

Although it is not intended to suggest that all benches, regardless of function, should be made to the sizes stated below, they are given as an indication of the dimensions which have found general acceptance in practice.

2.202. *Working height.*

a. Standing. For adult workers a height of 3 ft 0 in. (91 cm) is general; when the bench is intended for use mainly by females a height of 2 ft 10 in. (86 cm) is desirable.

b. Sitting. For some types of work such as dissection or microscopy or where much writing is done, and long periods of sitting are required, the bench should be lower than that recommended for general work and a height of about 2 ft 6 in. (76 cm) is commonly used. This dimension, with due allowance for a front stiffening rail or shallow drawer, gives reasonable knee space when using a seat height of about 17 in. (43 cm) conforming to B.S. 2582* and B.S. 3079†. For the higher 2 ft 10 in. (86 cm) or 3 ft 0 in. (91 cm) bench, chairs with adjustable-height seats, or alternatively a fixed seat height of about 2 ft or 60 cm can be adopted.

2.203. *Working width.* The overall width of a bench can include service outlets or a service upstand casing leaving the remainder as free working space. For most purposes it is recommended that single sided benches should have a clear width of 2 ft 0 in. (61 cm) with equivalent increase for double-sided benching.

2.204. *Thickness of top.* For solid timber tops a nominal thickness of 1 ¼ in. (32 mm) is recommended and a finished thickness of not less than 1 ⅛ in. (27 mm). For timber blockboard tops a similar finished thickness is desirable. For compressed asbestos cement a thickness of ¾ in. (19 mm) may be suitable, and for tiles the top (usually reinforced concrete) should be at least 2 in. (51 mm) thick.

2.205. *Spacing of benches.* The distance between adjacent bench tops is related to economy in floor space and the safety and convenience of persons working in or using the room.

For benches so arranged that persons work back to back it is recommended that the tops should be spaced at least 4 ft 6 in. (1.4 m) apart. If the space is also to be used as a communal passage then it should be increased to not less than 6 ft 0 in. (1.8 m).

For single line working the distance between the bench top and adjacent fixtures may be limited to 3 ft 6 in. (1.1 m) with an increase to not less than 4 ft 0 in. (1.2 m) if it is intended to be used as a passage way. Space for gangways used solely as such should be made not less than 4 ft 9 in. (1.4 m).

* B.S. 2582, 'Office chairs'.

† B.S. 3079, 'Anthropometric recommendations for dimensions of non-adjustable office chairs, desks and tables'.

Sub-section 2.3. Benches for sensitive instruments.

2.301. General. Bench tops for supporting precision balances and sensitive instruments should be rigid and have a surface that is hard and stable and readily cleaned. The recommended materials are slate and toughened glass with compressed asbestos cement and laminated plastics as possible alternatives.

When planning the siting and construction of these benches the effect of vibration should be considered since this, in addition to affecting the accuracy of reading the instruments, could ultimately cause damage to precision components such as balance knife-edges.

2.302. Methods of avoiding vibration. As a general rule the outer rim of a floor is less likely to be disturbed by vibration than the centre, especially in upper floors, but to avoid the possibility of vibration being transmitted from the walls of the room, the benches should be mounted so as not to touch the walls. When necessary approach should be made to firms who specialize in this field of engineering, but where the level of vibration is low it is usual to mount the bench top on piers built from the floor. The piers may be constructed of brick, concrete or stone and should be not less than 9 inches (23 cm) wide. If there is a likelihood of a disturbance being caused by equipment on the floor or by the movement of people, the piers may be extended downwards, out of contact with the floor, into the subsoil for a depth dependent upon conditions from 2–6 ft (60–180 cm). Where this is not possible, and in the case of upper floor installations, the bench top may be isolated from the supports by insulating materials such as rubber, felt or cork; alternatively commercial anti-vibration mountings may be used. The degree of isolation effected by these mountings, although satisfactory for many cases, may however not be adequate if the frequency of the disturbing vibration is lower than 15 cycles per second. In such a case the bench top or its equivalent should be supported on springs, together with a suitable degree of damping, if the application is such that swaying of the undamped suspension is unacceptable.

