 2nd edition of *Controlling Airborne Contaminants at Work, HSG258*¹⁸ which describes the principles and good practice of deciding on, designing, commissioning and testing cost-effective LEV. The original *Building Bulletin 88* contained much that is now expressed in the HSE document. Its guidance has therefore largely been followed except where, in the experience of CLEAPSS, there are good reasons to deviate as far as schools are concerned.

7.6 Installation, information and training

7.6.1 Documentation to be provided by suppliers

Section 6¹⁹ of the Health & Safety at Work, etc Act requires suppliers to provide articles which are safe and without risks to health. Further, they have to provide, with articles supplied, **Instructions for their Safe Use**. For fume cupboards, this should cover any restrictions on their use: eg, gases which cannot be contained or releases too large to be contained. It should also cover the necessary monitoring and maintenance procedures, eg, tests of filter saturation. A summary of this information, as described in paragraph 6.5 should be prominently and permanently displayed on the fume cupboard, not hidden in the back of a handbook.

Suppliers should also provide a **User Manual** and a **Logbook** for the fume cupboard to record the findings of checks and maintenance and a **Commissioning Report** (see 7.6.2).

7.6.2 Installing and commissioning fume cupboards

The installers of the fume cupboard should preferably be the suppliers. Whoever does it, the fume cupboard must be installed safely. The people who commission the fume cupboard may be the same as the installers and/or suppliers. They should check the fume cupboard is working to the agreed supplier quotation, taking account of guidance in this publication. The report should include:

- diagrams and a description of the LEV, including test points;
- details of the LEV performance specification;
- results, such as pressures and velocities at stated points and noise levels;
- calculations;
- written descriptions of the commissioning, the tests undertaken, and the outcome, including a prominent and clear statement **SAFE TO USE**.
- a description of how operators should use the system so it works effectively.

The report is the benchmark against which future performance is judged.

¹⁸ *Controlling Airborne Contaminants at Work, HSG258* (2nd edition), HSE, 2011, ISBN 978 0 7176 6415 3. All Health & Safety Executive documents are available as a free download.

¹⁹ As amended by the *Consumer Protection Act 1987*, ISBN 10:010 5443875, (see http://www.opsi.gov.uk/RevisedStatutes/Acts/ukpga/1987/cukpga_19870043_en_1) and modified by the *Health and Safety (Leasing Arrangements) Regulations 1992*, (http://www.opsi.gov.uk/si/si1992/Uksi_19921524_en_1.htm).

7.6.3 Training users

The Health & Safety at Work, etc Act requires adequate health and safety training for employees; Regulation 12 of the COSHH Regulations specify adequate training for those who might be exposed to hazardous substances. HSG 258 suggests that suppliers include user instructions in the User Manual and provide specific training if needed. In the experience of CLEAPSS, problems sometimes arise when members of a school staff have not had adequate training in the use of a newly-installed fume cupboard. Therefore, users of school fume cupboards should be instructed to use fume cupboards when the risk assessments provided by the employer require it and trained in the safe use of the fume cupboards available in the school.

7.7 Fume cupboards in use

7.7.1 The need for fume cupboard maintenance, examination and testing

It is important to distinguish the regular checking and routine maintenance of fume cupboards from the annual (14-month) thorough examination and test although both might be carried out by the same person.

COSHH Regulation 9 (1) (a) requires that equipment to control exposure is

maintained in an efficient state, in efficient working order, in good repair and in clean condition.

Section 8 of this publication gives guidance on suitable procedures for school fume cupboards.

COSHH Regulation 9(2)(a) requires that the employer

shall ensure that thorough examination and testing of those [engineering] controls is carried out in the case of local exhaust ventilation plant at least once every 14 months.

The CLEAPSS interpretation is that this should be done every year, with a bit of flexibility.

The *Approved Code of Practice* (ACOP) to these Regulations states in paragraph 175 that

the examination and test should be sufficient to ensure that the LEV plant (ie, fume cupboard) can continue to perform as intended by design and will contribute to the adequate control of exposure

Detailed guidance is provided by the HSE in *Controlling Airborne Contaminants at Work*²⁰ (HSG258). Every employer's LEV system requires statutory 'thorough examination and testing' by a competent person. (HSG258 chapter 10). 'Thorough' means a detailed and systematic examination sufficient to ensure that the fume cupboard can continue to perform as intended (HSG258 paragraph 327).

The examiner needs to know the following according to HSG258 (paragraph 23).

- The parts of a fume cupboard and their function.
- The legal requirements for the thorough examination and testing of fume cupboards.
- How to recognise a damaged part from a visual inspection.
- The purpose of, and how to use, the measuring and assessment instruments and techniques.
- The standard to which each part of the fume cupboard should perform.

20 *Controlling Airborne Contaminants at Work*, HSG258 (2nd edition), 2011, Health & Safety Executive, ISBN, 978 0 7176 6415 3.

- How to recognise when a part of the fume cupboard is performing unsatisfactorily, based on the measurements taken and assessment methods used.
- How to assess whether the fume cupboard is effectively reducing airborne contaminant emission and operator exposure.
- How to collate and record information in a clear, concise and useable way.
- How to work safely with the fume cupboards and the hazards associated with it.

Section 8 of this guide interprets these requirements for the benefit of those carrying out a thorough examination and test of school fume cupboards.

COSHH Regulation 9 (4) requires that

Every employer shall keep a suitable record of the examinations and tests ... and that record or a suitable summary thereof shall be kept available for at least 5 years from the date on which it was made.

7.7.2 Who carries out maintenance and thorough examination and testing?

COSHH Regulation 12(4) requires that

Every employer shall ensure ... any person ... who carries out work ... under these Regulations ... has suitable and sufficient information, instruction and training.

The *Management of Health and Safety at Work Regulations* 1999 (MHSWR) state that an employer should be competent for health and safety purposes or employ or obtain advice from competent people. People are seen as competent where they have enough training and experience or knowledge and other qualities to enable them 'properly to assist in undertaking the measures referred to'.

Sometimes, local authorities or school governors (if they are the employer) will employ an engineer or consultant, sometimes on the advice of an insurance company to carry out the thorough examination and test. However, unless the LEV system is a complicated multi-branch system, there is **no** reason why a trained school laboratory technician will not have the competence to carry out routine maintenance and the statutory thorough examination and test, provided that there is a procedure for referring borderline cases or inexplicable behaviour to a person or agency with more experience.

Paragraph 31 of HSG258 states that "... those wishing to improve their LEV knowledge and skills should consider attending a suitable training course providing qualifications such as those provided the Institution of Local Exhaust Ventilation Engineers or the British Occupational Hygiene Society."

As a result, some people have claimed claim that individuals are only competent to undertake the thorough examination and test if they have attended and passed a specific course, for example a BOHS (British Occupational Hygiene Society) P601 course. This is **not** correct and indeed CLEAPSS has evidence that some trained on such courses have applied quite inappropriate standards to school fume cupboards. HSE policy is clearly laid out on the HSE web site²¹. Specific qualifications are not required but the person undertaking the work needs to be competent. This

comes from a combination of knowledge, skills and experience.

²¹ See <http://www.hse.gov.uk/lev/faqs.htm>.

As long as the person undertaking the thorough examination and test fulfils these criteria and is properly supervised then a competent job should be done. Attendance at the CLEAPSS Fume Cupboard Testing course (which is specifically intended for those in member schools who are testing school fume cupboards) may well be a better alternative.

Although school technicians are, with suitable training, capable of carrying out a thorough examination and test, CLEAPSS can supply members with a list of companies which will carry out the work in its guidance leaflet PS48, *Fume Cupboard-Testing Contractors*.

Technicians who check, maintain, or thoroughly examine and test fume cupboard performance are often worried that once they have carried out an examination, they are “responsible” for the cupboard from that moment on. This is **not** true. The employer is responsible for compliance with safety legislation and the technician is acting on their behalf. Providing the technician carries out the examination and test in accordance with clear instructions and training and unless s/he has been grossly incompetent and signed off a fume cupboard that is failing to protect users, then s/he does not bear personal responsibility.

8 Maintaining, examining and testing school fume cupboards

8.1 Routine maintenance and checks

For detailed legal requirements, see section 7.