When several instruments of different types are used on the same bench and it is desired to retain a rigid bench top, an alternative is to obtain a measure of protection by one of the methods described above and to complete the isolation by mounting the instruments individually on anti-vibration supports.

In addition to vibration, other factors such as changing conditions of humidity and temperature should be taken into account when considering the location of benches for sensitive instruments. In such events the effects of nearness to open doors and windows or heat from furnaces or direct sun-rays should be borne in mind.

Sub-section 2.4. Materials for bench tops.

2.401. General. Materials for the construction of bench tops are required to possess a variety of properties dependent upon their use, such as mechanical

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strength, stability under changing conditions of moisture, temperature and sunlight; and, for certain purposes, resistance to attack by chemicals or contamination by bacteria or radioactive sources.

The materials economically available do not necessarily possess all the properties desired for particular applications and in consequence selection must be based on the features considered to be the most important for the work in view. Sometimes a compromise is possible by using two or more materials, one of which may provide the required mechanical strength whilst the others provide the necessary surface qualities. Examples of these are metal-faced plywoods, plastics-coated metals, plastics veneered on to plywood, plastics-faced hardboard or blockboard, teak-faced blockboard and the replaceable coatings such as wax and polish for timber.

The materials likely to be of service for bench top purposes have been considered in four main groups, timbers, plastics, metals and other materials: Notes about these materials are given for each group together with some data on their physical properties.

The physical properties selected are those which give an indication of the important characteristics of each material: resilience and durability of surface: heat gain or loss when in contact with or when touched by temperature-sensitive apparatus; highest temperature to which it may be subjected without hazard or deterioration.

2.402. *Timbers.*

a. Teak. The material recommended for bench tops in most laboratories is teak *Tectona grandis*. This outstanding timber is notable for its combination of desirable properties: stability, strength with moderate weight, relative ease of working and repair, durability and agreeable appearance. Its usual colour is golden brown when fresh but this darkens on exposure.

Teak may be used as a solid top or in the form of blockboard faced with teak on both sides. The latter should be resin-bonded and the teak surface should be not less than $\frac{1}{8}$ in. (3.2 mm) thick. All exposed edges, sink holes, etc., should be lipped with solid teak.

b. Other timbers. Although teak is the pre-eminent material for bench tops several other less costly timbers can give good service, provided attention is paid to selecting good quality, properly seasoned timber of reasonable robustness and resistance to indentations; a density of 40–50 pounds per cubic foot (0.64–0.80 g/cm³) is desirable. Some of the timbers worthy of consideration are iroko, kokrodua, afzelia, mahogany, makoré and European beech. Table 1 lists some of the physical properties of these timbers, in comparison with teak.

c. Possible alternatives. Other timbers such as opepe, cypress, guarea, New Zealand kauri and Pacific maple are not unsuitable, but have not found ready application in Britain.

TABLE 1. PHYSICAL PROPERTIES OF TIMBERS SUITABLE FOR BENCH TOPS

NOTE: The figures are based on a moisture content of 12 per cent.

Trade name	Botanical name	Specific gravity	Density lb/ft ³ *	Specific volume in ³ /lb†	Thermal conductivity (across the grain)	Hardness of side grain. Unit: pounds weight (0.45 kg) required to embed a ball of diameter 0.444 in. (11.28 mm)	Notes
Teak	<i>Tectona grandis</i>	0.66	41	42.2	About 0.004 cal/cm s degC or 1.0 Btu in/ft ² h degF	1130	—
Iroko	<i>Chlorophora excelsa</i>	0.66	41	42.2		1260	Generally stable but may distort especially if irregular in grain. Long used as substitute for teak where initial cost is a decisive factor. Brown to dark reddish-brown after exposure.
Kokrodua	<i>Afromosia elata</i>	0.70	44	39.3		1560	Generally stable, but may distort, especially if irregular in grain. Golden brown. Under moist conditions will corrode ferrous metals and become stained.
Afzelia	<i>Afzelia</i> species	0.83	52	33.3		1770	Generally stable, but may distort, especially if irregular in grain. Alkaline materials will produce yellow stains.
African mahogany	<i>Kilaya</i> species (principally <i>K. ivorensis</i>)	0.56	35	49.4		790	Too soft for heavy duty. Reddish-brown. Stable.
Makoré	<i>Minusops heckelii</i>	0.72	45	38.4		1380	Comparable to mahogany but stronger. Reddish-brown.
European beech	<i>Fagus sylvatica</i>	0.72	45	38.4		1440	Unsuitable for damp conditions.