The *COSHH Regulations* recommend that a fume cupboard be given a simple regular check to see that it is functioning correctly. In school and college laboratories, where fume cupboards are used at irregular intervals, it is best if simple checks are made by teachers or technicians before each use. This should be done before any procedures in the fume cupboard are started. Any user of a fume cupboard should ensure that it does indeed work and if there is any poor performance (eg, odours from a filtration fume cupboard are noticed), it should be reported immediately and further tests should be carried out.

The supplier's User Manual should contain suggestions for regular checks. These are likely to include looking for:

- Evidence of duct integrity, especially for flexible ducts
- Evidence of mechanical integrity, eg signs of corrosion, problems with sash suspension
- Cleanliness
- Illumination
- Unusual noise from the extraction system
- Evidence of satisfactory air flow
- Ensuring water is in the sink traps.

One means of checking for satisfactory air flow is to observe and listen to the audible air flow indicator which is now attached to all fume cupboards made to BS EN 14175:2 Section 8.2. The airflow indicator should be observed to see that the flow of air is in the correct direction and adequate for the procedure. Fume cupboards made to previous standards will not have an electronic or audible device but it is possible to buy cheap anemometers²² which can be moved from cupboard to cupboard or even fixed to each cupboard, although these are not accurate enough for the statutory thorough examination and test.

8.2 Statutory thorough examination and test

Those undertaking the thorough examination and testing of a fume cupboard must be competent to do so. A school fume cupboard is a relatively simple device and people carrying out the thorough examination and test of it may require only:

- an understanding of relevant best practice;
- an awareness of the limitations of their own experience and knowledge; and
- the willingness and ability to supplement existing experience.

²² For example, the M480 (metric version) of the Vaneometer (a swing vane anemometer) costs about £35 and is available from Dwyer Instruments Limited, Unit 16, The Wye Estate, London Road, High Wycombe, Bucks HP11 1LH. Tel: 01494 461707, Fax: 01494 465102, Email: sales@dwyer-inst.co.uk.

The thorough examination and test may be carried out by

- *an outside contractor; or*
- *a competent employee of the [fume cupboard] owner*

HSG258 PARAGRAPH 327

With suitable training, school technicians are perfectly capable of carrying it out (see section 7.7.2).

The examination of a school fume cupboard should follow the guidance in section 9.2 which summarises what is to be done. The equipment used for testing fume cupboard is shown in section 9.1. Any newer or alternative versions should meet the requirements as demonstrated by this equipment. Details of the examination and individual tests are described in sections 9.3 to 9.4 and suitable recording forms for use are given in section 9.5.

The examination and testing will:

- ensure that the fume cupboard has a User Manual which includes the results of the commissioning test
- a log book which records the annual tests from previous years (the examination will look for any deterioration of the fume cupboard compared to previous years);
- produce a report of a visual inspection;
- measure the noise level of the fume cupboard;
- measure the face velocity in 9 separate positions with the sash set at 400 mm (or the working aperture specified by the manufacturer);
- identify the upper and lower variation of face velocities;
- measure the face velocity in 3 separate positions when the sash is reduced to 200 mm;

A report will then be produced (see section 9.6). The report should state clearly that the fume cupboard is still performing in accordance with the original specification and/or the commissioning or initial test data. A copy of that report will be filed in the fume cupboard User Manual. The fume cupboard examiner and the employer (or representative of the employer) will keep further copies. The report of the thorough examination and test must be kept for a minimum of 5 years.

8.2.1 Additional measures for recirculatory filter fume cupboards

It is necessary to replace filters from time to time, either in accordance with an agreed schedule or as a result of a test showing it has lost too much absorption capacity. CLEAPSS has encountered cases where filters have not been replaced sufficiently often for the following reasons:

- No initial training was provided by the supplier and hence nobody realised filters needed replacing;
- Staff turnover resulted in expertise being lost;
- Schools were trying to save money.

In the past CLEAPSS has recommended²³ that for recirculatory filter fume cupboards the seal of the filter should be tested by measuring the containment of organic gases and vapours and the efficiency of the filter tested by measuring the containment of acidic and/or alkaline gases.

These tests have been questioned on the grounds that the procedures are complex (hence unlikely to be used), employ hazardous chemicals and are unnecessary because alternatives exist.

Having reviewed the matter CLEAPSS can confirm that many schools and independent contractors do in fact carry out such tests. Nevertheless it may be possible to avoid testing the seal if the seal is examined for small gaps before inserting a filter and great care is taken to avoid causing damage to the seal when inserting the filter. However, if any doubts arise, eg if any odours are detected after a new filter is inserted, it may still be necessary to test for containment.

Trichlorethene was recommended for leak testing in the previous version of this document. There are serious health and safety concerns over the use of trichloroethene. It is a category 1B carcinogen and a category 2 mutagen and under the GHS/CLP Regulations it carries the Signal Word DANGER and Hazard Statements H350, H341, H319, H315, H336. It has also been identified as a Substance of Very High Concern (SVHC) and has recently been added to the REACH Authorisation List with a sunset date of April 2016, after which it will no longer be possible to purchase it, except for any exempted uses. It is used in this test because its presence can be detected at very low levels – because it is so toxic, gas detector tubes have been developed which are extremely sensitive.

Methylbenzene (toluene) has been suggested as a safer alternative. CLEAPSS has investigated this and found that, unlike trichlorethene (or sulfur dioxide), methylbenzene cannot detect small leaks. Presumably this is because with a small leak most of the contaminant still passes through the filter and if it is strongly absorbed by the filter the total concentration which gets through the cupboard is not detectable.

Alternatively, propan-2-ol (iso-propanol, IPA) might be used but that would require an electronic detector which would be too expensive for occasional use by schools although it might be appropriate for contractors. CLEAPSS has not investigated how efficient propan-2-ol is at detecting small leaks.

Following recent investigations, CLEAPSS now considers that tetrachlorethene²⁴ may be the best option for those carrying out leak-testing in schools. Under the GHS/CLP Regulations it carries the Signal Word WARNING and Hazard Statements H315, H351, H411, making it less hazardous than trichlorethene. It is widely used in dry-cleaning.

As an alternative to testing filter saturation, it has been suggested that the likely lifetime of a filter could be estimated knowing the standard experiments used in schools given standard school syllabuses. CLEAPSS had considered this impractical because there would be too many variables – how many laboratories a fume cupboard is shared between, how much emphasis a school places on practical work, whether or not there is a 6th form, etc, quite apart from frequently changing curricula. However, some employers/contractors have successfully adopted an alternative procedure whereby the filter is replaced at regular intervals of 1, 2 or 3 years, usually

²³ This advice also appeared in *Building Bulletin 88 Fume Cupboards in Schools* (DfEE Architects & Building Branch, 1998).

²⁴ Also known as tetrachloroethylene.

at the time of the statutory annual thorough examination and test. In 2012/13 CLEAPSS carried out a survey in approximately 140 schools/colleges about how long a filter lasts in their experience. A few had lasted more than 10 years, which is probably a comment on how little practical work is done in some schools.

However, CLEAPSS now recommends that for most schools, testing for filter saturation can be avoided if

- **Filters in fume cupboards with normal use, used in teaching laboratories, are changed every 4 years.**
- **Filters in fume cupboards with heavy use, used in teaching laboratories, are changed every 3 years.**
- **Filters in fume cupboards used in prep. rooms are changed every 2 years**

This would result in filters often being replaced before the end of their working life but accords with practice in other industries, eg the recommendations of the National Environmental Research Council. However, testing (or replacement of filters before the 2/4-year deadline) may still be required if a school places a heavy emphasis on practical work or if there is any suspicion of filter saturation or a poor seal, eg the detection of odours. (Note this is not an infallible test, as the human nose varies considerably in sensitivity and some substances can only be detected at levels approaching the Workplace Exposure Limit).

Thus the examination and testing will include the following additional items for recirculatory filtration fume cupboards:

EITHER

- check the records showing when the filter was last changed;
- change the filter if the 2-/3-/4-year period for that fume cupboard is up;
- check the condition of the seal if replacing the filter.