For further technical data on most of these timbers see 'A Handbook of Hardwoods' and 'A Handbook of Softwoods,' H.M.S.O.
 * 1 lb/ft³ = 0.016 g/cm³ approximately. † 1 in³/lb = 3.6 × 10⁻⁴ m³/kg approximately.

2.403. *Plastics.*

a. General. Plastics are eminently suitable for use in food, biological and pathological laboratories where bacteriological cleanliness is essential, and in analytical laboratories and laboratories dealing with radioactive materials where easy maintenance of surface cleanliness is important. Table 2 lists some of the physical properties of the most important plastics. Some of these materials are relatively costly and are commonly used in thin sheets supported on a cheaper base material such as plywood, blockboard, hardboard or metal.

b. Laminated plastics. Useful materials for bench tops are the phenolics and aminoplastics in sheet form, laminated with such materials as paper, fabric, glass and asbestos. Whilst the mechanical properties of the finished materials are governed to a considerable extent by the type of reinforcement, for bench top material these properties are probably of secondary importance. The most important factors are the chemical and thermal stability of the bench top and these in turn are governed primarily by the chemical and thermal resistance of the resin binding the reinforcement. These resins show a fair to good thermal resistance, fair to good resistance to attack by dilute acids and alkalis, and excellent resistance to common organic solvents. All show very poor to poor resistance to prolonged exposure to strong alkalis and strong inorganic acids. In selecting these materials it is important to test their suitability if there is any doubt as to their effectiveness as a bench top.

c. Polyvinyl chloride. Unplasticized polyvinyl chloride and its copolymers are tough weldable materials softening materially at temperatures above 70°C but at normal temperatures having a high degree of dimensional stability, even under conditions of high humidity. They are not suitable for service with ketones, esters and aromatic or chlorinated hydrocarbons but have a high resistance to corrosive chemicals other than organic acids.

d. Polythene. This is a weldable polymer of ethylene having a tough but flexible character and a wax-like feel. The grades which first became widely available soften appreciably at temperatures above 70°C, but other grades have been developed which will withstand considerably higher temperatures. It is non-wetting and is inert to many chemicals at normal temperature, but not to bromine, iodine, glacial acetic acid, benzene, carbon tetrachloride, mineral oils, petrol and trichloroethylene.

e. Polytetrafluoroethylene. This is one of the newer plastics and at present rather costly but may be suitable for specialized purposes. It is a hard and tough resin substance, whitish in colour with a surface having a very low coefficient of friction. It has outstanding resistance to solvent and chemical attack at temperatures as high as 250°C, up to which temperature only fluorine and the molten alkali metals have been observed to attack it.

**TABLE 2. PHYSICAL PROPERTIES OF PLASTICS
SUITABLE FOR BENCH TOPS**

Material	Specific gravity	Specific volume, in ³ /lb*	Hardness (Brinell)	Thermal conductivity CGS units	Normal temperature limit, °C
Laminated plastics	1.3-1.9	22-14.6	45	0.0004-0.0007	120
Unplasticized polyvinyl-chloride	1.5	18.5	15-20	0.0004	70
Polythene	0.92-0.94	30	1.6-2.0	0.0007	70-100
Polytetrafluoroethylene	2.2	12.6	1-2	0.0006	250

* 1 in³/lb = 3.6×10^{-5} m³/kg approximately.