OR

- if it has been decided that the 2-/3-/4-year replacement period is inappropriate or if concerns have been raised about possible filter saturation or a poor seal, test the seal of the filter using tetrachlorethene, methylbenzene (toluene) [or propan-2-ol (iso-propanol, IPA) if suitably sensitive detection equipment is available]
- and the containment of acidic and/or alkaline gases using sulfur dioxide and/or ammonia (see sections 9.3 and 9.4).

8.3 Failure to pass the thorough examination and test

A fume cupboard should meet the following basic standards:

- Adequate air flow is maintained
- Fixed parts, eg internal surfaces, are in satisfactory condition
- Moving parts, eg sash, fan, are in satisfactory condition
- (for recirculatory filtration fume cupboards only) the filter should prevent sufficient airborne contaminants from entering the laboratory.

While school laboratory technicians are perfectly capable of seeing if a fume cupboard meets simple criteria, it is essential that there is a procedure for reporting borderline cases, inexplicable behaviour or damage to someone more experienced. CLEAPSS staff can often help, in the first instance, if member schools contact CLEAPSS before a specialist company is called in.

It is important that a fume cupboard which fails to meet the standards stipulated in section 9 of this guide is not used until it is repaired or upgraded so that it does meet the standards.

Alternatively, the operations carried out should be reviewed and a new assessment made of the risks of exposure; restricting the operations in various ways might enable some to be carried out but the onus would be on the employer to ensure that users were adequately protected.

A fume cupboard which fails to meet standards should be appropriately labelled as out of use or to be used only for carefully-defined, restricted operations.

School fume cupboards are not used every day, unlike those in industry, so older schools will still have systems which may be up 40 years old. If that cupboard is still providing users with good exposure control, then there is no reason to stop using it. Some simple improvements can be achieved such as putting in a lip to stop liquids pouring out and perhaps to smooth airflow entry. For around £300 it is possible to retro-fit airflow sensors to older fume cupboards which do not have an electronic or audible device. Alternatively about £35 will purchase a simple anemometer which gives a rough indication of the air-flow rate. If improvements are made then they should be according to the specification in this publication, *Fume Cupboards in Schools*. However, often it would be better to start again with a new fume cupboard.

9 Procedures for examining and testing school fume cupboards

9.1 Equipment

9.1.1 Anemometer

An anemometer measures the air velocity. There are two main types: rotary vane and hot wire. The easiest to use is a rotary vane anemometer which should be able to detect air velocity between 0.25 and 1.00 m s^{-1} (to 2 decimal places). Avoid cheap machines (certainly any costing less than £100) because it is unlikely they will be able to measure air velocity at relevant speeds with sufficient accuracy for a thorough examination and test.

A typical rotary vane anemometer that can be used is the Airflow LCA301^{25, 26} (Figure 9.1). Any instrument used should come with a certificate of calibration, which should be renewed regularly. It is important to request more calibrations at velocities below 1 m s^{-1} .

The required frequency of calibration depends on use. Manufacturers usually recommend annual calibration but this is excessive for a rarely-used anemometer in a school. It is sometimes possible to compare the readings from one instrument with those of another, eg from a neighbouring school. If the values are the same, it can be assumed that both anemometers are still functioning satisfactorily.

If readings from the same fume cupboard, using the same instrument, are the same year on year, it is reasonable to assume that both are functioning satisfactorily. It is highly improbable that both would deteriorate at exactly the same rate such that the readings remained unchanged.



Figure 9.1 Vane anemometer

9.1.2 Sound meter

Sound level is not a critical measurement for safety but is useful to ensure that the teacher can be heard above the noise of the fan and teach effectively. Any sound meter used in the school will suffice or a mobile phone app may be used.

²⁵ This has replaced the Airflow 600RVT (cost is about £260). The 600RVT can still be calibrated and used, however. For details consult the *website* <http://www.airflowinstruments.co.uk/products/detail.aspx?Cid=4&Pid=99> or contact TSI Instruments Ltd, Stirling Road, High Wycombe, HP12 3RT, Tel: 01494459200, Fax: 01494 45970, e-mail: info@airflowinstruments.co.uk.

²⁶ This instrument can also be used for measuring the ventilation rates from extraction fans!

9.1.3 Smoke tubes (air current tubes) (if required)



Figure 9.2(a) Gastec



9.2(b) Draegar

Smoke tests, carefully used, can give a qualitative indication of unsatisfactory airflow. Use smoke tubes, not smoke bombs.

Gastec equipment is shown in *Figure 9.2(a)*, and Draegar equipment in *Figure 9.2(b)*. Alternatively, MSA smoke tubes use a less hazardous smoke.²⁷

9.1.4 Gas detecting apparatus

(for filtration fume cupboards only)

Figure 9.3 shows the Accuro Pump²⁸ from Draeger Safety UK Ltd with a sampling tube. The tube detects the concentration of a vapour in the atmosphere by showing a small colour change.

The catalogue numbers of the required tubes are:

6728491	sulfur dioxide
6728541	trichloroethene (trichloroethylene)*
8101501	tetrachloroethene (tetrachloroethylene)*
6733231	ammonia
CH25301	airflow test tubes.



Figure 9.3 Accuro pump & Draegar tubes



Figure 9.4 Gastec system

Figure 9.4 shows the Gastec system²⁹. A whole kit can be bought which includes the air current indicator. It works on a similar principle to the machine above.

The catalogue numbers of the required tubes are:

5LA	sulfur dioxide
132L	trichloroethylene*
133LL	tetrachloroethene*
3L	ammonia
G500	airflow test tubes.

*** You need EITHER tetrachloroethene (preferably) OR trichloroethene, not both.**

²⁷ Available, for example, from <http://www.sitebox.ltd.uk/msa-smoke-tubes-pack-of-12-ovs2mt12>

²⁸ Draeger Safety UK Ltd., Ullswater Close, Blyth, Riverside Business Park, Blyth, NE24 4RG, Tel: 01670 352891, Fax: 01670 356266, Web site: http://www.draeger.co.uk/STms/internet/site/MS/internet/UKen/ms/Products/Detection/Tubes/draeger_tubes.jsp

²⁹ Web site: <http://shop.a1-cbiss.com/catalogsearch/result/?q=GAS133LL>

9.2 Carrying out a thorough examination and test

9.2.1 Preliminary Information

The examiner needs to have the following information to hand.

- The commissioning report (or initial test data);
- The User Manual;
- The Log Book (may be part of the User Manual);
- Previous test reports; and
- General guidance on fume cupboard design.

The reality in many schools is that there may be no commissioning report, User Manual, Log Book or previous test reports available. In practice, most school fume cupboards, certainly those installed in the last 20 years, will – or should - have been designed in accordance with this publication or its predecessors. It is therefore reasonable in the absence of other documentation to take this publication (especially section 4) as setting a reasonable standard. In effect the thorough test and examination is being used as a form of retrospective commissioning.

9.2.2 Stage 1: A thorough visual and structural examination

Work surface and linings	<p>Is there any damage?</p> <p>If it is made of asbestos cement, has it been reported, particularly noting if dusty or flaking?</p> <p>Fail if it has the potential to produce significant asbestos dust levels in the room. Otherwise, consult the employer. Sealing it may be possible.</p>
Glazing	<p>Is it dirty?</p> <p>Are there any cracks or other damage?</p> <p>Is it plastic or glass? If glass, report if there is no evidence that it is safety glass: eg, no engraving on the glass or no statement from the supplier of the fume cupboard. (Explosions in fume cupboards are very rare so that the presence of ordinary glass is not a reason for failing the fume cupboard unless the employer stipulates it. It is possible to cover glass with safety film.)</p>
Baffle	<p>Is it dirty?</p> <p>Is there any damage?</p> <p>(Very old fume cupboards may not have a baffle. This is not a reason for failing the fume cupboard.)</p>
Sash mechanism	<p>Does it function satisfactorily?</p> <p>Are there signs of damage to the cables?</p> <p>Fail only if the sash is likely to descend rapidly, ie, one side is broken. Take steps to repair it before further deterioration.</p>

Sash limits	<p>Are there stops to:</p> <p>(a) limit the aperture to the correct maximum height?</p> <p>(b) prevent it being closed completely?</p> <p>(While stops should be fitted, labels indicating sash limits are temporarily acceptable. Take steps to fit stops. Fail only if the employer stipulates there must be stops; fix labels.)</p>
Electricity, gas, water and drainage services	<p>Is there any corrosion or damage which makes the services unsafe?</p> <p>Check the drip cup, trap and drain for signs of leaks, blockage, etc.</p> <p>Check that there is water in the trap (thus forming a seal).</p> <p>Check the pipes and wires under the fume cupboard.</p> <p>Fail only if there is a real possibility of a gas leak, of electric shock or of a spark from an electric circuit igniting the gas.</p>
Fan	<p>Is the direction of air flow correct?</p> <p>Is there any sound of excessive vibration? (Tests on the performance of the fan are in the next section.)</p> <p>Fail if the direction of the air flow is incorrect.</p>
Ducting (where visible)	<p>Are there any signs of damage, particularly to seals?</p> <p>Are there any reports of smells along its route?</p> <p>Fail if there is a significant leak at a point where the pressure inside the duct is above atmospheric.</p>
Duct exit (where visible)	<p>Is there anything which obstructs it or which might eventually obstruct it? (The extent of inspection possible will depend on the nature of the site at the exit and who is conducting the inspection.)</p> <p>Fail if the duct is obstructed, or about to be obstructed, by birds' nests, footballs, vegetation, etc</p>

9.2.3 Stage 2: Measuring technical performance

Measuring the face velocity

Do not attempt measurements on a windy day. Readings may be affected if doors are opened and shut elsewhere in the building. Arrange the ventilation of the room so that it is most unfavourable to extraction by the fume cupboard concerned, ie, shut all doors and windows and switch on any other fume cupboards and extraction fans³⁰.

You will need to measure the air velocity at 9 different points at a sash height of 400 mm. Lift the sash window to a height of 400 mm and imagine the face of the fume cupboard to be divided into nine sections. Stand to one side or as far away as possible from the fume cupboard with the sensing head of the anemometer in the plane of the sash and take airflow rate readings at

³⁰ In one small prep room, the effect of the mechanical ventilation situated about 5 m from the fume cupboard, was enough to draw air down the fume cupboard stack and reverse the airflow even when the fume cupboard was on! With the mechanical ventilation off, the fume cupboard passed the test. A very important warning notice had to be attached to the fume cupboard!

approximately the centres of the nine rectangles see *Figure 9.5(a)*. Modify the procedure if the aperture is not rectangular (see *Figure 9.5(b)*).

Record for each rectangle the approximate average reading over a period of at least 10 seconds, applying any correction from the calibration chart supplied with the meter.

Fail if any value is less than 0.3 m s^{-1} .

Calculate the average reading and also the variations between the average and the highest and lowest readings (for details, see section 9.6. Stage 2).

Fail also if the variation is excessive (eg, more than 30%) or if there is less variation (eg, 20%) but it tends to be at one side.

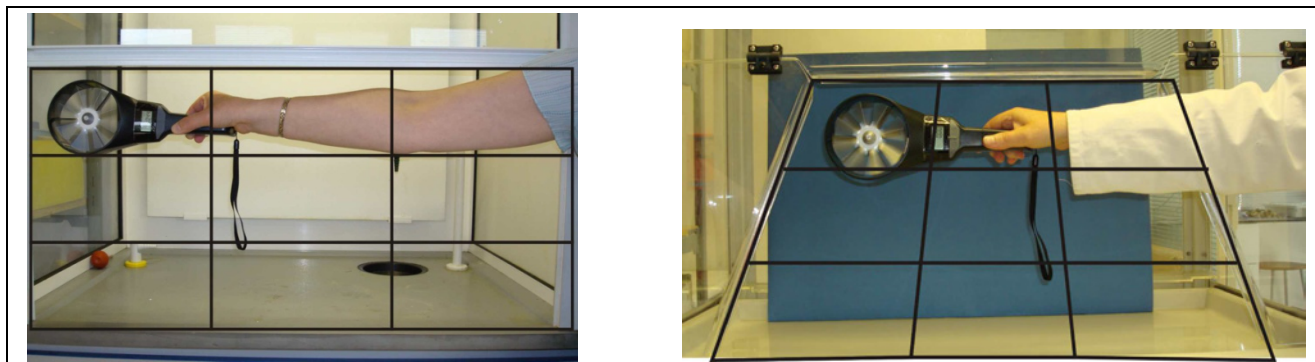


Figure 9.5 Measuring face velocity (a) rectangular aperture (b) trapezoidal aperture

If the fume cupboard **fails**, check the position of the damper or for re-circulatory (filtration) fume cupboards the condition of the pre-filter. If these are not the cause then seek specialist advice.

Check the bypass system

For systems with a bypass, lower the sash window to a height of 200 mm and imagine the face of the fume cupboard divided into three sections. Take measurements in these 3 sections, see *Figure 9.6*.

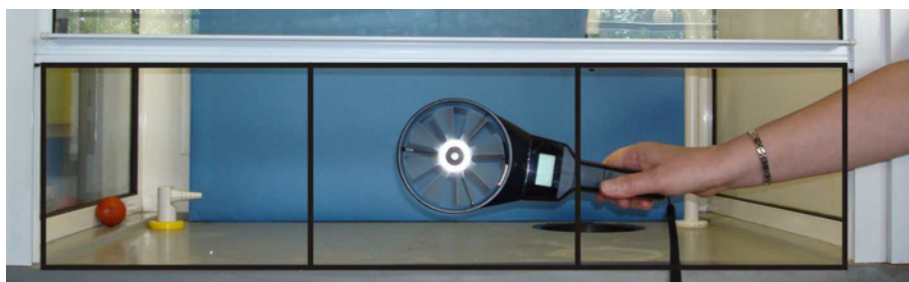


Figure 9.6 Testing efficiency of the bypass

A good bypass should not allow the face velocity to rise by more than 50% when the sash is lowered from its position at 400 mm to 200 mm.

Older fume cupboards **may fail** this test but this not enough to ban the use of the fume cupboard. Operators need to be warned that closing the sash may affect flames or even blow out a Bunsen burner.

Check any low velocity testing alarms (if fitted)

If a low velocity alarm is fitted, then it must be tested otherwise users may be lulled into a false sense of security. Consult the manual as to how this testing might be carried out.

Possible ways of reducing the airflow rate include:

- (for filtration and ducted fume cupboards) raising the sash window to full height;

- (for ducted fume cupboards) altering the position of the damper (NB: mark the original position of the damper before altering it); or
- (for filtration fume cupboard), partially covering the filter with sheets of paper.

If the alarm fails, the supplier should be contacted.

Check fume cupboard noise level

Close the laboratory door. Only the person carrying out the test should be present in the room and there should be no abnormal noise, eg from nearby building work.

Use a sound sensor or datalogger (which should be available in most science departments), or a mobile phone app (although some of these may not be very reliable).

With the sash set at a height of 200 mm, measure the sound level 1.5 m above the floor and 1.5 m from the sash, with the fume cupboard switched OFF. Repeat with the cupboard switched ON.. Sound levels should be less than 55 dB, ideally below 50 db. If it is more than this, the class will not be able to hear the teacher clearly. The problem may be solved by lowering the face velocity but only if this can be done whilst maintaining containment.