2.404. Metals.

a. General. The metals most suitable for bench tops are mild and stainless steels, nickel, nickel-copper alloy, zinc, aluminium and its alloys, and lead. Metals are particularly suited to applications where fire hazard might arise from heat emanating from apparatus such as combustion furnaces, radiant heat evaporators and the like, or where cleanliness or a high degree of resistance to chemicals or radioactive contamination is essential. The softer metals have use where rubber and textile materials are cut and manipulated. Other metals by reason of their non-magnetic properties find use in physics laboratories.

Metal bench tops can be mounted on a plywood or blockboard base if desired, but where fire hazard can arise a metal support system is preferable.

Table 3 lists some of the physical properties of the most important metals.

b. Mild steel. This is generally suitable for the support of equipment such as combustion and muffle furnaces, but a protective surface finish is desirable, for example painting, to avoid the rusting that might otherwise occur.

c. Stainless steel. This is particularly useful in laboratories where radioactive work is carried out and where cleanliness and a high degree of acid resistance is required. It is suitable for washing-up sinks and benches and for work involving fine powders where its entirely non-dusting feature is of value. It is, however, affected to some degree by all concentrations of hydrochloric and sulphuric acids.

There is a wide range of specifications for stainless steel but, apart from specialized requirements, steels of the 18 per cent chromium 8 per cent nickel type are generally used.

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d. Nickel-copper alloy. This alloy (67Ni 30Cu 1.4Fe 1Mn) is widely used where resistance is required to common corrosives such as strong caustic soda, sulphuric acid and salts.

e. Zinc. This is soft and subject to chemical attack but has an application in paint and colour laboratories for mixing benches and is suitable for bench tops on which rubber and textiles have to be cut and manipulated.

f. Aluminium. The 99.5 per cent pure metal is resistant to fruit juices, alcohols and phenols, nitric acid and the organic fatty acids except formic. It is unsuitable for use with caustic alkalis, the halogen acids and mercury. Generally the aluminium-manganese, aluminium-magnesium and aluminium-magnesium-silicon wrought alloys will offer improved mechanical properties without serious diminution of resistance to chemicals.

g. Lead. Chemical lead (99.99 per cent pure to B.S. 334*) is used as a lining material for benches subject to moist conditions (e.g. developing or washing-up benches) and for accumulator charging benches for which it is suitable due to its resistance to sulphuric acid. It is not suitable for use with heat owing to its tendency to creep and buckle.

TABLE 3. PHYSICAL PROPERTIES OF METALS
SUITABLE FOR BENCH TOPS

Material	Specific gravity	Specific volume, in ³ /lb†	Hardness (Brinell)	Thermal conductivity CGS units	Normal temperature limits, °C
Mild steel	7.8	3.55	110-130	0.06	300
Stainless steel	7.96	3.5	160-200	0.039	750
Nickel-copper alloy	8.8	3.16	120-140	0.06	500
Zinc	7.13	3.9	44-52	0.27	120
Aluminium (99.5 per cent)	2.71	10.2	21-39	0.55	300
Lead (99.99 per cent)	11.35	2.44	4	0.083	100

† 1 in³/lb = 3.6×10^{-5} m³/kg approximately.

2.405. Other materials.

a. General. Many other materials are used successfully for bench tops, often for particular purposes rather than general laboratory use. Examples are the

* B.S. 334, * Chemical lead (types A and B) .

use of asbestos cement tops for combustion benches, and of rubber or linoleum where fragile apparatus may be damaged if harder or denser materials are used.

Table 4 lists some of the physical properties of these materials.

**TABLE 4. PHYSICAL PROPERTIES OF VARIOUS
OTHER MATERIALS SUITABLE FOR BENCH TOPS**

Material	Specific gravity	Specific volume, in ³ /lb*	Hardness	Thermal conductivity CGS units	Normal temperature limits °C
Glazed earthenware tiles	2.2	12.6	7 (Mohs')	0.0046	n.a.
Quarry tiles	2.5	11.0	8 (Mohs')	0.0019	n.a.
Highly compressed asbestos cement board	1.9	14.5	17 (Brinell)	0.0015	315
Glass	2.2-2.5	12.5-11.3	6 (Mohs')	0.002	Thermal shock of 40 degC (annealed) or 250 degC (toughened)†
Vitreous enamelled mild steel	7.8	3.6	5-6 (Mohs')	0.002/3	n.a.
Acid-resisting concrete	1.85 app.	15.0	n.a.	0.002	1100
Slate	2.6-3.3	10.7-8.5	n.a.	0.0036	n.a.
Rubber	1.7	16.0	60-70 B.S. degrees	0.0003/4	70
Linoleum	1.2-1.4	23-20	n.a.	0.00045	n.a.