Note that this limit is more severe than in *Building Bulletin 88*, the predecessor of this guide, although as the measurement was done in a slightly different way, direct comparison is not possible. Sound levels above this limit are not a reason to FAIL the use of an existing fume cupboard (although newly-installed cupboards should be expected to comply when being commissioned) but teachers will need to be warned that they must not switch off the fume cupboard with toxic fumes inside to make themselves audible. Gradual deterioration over a period of years may indicate impending more serious problems.¹

9.2.4 Stage 3: Assessing control effectiveness

<p>Check the upper and lower variations in face</p>	<p>Fail if any reading varies by more than 30% from the average of the 9 values. Fail if more than one reading varies by more than 20% from the average of the 9 values, especially if they are at the same side of the cupboard. If the value is greater than about 20%, eddies may be formed and the hazardous gases will not be removed as quickly as they should be. Also, any movement outside the fume cupboard could let gases in the fume cupboard escape into the room. This is testing the effectiveness of the baffle (although it may also be affected by the aerodynamic design of the front of the cupboard).</p> <p>If the fume cupboard fails this test, users should be informed, and a fume cupboard repairer should be contacted. The cupboard should normally be taken out of use although it may be possible to continue using it for some operations following a new risk assessment.</p>
<p>A smoke test (optional)</p>	<p>The fume cupboard may not be able to cope with a sudden release of smoke. For a recirculatory filter fume cupboard, unless a HEPA filter is fitted (not normal in schools), smoke may pass through the pre-filter.</p> <p>Smoke should be released gently around the perimeter of the sash opening. If smoke can be seen to escape from the fume cupboard this is a Fail. The operator is also looking for stalling of the smoke and eddies around the sash opening perimeter. This will illustrate the removal (or not) of hazardous gases from the fume cupboard. Note that a smoke machine (which produces significantly more smoke than a smoke tube) could be used could be used to fill the fume cupboard and look for leakage.</p>
<p>Observations of employees using the fume cupboard</p>	<p>Users may comment about the performance of the fume cupboard and these should be in the Log Book.</p> <p>For recirculatory filter fume cupboards especially be alert to complaints about odours, which may indicate a filter approaching saturation or a damaged seal. (It may also show that staff are using the fume cupboard incorrectly!)</p>

<p>Filter efficiency tests (for re-circulatory [filtration] fume cupboards only)</p>	<p>CLEAPSS now recommends that filter efficiency tests can be avoided if</p> <ul style="list-style-type: none"> • Filters in fume cupboards with normal use, used in teaching laboratories, are changed every 4 years. • Filters in fume cupboards with heavy use, used in teaching laboratories, are changed every 3 years. • Filters in fume cupboards used in prep. rooms are changed every 2 years <p>However, tests may still be necessary if schools place a heavy emphasis on practical work or if there are suspicions of filter saturation or a leak around the seal.</p> <p>The tests, if used, are carried out with hazardous chemicals and great care should be taken. An experienced senior technician or teacher of chemistry should be able to follow the instructions. It needs to be carried out when there are likely to be no interruptions. CLEAPSS runs a suitable training course: teachers and technicians in member schools should contact CLEAPSS for further details.</p> <p>For the tests to be successful, a chemical gas or vapour needs to be produced at a constant rate in the fume cupboard. The gas will then pass through the filter and hopefully be absorbed. The concentration of gas emitted through the filter is measured using a gas detector tube. The length of tube which changes colour gives a measure of the concentration of gas, working on a similar principle to a breathalyser.</p> <p>There are two reasons a filter can fail this test:</p> <ul style="list-style-type: none"> • the filter is incorrectly seated within the fume cupboard and the gas finds the least line of resistance and bypasses the filter altogether (how likely this is varies from model to model); • the absorbing sites in the filter will gradually become neutralised and the number of these sites will fall leading to a gradual lowering in efficiency of the filter. <p>Sulfur dioxide is used to test the saturation of the filter as sulfur can be burned at a steady rate but it can also be used to test the integrity of the seal at the same time. Originally the test was carried out using small sulfur dioxide canisters but these are no longer available. Companies who carry out the tests on behalf of employers may use sulfur dioxide gas cylinders.</p> <p>Tetrachlorethene (or in the past trichlorethene) can be used to test the integrity of the seal using gas detection tubes. CLEAPSS has found that these give very similar results to sulfur dioxide.</p> <p>Ammonia is used to test the efficiency of a filter with regard to alkaline gases.</p>
---	--

9.3 Testing the seating of the filter using polychloroethenes³¹

9.3.1 When to do the test

- When commissioning a new fume cupboard or when a new filter is fitted (to check it is correctly seated);
- (optionally) at the regular 14-month thorough examination and test.

9.3.2 What you need

- a gas detection kit
- a balance weighing to 0.1 g or better
- about 25 to 35 ml of a polychloroethene (*either* tetrachloroethene³² (preferred) *or* trichloroethene³³ (see CLEAPSS Hazcard 99))
- a stop clock
- a 100 ml narrow-neck conical flask and a bung
- anti-bumping granules
- 250 ml beaker with about 25 ml of cold water
- a cloth (or paper towel)
- an electric hot plate or a Bunsen burner, tripod, gauze and heat-resistant mat

9.3.3 Procedure

- Locate the exhaust vent or port.
- Wearing eye protection, pour about 25 ml of your chosen polychloroethene into the conical flask containing a few anti-bumping granules.
- Inset the bung and find the overall mass, m_1 grams.
- In the fume cupboard either switch on the hot plate or set up the Bunsen burner, tripod and gauze and light the gas. Switch on the fume cupboard, remove the bung from the flask and



Figure 9.7 Testing with polychloroethenes

³¹ CLEAPSS has recommended the use of trichloroethene in the past but there are serious health and safety concerns over its use. It is a category 1B carcinogen and a category 2 mutagen and under the GHS/CLP Regulations it carries the Hazard Statements H350 (May cause cancer) and H341 (suspected of causing genetic effects). It has also been identified as a Substance of Very High Concern (SVHC) and has recently been added to the REACH Authorisation List, with a sunset date of April 2016, after which it will be impossible to purchase except for any exempted uses.. Tetrachloroethene is a category 2 carcinogen. Under the GHS/CLP Regulations it carries the Hazard Statement H351 (suspected of causing cancer). The latter seems to be a safer alternative to trichloroethene. It appears to give similar results to trichloroethene and so under the COSHH Regulations should be used as the safer alternative. These liquids are used in this test because their presence can be detected as very low levels – because it is so toxic, gas detector tubes have been developed which are extremely sensitive. Both butane and methanol have been suggested as alternatives but currently there are no detector tubes available which are quite as sensitive. Methylbenzene (toluene) has also been suggested but CLEAPSS has found that it fails to detect small leaks, which are detected by tetrachloroethene, trichloroethene and sulfur dioxide.

³² Tetrachloroethene (C_2Cl_4) is also known as tetrachloroethylene.

³³ Trichloroethene, CCl_2CHCl (or C_2HCl_3) is also known as 1,1,2-trichloroethene, trichloroethylene or 1,1,2-trichloroethylene. Do not confuse this with 1,1,1-trichloroethane, CH_3CCl_3 (or $C_2H_3Cl_3$) which is not available from suppliers.

place the flask on the hot plate or gauze. See *Figure 9.7*.

- As the polychloroethene begins to boil, the vapour condenses on the cooler parts of the flask forming a boundary line. When the boundary reaches the top of the flask, start the stop clock.
- After about 60 seconds, begin to take a reading of the concentration of polychloroethene in the exhaust gas, using the pump and analyser tube³⁴ (see *Figure 9.8*). If the seal around the filter is poor, excess harmful vapour may be emitted from the exhaust. If this occurs, the operator should stop the test, open the windows, leave the room and report the problem to her/his line manager.
- Record the reading on the detection tube, c ppm.
- After taking the reading on the detection tube, switch off the hot plate or turn off the Bunsen burner.
- Stop the clock and record the time of the run, t seconds.
- Handling the hot conical flask with care (use the cloth), place it into the beaker of cold water in the fume cupboard and replace the bung (see *Figure 9.9*).
- After about 3 minutes, remove the flask from the water, dry the outside of the conical flask and find the mass of the flask, contents and bung, m_2 g .
- Calculate the rate of release of polychloroethene vapour from the conical flask, R , according to the following equation.



Figure 9.8 Taking reading of polychloroethene concentration in exhaust gas



Figure 9.9 Cooling the hot flask

$$R = \frac{(m_1 - m_2)}{t} \times f \text{ cm}^3 \text{ s}^{-1}$$

where $f = 145$ for tetrachloroethene and $f = 183$ trichloroethene³⁵

³⁴ The analyser tube is placed in the stream of the exhaust gas. The fume cupboard used in the picture had a special hole to do this.

³⁵ The factor of 145 (for tetrachloroethene) or 183 (for trichloroethene) converts the mass of liquid into the volume of vapour.

9.3.4 Interpreting the results

Compare the calculated value of the rate, R , and the concentration of polychloroethene vapour in the exhaust gas with the data in Table 9.1. If the concentration of polychloroethene vapour at the relevant release rate is greater than the corresponding value in Table 9.1, the filter is not properly seated or a new filter is required³⁶.