* 1 in³/lb = 3.6 × 10⁻⁴ m³/kg approximately.

† Toughened glass is stable up to 295°C and can be used at slightly higher temperatures provided the exposure is neither prolonged nor frequent.

b. Ceramics. These include glazed earthenware and quarry tiles and are characterized by fire-resistant properties, low thermal expansion and resistance to attack by a wide range of chemicals. They are often used where the surface can readily be kept clean.

Glazed earthenware tiles are usually white or cream in colour and are bedded on to a cement or asbestos cement base. It is very difficult to obtain a truly level surface, and the joint forms the weakest point of a bench top so constructed.

Quarry tiles are usually red or buff in colour, and to form a bench top they are bedded on to a cement or asbestos cement base. They are more resistant to chemical attack than earthenware tiles, but again it is difficult to ensure a level surface, and the jointing and bedding compound should be specially selected.

c. Asbestos cement compounds. Good quality highly compressed asbestos cement board is suitable as a bench top material for many purposes. It should contain about 50 per cent of Portland cement. The self-colour is light grey. Many of these materials have a reasonably good tensile strength and are capable of being worked to a fine finish. Their fire-resistant properties are good and they are therefore very useful for the tops of glass working benches and for other applications where protection from heat is necessary. In their natural state these materials stain easily, but some protection against this may be given by the application of acid-resisting lacquers or paints.

d. Glass. Glass is a durable but brittle material unaffected by liquids, other than hydrofluoric acid and hot strong caustic solutions. It has a hard, high gloss surface, readily cleaned by wiping and eminently suitable for service where bacteriological or equivalent cleanliness is desired.

For bench tops the thickness of glass should not be less than $\frac{1}{4}$ in. (6.4mm); a thickness of $\frac{3}{8}$ in. (9.5 mm) is commonly used. In general the glass need not be bedded or fixed provided the substructure is true, even and free from hard points that could cause local stress in the glass. If permanent fixing is required the bedding material used should give solid support and remain resilient.

Toughened glass. The toughening process induces compressive stresses in the surface layers which gives the material greater flexibility and an ultimate strength some 4 or 5 times greater than that of annealed plate glass of the same thickness. If breakage of toughened glass does occur it fractures into characteristic granular particles which are not likely to inflict injury and are safe to handle.

Toughened glass cannot be cut, drilled or edge worked in any way. All such operations must be carried out before the toughening process.

A slight bow is inevitable in toughened glass and this may prevent butt joints being completely flush, but in general this only becomes a disadvantage where scrupulous cleanliness is essential.

White opal glass. This glass is useful for titration benches and for work where a white background is desired, but it cannot be toughened.

Polished black glass. This glass is suitable for balance bases and can be toughened in a restricted range of sizes.

Painted and fired toughened glass. A wide range of coloured toughened glass is also available, the colour being permanent as an integral part of the glass surface.

e. Vitreous enamelled mild steel. Tops of this material are very suitable for combustion benches and for any work involving fire risk. The vitreous coating, applied after the top has been shaped, gives ease of cleaning but is not very resistant to sharp impacted loads.

f. Acid-resisting concrete. This is not suitable for general use as a bench top, as the surface is readily attacked by many alkalis. Mechanically it is very strong if properly reinforced.

g. Slate. This is suitable for the tops of balance benches but presents jointing difficulties. It is not very resistant to local heat and some forms of chemical attack, particularly by water-absorbing acids such as chromic and sulphuric.

h. Linoleum. This is particularly suitable for physical laboratories because of its slight resilience, comfortable feel and good surface. It has a satisfactory resistance to most common chemicals, solvents and oils, but not to alkalis. A surface protection with wax polish will help to overcome this disadvantage and generally keep the linoleum in a good condition.

j. Rubber. Natural and synthetic rubbers possess useful resistance to chemicals, dependent upon their compounding constituents and processing. They are, however, affected by oxidizing agents. They are available in a variety of colours, and vary in hardness from very soft to hard.

2.406. Recommendation. The choice of a bench top material from among those suitable for any particular application must be based on such factors as first cost of finished article, availability, service life and cost of maintenance. Concerning first cost there appears to be no easy correlation between the raw material cost and the final cost of each material supplied as a bench top ready for fixing, and therefore no assessment in terms of price relationship has been attempted. Taking into account the factors already mentioned and the confirmation of past practice it is considered that in general *teak* is the best material. All the others listed have their value and may be selected for special purpose benches.

Sub-section 2.5. Timber benching.

2.501. General.

a. Sizes. The dimensions (especially thickness of the bench top) of timber benching should be selected so that the boards required can be conveniently cut from the nominal sizes of imported timbers, due allowance being made for machining.

b. Quality requirements. Laboratory benching when installed is expected to provide a working surface and storage space which will last and give good service for many years. It is important, therefore, that the materials used should

be of good quality, that the benching structure should be soundly constructed, and that the workmanship should be sound. As a general guide, the quality of timber and workmanship should not be inferior to the requirements of B.S. 1186*.

c. Moisture content. Timber for benches should have a moisture content as laid down in B.S. 1186, Part 1*, with the intention that it should have at the time of machining and fabrication the condition appropriate to its environment when in service, so that on assembly and installation only negligible movement or shrinkage will occur. For a normally centrally heated building, a figure of 10 to 12 per cent would be suitable.

d. Metallic corrosion. When very dry conditions exist within and without the wood serious corrosion is not likely to occur when direct contact between wood and metal is involved in any form of construction. Serious corrosion may occur when the moisture content of certain timber is unduly high; the aqueous extracts of the hardwoods such as oak, sweet chestnut and some species of eucalyptus (e.g. jarrah) and of Douglas fir and western red cedar among softwoods are acidic and under such conditions corrosion of some metals may occur when embedded in or in contact with these timbers.

e. Storage and installation. Timber furniture can readily deteriorate if the conditions of storage or installation are unfavourable. The efforts of manufacturers in constructing sound well-finished furniture, using the best materials available and employing the most modern production methods may all be in vain if proper and reasonable treatment is not given. It is most important that timber furniture should be stored and installed under dry well-ventilated conditions; it is therefore recommended that it should not be installed in buildings before they are properly dry and clean and, preferably, decorated. Where this is impossible space heating for purposes of drying the building should be applied slowly with doors and windows open to maintain proper ventilation.

Periodical polishing with a good quality bench wax is desirable for timber furniture.

2.502. Bench tops.

a. General. Bench tops should be constructed from reasonably straight-grained timber boards joined throughout their length by one of the methods described in B.S. 1186, Part 2*. The boards when glued should be kept together by cramps for an adequate period varying with the setting time of the adhesive used.

Underbench heating is not recommended, but if used suitable protection should be provided for the underside of the bench top. To minimize deterioration, bench tops should be finished on the under as well as on the upper surface.

* B.S. 1186, 'Quality of timber and workmanship in joinery'.

Part 1, 'Quality of timber'.

Part 2, 'Quality of workmanship'.

The surface should be well oiled and waxed before use unless a special coating such as epoxy resin is required.

b. Width of boards. Whether narrow or wide boards should be used for the construction is a matter for the constructor to decide. Narrow boards involve more machining and fitting than wider boards and additional care where holes for sinks and services have to be cut. Colour variations are also likely to be greater unless specially matched boards are selected. Wide boards with their lesser number of joint faces may be considered to have an advantage, but their first cost is greater, and they are more liable to split or shrink when variations in atmospheric conditions occur.

c. Length of boards. Where bench tops are made with wide boards, any heading joints that would extend across the whole width of the bench top should be avoided. Long bench tops should be made, where practicable, from boards 10 to 12 feet (3-3½ m) in length. The joints should be handrail bolted and tongued or otherwise constructed so that they are and remain tight and flush.