Table 9.1: Safe filter efficiencies for polychloroethene

<i>Rate of polychloroethene vapour release / $\text{cm}^3 \text{s}^{-1}$</i>	<i>Maximum permitted concentration of polychloroethene vapour in the exhaust gas / ppm</i>
10	4
15	6
20	9
25	11
30	13
35	16
40	18
45	20

Although 96% efficiency would not cause problems with tetrachloroethane or trichloroethene, in practice neither these nor other organic solvents present much of a challenge to school fume cupboards, as the quantities used are normally small. The polychloroethene is being used here to test for leaks, ie the seating of the filter in the fume cupboard, and so the acceptable efficiency should be set at a level that would be acceptable for any of the likely gases used in a school fume cupboard. For sulfur dioxide this would be 98%.

³⁶ This assumes that the efficiency of the filter has dropped to 96% for polychloroethene; at this level the fume cupboard will still not emit a dangerous level of organic vapour for the substances likely to be used in a normal-sized laboratory.

9.4 Testing the filter for saturation by acid gases

9.4.1 When to do the test

- Not needed if a decision has been made to replace the filter at regular intervals and if there is no reason to suspect the filter is not absorbing a sufficient fraction of the contaminant;
- Also not needed if a decision has been made to replace the filter automatically even before the normal replacement period, if there are reasons to suspect the filter is not absorbing a sufficient fraction of the contaminant;
- Otherwise, test at the regular 14-month thorough examination and test;
- Or test if the filter is suspected of being saturated, eg because of complaints about odours.

9.4.2 What you need

- powdered roll sulfur (150 - 200 g)
- a mortar and pestle
- a flat-bottom, porcelain evaporating basin
- a gas detection kit
- a balance weighing to 0.1 g or better
- two gauze mats with ceramic centres
- a stop clock
- a ruler
- a Bunsen burner, tripod and heat-resistant mat

9.4.3 Procedure

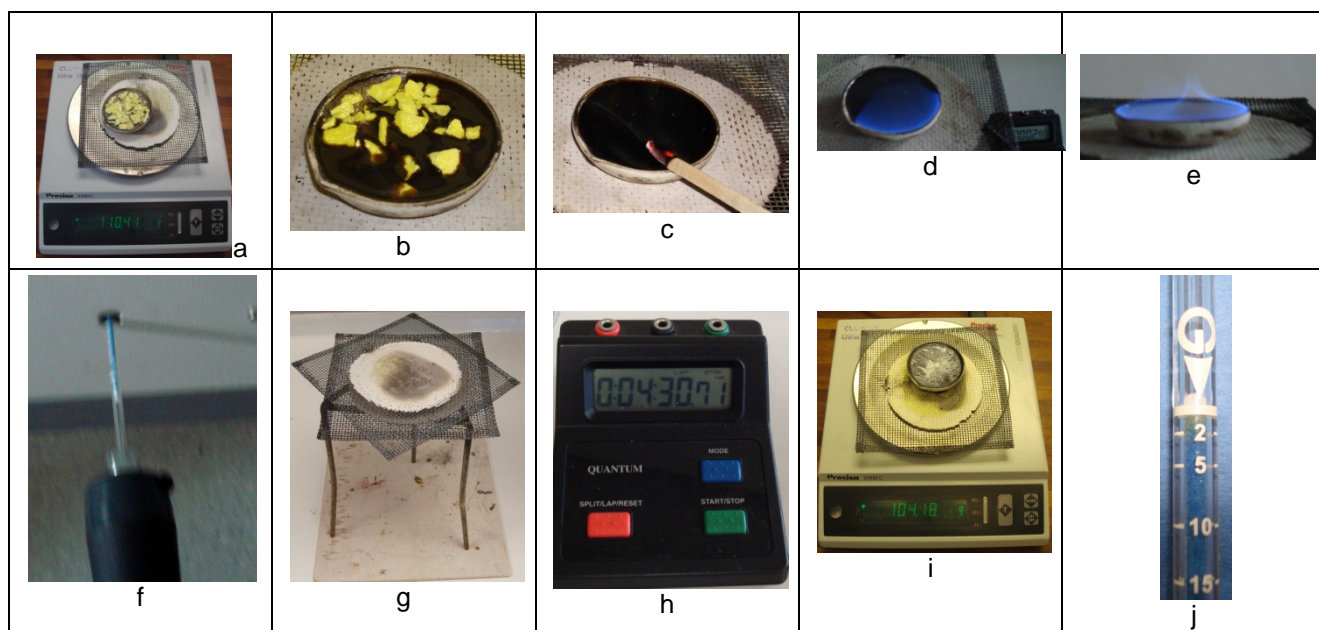


Figure 9.10 Testing filter saturation by burning sulfur

- Wear eye protection.
- Take 150 – 200g of roll sulfur and powder it in a mortar with a pestle.
- Fill the flat-bottom porcelain evaporating basin with the sulfur so that it is level with the rim.
- Weigh the porcelain basin containing the sulfur with one of the gauzes (see *Figure 9.10(a)*). Record this mass, m_1 g.
- Set up the Bunsen burner, tripod, the **other** gauze and the evaporating basin on a heat-resistant mat so that the centre of the basin is **5 cm inside the front rim of the fume cupboard aperture** (see *Figure 9.11*). This places the sulfur in the maximum incoming draught and encourages complete combustion. Switch on the fume cupboard.

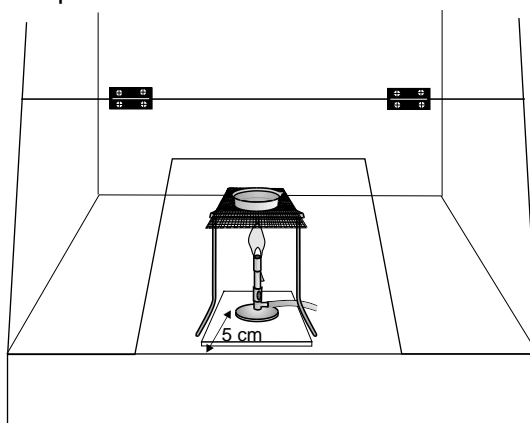


Figure 9.11 Arrangement for burning the sulfur

- Light the Bunsen burner with the gas tap half-open and the collar open enough so that the flame is non-luminous. The incoming draught may require that the burner is placed slightly further forward rather than directly under the centre of the basin. The sulfur will melt slowly (see *Figure 9.10 (b)*) to a pale amber liquid. **Extreme care is now required not to knock the tripod base with your hands or the Bunsen burner; molten sulfur can cause severe burns.**
- Adjust the collar of the Bunsen burner so that it is now half open. (The liquid will quickly darken.) Changes in the appearance of the liquid surface indicate that burning is about to

start. Sulfur burns with a blue flame. It often catches fire on its own but if not, apply a lighted wooden splint to the surface (see *Figure 9.10(c)*).

- **Start** the stop clock when half of the surface of sulfur is burning (see *Figure 9.10 (d)*).
- **Immediately turn off the Bunsen burner at the gas tap.** The flame above the sulfur often has two coloured areas, the inner brown flame of incomplete combustion and the outer blue flame of complete combustion. Extinguishing the Bunsen burner should cause the area of brown flame to diminish, leaving the blue flame covering almost the entire surface (see *Figure 9.10 (e)*).
- After 60 seconds, take a reading of the concentration of the sulfur dioxide being emitted through the exhaust with the gas detection kit surface (see *Figure 9.10 (f)*). **A slight smell of sulfur dioxide should be ignored but, if the exhaust gas causes breathing difficulties, stop the test, open the windows, leave and lock the room. This incident should be reported to the line manager as it means that the filtration fume cupboard is not performing adequately.**
- Record the reading on the detection tube see *Figure 9.10 (j)*, *c* ppm.
- Place the **other** gauze (the one which was used in the weighing) on top of the basin surface (see *Figure 9.10(g)*). (The gauze puts out the flame but some sulfur condenses onto it, which is why it should be included in the weighing.)
- **Immediately**, stop the clock (see *Figure 9.10 (h)*) and record the time of the run, *t* seconds.
- Allow the sulfur to cool down and solidify for about 20 minutes. Reweigh the basin, the remaining sulfur and the gauze (see *Figure 9.10 (i)*). Record the mass, *m*₂ g.
- The sulfur and dish may be kept and used the next time the test is carried out. More powdered roll sulfur will need to be added to make up for that lost in this test.
- Work out the rate of release of sulfur dioxide, *R*, according to the following equation³⁷.

$$R = \frac{(m_1 - m_2)}{t} \times 751 \text{ cm}^3 \text{ s}^{-1}$$

9.4.4 Interpreting the results

Compare the calculated value of the rate, *R*, and the concentration of sulfur dioxide in the exhaust gas with the data in *Table 9.2*. If the concentration of sulfur dioxide at the relevant release rate is **greater** than the corresponding value in *Table 9.2*, the filter is not absorbing acidic gases efficiently enough and a new filter is required³⁸ (or there is a leak around the seal).