Where narrow boards are used, no heading joint in a single board should be permitted within a distance of 9 in. (23 cm) from a similar joint in the board on either side, nor should more than two such joints be permitted in any one foot (30 cm) of the length of the top. The joints should be properly fitted and cramped up, tongued and/or glued or otherwise constructed so that they are and remain tight and flush.

d. Facings. Bench tops which are faced with other materials may be constructed from blockboard or multi-ply frames or laid on skeleton framing. When surfaced with soft material such as linoleum the upstand edges of the bench should be fitted with a hardwood or metal edge-trim finished flush with the upper surface.

e. Attachment of bench top. The bench top should be attached to the under-bench components by shrinkage plates or hardwood buttons, to enable any movement of the top to occur without danger of splitting.

Where the top at the back abuts a wall it is usual to support the top by a batten fixed to the wall along the length of the bench. Where a top skirting is fitted, this too should be plugged and screwed to the wall to form a seal and cover for any movement of the bench top away from the wall.

f. Fitting of sinks. It is recommended that sinks for general use should be fitted beneath the bench top, the hole being cut to reveal part of the rim and sealed with a non-hardening mastic or protected by a lead flashing; alternatively the bench top can be cut to overhang the sink and be throated on the underside to provide a water break.

Flanged sinks may be set flush with or slightly below bench level in a hole rebated to take the flange and should be bedded on a non-hardening mastic to give a watertight joint.

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g. Service holes. When services are to be installed by a contractor other than the one constructing the bench it may not be possible to drill the bench for services before it is in its final position. It may then be found that holes for sinks or pipes are wanted just where it is not possible to put them i.e., close to or at a leg support or partition.

To avoid these difficulties co-ordination between contractors on such matters is most important. All location points for services should be agreed before construction. Whether the holes should be cut during construction or on site should also be by agreement. The positioning of the holes and the fixing of service pipes and fittings should permit slight movement of the bench top as a result of changes in moisture content.

h. Maintenance. Spillage should be removed at once, especially corrosive fluids; cleanliness at all times does much to ensure maintenance in a satisfactory condition.

For teak tops the application of a wax polish sparingly applied at reasonable intervals and well rubbed in should keep them in a state of good preservation and act as a replaceable barrier against damage to the surface. As far as possible, equivalent treatment should be given to the underside of the bench top.

For linoleum covered tops, the installed linoleum should be cleaned with a damp cloth 48 hours after completion followed by two even coats of an approved resin or wax emulsion sealer, each being allowed to dry before applying a finish coating of good wax polish burnished with a soft cloth. Subsequent cleaning should be by wiping with a damp cloth with occasional restoration of wax polish where required.

2.503. Bench substructures

a. Pedestals. There are three main methods of constructing pedestal or carcass units:

1. The ends may be framed out of softwood or hardwood and either flush or recessed panelled with plywood or hardboard.
2. The ends may be made from multi-ply or blockboard and jointed to the other members.
3. The ends may be solid, with boards jointed as for bench tops.

Bottoms may be of tongued and grooved boards or of plywood suitably fixed in the sides.

Backs may be of plywood screwed, or glued and pinned, into rebates on the carcass ends or in the back edges of the ends, or in the case of removable panels where access to services is required, the backs can be inserted from the front and secured to fillets with fixing screws. For comfortable working, a toe rail or set back plinth housed in the ends should be provided. The plinth should be not less than 2 in. (51 mm) high and should be set back at least 1½ in. (38 mm) from the face of the carcass. To provide against lateral thrust a front frieze rail

(on edge) or fore-edge (on face) should be housed or dovetailed into the ends. Pedestals when butted together to form a long underbench unit may have cover strips to seal any discrepancies at the junction.

b. Drawers. Construction should follow sound cabinet making practice, i.e. dovetailed joints at corners, bottoms grooved into the sides with sufficient depth from bottom of drawer sides to underside of drawer bottom to obviate fracture at this point. As an alternative to grooving the drawer sides, fixing fillets for both sides of the bottom may be provided. The bottoms should be of $\frac{3}{4}$ in. or $\frac{1}{4}$ in. (5 or 6 mm) plywood.