Table 9.2: Safe filter efficiencies for sulfur dioxide

Rate of sulfur dioxide released / cm³ s⁻¹	Maximum permitted concentration of sulfur dioxide in the exhaust gas / ppm
5	1
10	2
15	3
20	4
25	5

³⁷ The factor of 751 arises to convert the mass of sulfur burnt into the volume of sulfur dioxide vapour.

³⁸ This assumes that the efficiency of the filter has fallen to 98% for sulphur dioxide; at this level, the fume cupboard will still not emit a dangerous level of gas in a well-ventilated laboratory, although its odour may be detected.

9.5 Testing the filter for saturation by alkaline gases

9.5.1 When to do the test

- Not needed if a decision has been made to replace the filter at regular intervals and if there is no reason to suspect the filter not be absorbing a sufficient fraction of the contaminant.
- (optionally) at the regular 14-month thorough examination and test (if large amounts of ammonia are used in the fume cupboard, it would be wise to carry out this test to check the efficiency of the absorption of alkaline gases but is not normally necessary in most schools).
- If the filter is suspected of being saturated, eg because of complaints about odours.

9.5.2 What you need

- a gas detection kit
- a balance weighing to 0.1 g or better
- about 40 ml concentrated ammonia solution (see CLEAPSS *Hazcard 6*)
- 400 ml beaker with about 25 ml of hot water from the tap
- a 100 ml conical flask and a bung
- anti-bumping granules
- a stop clock
- a cloth (or paper towel)
- a magnetic/stirrer hot plate
- a magnetic follower
- thermometer (–10 to 110 °C)

9.5.3 Procedure

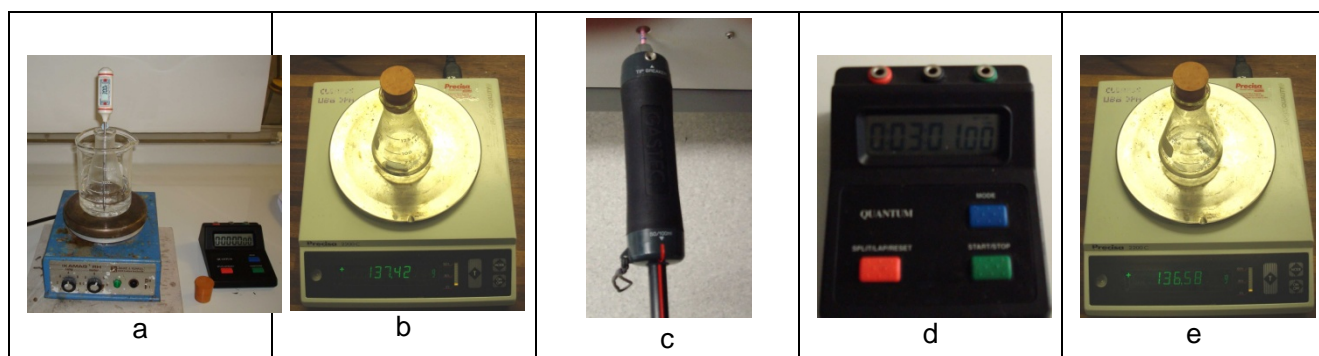


Figure 9.11

- Switch on the fume cupboard. Place a heater/stirrer in the fume cupboard. Turn up the heater control to about half a full turn.
- Wearing goggles, pour about 40 ml of concentrated ammonia solution (CORROSIVE solution with TOXIC and CORROSIVE vapour) in a 100 ml conical flask. Add the magnetic stirrer bar and thermometer. Place the conical flask in the 400-ml beaker containing about 25 ml of hot water from the hot water tap. Place the beaker on the heater stirrer and start the stirring at a gentle pace (see Figure 9.11 (a)).
- When the temperature reaches about 35 to 40 °C and is reasonably constant, remove the thermometer and add a stopper to the flask. Remove the flask from the beaker and wipe the flask with a cloth to dry it. Weigh the conical flask with the stopper and the warm concentrated ammonia (see Figure 9.11 (b)). Record the mass, m_1 g.
- Place the conical flask back in the beaker on the heater/stirrer which is in the fume cupboard. Remove the stopper and start the stop clock.
- After 60 seconds, take a reading of the concentration of the ammonia being emitted through the exhaust with the gas detection kit (see Figure 9.11 (c)). **A slight smell of ammonia should be ignored but, if the exhaust gas causes breathing difficulties, stop the test, open the windows, leave and lock the room. This incident should be reported to her/his line manager as it means that the filtration fume cupboard is not performing adequately.**
- Record the reading on the detection tube c ppm.
- **Work quickly.** Stop the clock (see Figure 9.11 (d)) and **immediately** place the stopper in the flask. Remove the stoppered flask from the beaker and wipe the outside with a cloth to dry it. Record the time on the stop clock, t seconds
- Weigh the conical flask with remaining concentrated ammonia (see Figure 9.11 (e)). Record the mass, m_2 g.
- Place the ammonia back in the fume cupboard and remove the stopper. To dispose of the ammonia solution either pour it down the fume cupboard sink with plenty of running water or pour the ammonia in a bucket of cold water and pour it down the sink.
- Calculate the rate of release of ammonia vapour from the conical flask, R , according to the following equation³⁹.

$$R = \frac{(m_1 - m_2)}{t} \times 1412 \text{ cm}^3 \text{ s}^{-1}$$

³⁹ The factor of 1412 arises to convert the mass of ammonia into the volume of ammonia vapour.

9.5.4 Interpreting the results

Compare the calculated value of the rate of release of ammonia, R , and the concentration of ammonia in the exhaust gas with the data in *Table 9.3*. If the concentration of ammonia at the relevant release rate is **greater** than the corresponding value in *Table 9.3*, the filter is not absorbing alkaline gases efficiently enough and a new filter is required⁴⁰ (or there is a leak around the seal)

Table 9.3 Safe filter efficiencies for ammonia

<i>Rate of ammonia gas released / cm³ s⁻¹</i>	<i>Maximum permitted concentration of ammonia gas in the exhaust gas / ppm</i>
2	1
4	2
6	3
8	4
10	5
12	6
14	7
16	8

⁴⁰ This assumes that the efficiency of the filter has fallen to 96% for ammonia; at this level, the fume cupboard will still not emit a dangerous level of gas in a well-ventilated laboratory, although its odour may be detected.

9. 6 Fume cupboard thorough examination and test report (14-month) as required by the COSHH regulations

These pages may be freely copied to record testing results. Copies of the completed report should be held by the examiner, the employer and by the science department and retained for at least 5 years. *This sheet summarises the results gathered on the following pages.*

School/college and fume cupboard information

Establishment: Employer :

Fume cupboard ID: Location:
.....

Examiner's name, position and address

Preliminary details

- Have you seen the commissioning report? Yes/No
- and/or initial test data Yes/No
- Have you seen a User Manual? Yes/No
- Have you seen the Log Book? Yes/No
- Any preliminary observations?

Air-flow meter: Outdoor wind conditions:
.....

Stage 1 **Issues to be addressed from the visual and structural examination**

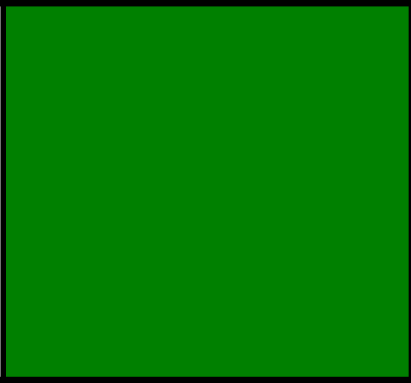
Stage 2 **Measuring technical performance**


Stage 3 **Assessing control effectiveness**


Comments

Labels should be attached to all the fume cupboards tested with the test date, name of examiner and whether the fume cupboard has passed, failed (ie it must not be used) or not satisfactory (ie, the fume cupboard can be used but with provisos which need to be written down.

Examiner's signature: Date:

Test date	
Next test	
Examiner	

Test date	
Examiner	

Test date	
Next test	
Examiner	
WARNING TO USERS	

Stage 1 Notes of visual inspection

<i>Inspection check</i>	<i>Results</i>
Work surface and linings Is there any damage? If it is made of asbestos cement, has it been reported, particularly noting if dusty or flaking? Fail if it could produce significant dust levels in the room. Otherwise, consult the employer. Sealing it may be possible.	
Glazing Is it dirty? Are there any cracks or other damage? Is it plastic or glass? If glass, report if there is no evidence that it is safety glass: eg, no engraving on the glass or no statement from the supplier of the fume cupboard. (Explosions in fume cupboards are very rare so that the presence of ordinary glass is not a reason for failure unless the employer stipulates it. It is possible to cover glass with safety film.)	
Baffle Is it dirty? Is there any damage? Very old fume cupboards may not have a baffle. This is no reason for failing the fume cupboard.	
Sash mechanism Does it function satisfactorily? Are there signs of damage to the cables? Fail only if the sash is likely to descend rapidly, ie, one side is broken. Take steps to repair it before further deterioration.	
Sash limits Are there stops to: (a) limit the aperture to the correct maximum height? (b) prevent it being closed completely? While stops should be fitted, labels indicating sash limits are temporarily acceptable. Take steps to fit stops. Do not fail unless the employer stipulates it; fix labels.	
Electricity, gas, water and drainage services Is there any corrosion or damage which makes the services unsafe? Check the drip cup, trap (does it contain water?) and drain for signs of leaks, blockage, etc and the pipes and wires under the fume cupboard. Fail only if there is a real possibility of a gas leak, of electric shock or a spark from an electric circuit igniting the gas.	
Fan Is the direction of flow correct? Is there any sound of excessive vibration? (Tests on the performance of the fan are in the next section.) Fail if the direction of the air flow is incorrect.	
Ducting (where visible) Are there any signs of damage, particularly to seals? Are there any reports of smells along its route? Fail if there is a significant leak at a point where the pressure inside the duct is above atmospheric.	
Duct exit (where visible) Is there anything which obstructs it or which might eventually obstruct it? (The extent of the inspection will depend on the site of the exit and who is conducting it.) Fail if the duct is obstructed or about to be obstructed by birds' nests, footballs, vegetation etc.	

Stage 2 Notes of technical performance measurements

Feature	Comments									
Measure air velocities at a sash height of 400 mm	<ul style="list-style-type: none"> Insert your results in the grid below. <table border="1" style="margin: 10px auto;"> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td></tr> </table> <ul style="list-style-type: none"> Look at the table of recorded readings and repeat any reading which seems to be very different from the general pattern. If any measurement is less than 0.3 m s^{-1}, the fume cupboard has failed at an opening of 400 mm (but it may be worth checking the accuracy of the anemometer used). If it fails at 400 mm, lower the sash height to 300 mm and repeat the readings. If the fume cupboard passes, the fume cupboard must not be used for carrying out chemical reactions but it could be used for dispensing chemicals. If the fume cupboard fails at even 300 mm, it must not be used under any circumstances and should be so marked. Make sure the safe working height for the sash is clearly marked on the fume cupboard. Add up the 9 measurements and divide the answer by 9 to obtain the average face velocity. Average face velocity at 400 mm m s^{-1} You will need the max and min face velocities to test for variation. Maximum face velocity m s^{-1} Minimum face velocity m s^{-1} 									
Check the bypass system by lowering the sash to 200 mm	<ul style="list-style-type: none"> Insert your results in the grid below. <table border="1" style="margin: 10px auto;"> <tr><td></td><td></td><td></td></tr> </table> <ul style="list-style-type: none"> Add up the 3 measurements and divide the answer by 3 to obtain the average face velocity. Average face velocity at 200 mm m s^{-1} 									
Check any low velocity alarms (if fitted)										
Check fume cupboard noise level	<ul style="list-style-type: none"> With door closed, room unoccupied except for tester, sash set at 200 mm, sound meter reading at a height of 1.5 m and 1.5 m in front of the face isdB when OFF anddB when ON. 									
Compare the present results with past results	<ul style="list-style-type: none"> Are there any notable changes from previous results? 									

Diagnose the causes of any problems	(Suggest calling in specialist engineers if necessary. See CLEAPSS guidance leaflet PS48)
Check the upper and lower variations in face velocity	<ul style="list-style-type: none"> Use the equation below to obtain the upper variation as a percentage. $\text{Upper variation (\%)} = \frac{(\text{maximum face velocity} - \text{average face velocity}) \times 100}{\text{average face velocity}}$ <p>Upper variation is %</p> <ul style="list-style-type: none"> Use the equation below to obtain the lower variation as a percentage. $\text{Lower variation (\%)} = \frac{(\text{average face velocity} - \text{minimum face velocity}) \times 100}{\text{average face velocity}}$ <p>Lower variation is %</p> <ul style="list-style-type: none"> Make a report if the upper or lower variation is greater than 30% or if greater than 20% with more than one variation at the same side of the cupboard
A smoke test (optional)	Comments
Observations of employees using the fume cupboard	Comments

Stage 3 Notes of control effectiveness tests

A filter efficiency test (See section 9.1)	Polychloroethene (tetrachlorethene or trichloroethene) test for testing the seating of the filter	Mass of flask, bung and contents before = m_1 = g
		Mass of flask, bung and contents after = m_2 = g
		Time on stop clock = seconds
		Reading on detection tube = ppm
		Rate of release of polychloroethene vapour = $R = \frac{(m_1 - m_2)}{t} \times f \text{ cm}^3 \text{ s}^{-1}$ where $f = 145$ for tetrachlorethene or $f = 183$ for trichloroethene $R =$
		Is the measured concentration of polychloroethene (tetrachlorethene / trichloroethene) vapour greater than value in <i>Table 9.1</i> for the measured release rate? If yes, check the seating; if seating OK, a new filter is required.
	Sulfur dioxide test for testing saturation of filter by acid gases (could also be used for testing the seating of the filter)	Mass of basin, sulfur and gauze before = m_1 = g
		Mass of basin, sulfur and gauze after = m_2 = g
		Time on stop clock = seconds
		Reading on detection tube = ppm
		Rate of release of sulfur dioxide gas = $R = \frac{(m_1 - m_2)}{t} \times 751 \text{ cm}^3 \text{ s}^{-1}$ =
		Is the measured concentration of sulfur dioxide gas greater than value in <i>Table 9.2</i> for the measured release rate? If yes, a new filter is required.
	Ammonia test for testing saturation of filter by alkaline gases (if required)	Mass of flask, bung and contents before = m_1 = g
		Mass of flask, bung and contents after = m_2 = g
		Time on stop clock = seconds
		Reading on detection tube = ppm
		Rate of release of ammonia vapour = $R = \frac{(m_1 - m_2)}{t} \times 1412 \text{ cm}^3 \text{ s}^{-1}$ =
		Is the measured concentration of ammonia gas is greater than value in <i>Table 9.3</i> for the measured release rate? If yes, a new filter is required.
Diagnose the causes of any problems	Comments	

9.7 Fume cupboard test summary sheet

We suggest that following each Annual Thorough Examination and Test, the main results should be transferred to this summary sheet (which may be freely copied) so that gradual changes over time can be easily assessed. Gradual changes in noise levels or face velocities may give early warnings of impending problems. If several fume cupboards are experiencing similar changes, this may indicate deterioration in the performance of the meter used.

Establishment: **Employer :**

Fume cupboard ID: **Location** (or usual location, if mobile):

Date of test	Any significant findings from visual inspection	Average face velocity at 400 mm / $m s^{-1}$	Average face velocity at 200 mm / $m s^{-1}$	Noise level at 200 mm / dB(A)	Upper variation in face velocity / %	Lower variation in face velocity / %	Filter efficiency (if tested)?		If filter efficiency <u>not</u> tested, years since last new filter
							Satisfactory?	Tested using?	