The practice of fixing drawer backs to sides by nailing is not approved.

Drawers wider than 30 inches (76 cm) may have central support muntins added to increase the strength of the bottom, or thicker plywood may be used.

c. Drawer runners. Drawers should be properly provided with hardwood runners, guides, kickers and stops.

d. Doors. Doors of flush construction may be made of blockboard, multi-ply, lamin-board or hardboard. If the outside face is veneered on the surface there should be a balancing veneer or seal on the inner face. If framed construction is preferred, softwood timber may be used, the rails being stub-tenoned into grooved stiles and the plywood facings being pressure-glued to the frame. In general doors should be hinged rather than sliding, should be of flush construction, and all edges should be lipped.

e. Shelves. Shelves in pedestals may be adjustable in height but are usually placed centrally in the height, resting on bearers and of half depth to allow tall equipment to be stored at the front. The depth of the shelves may not give easy access to items stored at the back and pedestals fitted with false backs and less deep shelves may for particular purposes be preferred. Loose shelves can be in the form of trays where convenient.

f. Finishing or supporting rails. The intervals between pedestals forming knee holes are usually bridged by rails of sufficient width and thickness to prevent deflection of the bench top, the rails being secured at their ends by screwed and glued blocks.

g. Leg-framed support structures. The maximum unbroken lengths in which this type of structure can be assembled before delivery to site will be determined by the available space giving access to the room. The jointing of the rails to the legs may be by mortice and tenon joints or bridge joints, or the rails may be housed to the legs, glued and screwed.

Fixing dowels should be of kiln-dried hardwood, passing through the face shoulder, the tenon and not less than two-thirds of the shoulder on the inner side.

All corners formed by legs and tie rails and subject to stress and lateral thrust should be adequately blocked and glued.

h. Floor and wall fitting. Bench understructures, whether cupboard pedestal or leg framed patterns should have provision for scribing or cutting to fit any minor unevenness or inclination in floor condition so that a true level surface may be presented by the bench top. End fillers or scribing pieces should likewise be provided to enable the carcass units to be aligned against any unevenness or inclination of the walls.

When poor floor conditions cannot be avoided, provision for adjustable levelling should be incorporated.

j. Locks. Locks should be made from good quality brass. The bolts should be solid and made in one piece, either drawn or cast. The box part of the lock should be cast and fastened securely to the back plate with not less than two screws.

For most laboratory purposes the 4-lever lock with pipe-type key is preferred, but 2- and 3-lever locks are satisfactory and may be used where a smaller number of differs is required.

The number of keys required can be reduced by using a master key system or by having keys able to pass a series of locks. This also overcomes the inconvenience caused by lost or mislaid keys.

The question of providing locks to drawers and cupboard doors should receive careful consideration from the point of view of cost. For instance, in industrial laboratories it is not always necessary to lock all drawers and cupboards whereas in school and teaching laboratories generally, it is usually necessary for students to have at least one cupboard and drawer in which to lock up their apparatus. The drawer or drawers may be arranged so that they can be secured from inside the cupboard, thus necessitating only a single key.

The most commonly used locks in laboratories are the ordinary drawer locks and double handed cupboard locks as shown in Fig. 12. In some laboratories padlocks with hasps and staples are preferred. Where it is desirable to eliminate keys combination padlocks may be used. For sliding doors hook bolt locks may be used. Special locks are available for frameless glass sliding doors of which one type is shown in Fig. 12. Another special arrangement which is commonly used where it is required to lock a tier of drawers is a locking bar. This is usually fitted to one side of the drawers, all of which it overlaps, and is secured with one lock.

Sub-section 2.6. Metal laboratory furniture.

2.601. General. The use of metal in laboratory furniture is generally confined to the bench underframing, and to storage cupboards and shelving. The bench top itself is not normally produced in metal, and the considerations governing the selection of a suitable bench top material for use with steel furniture are exactly the same as for timber furniture; consequently the bench top specifications may be similar for either metal or timber underframing.

Owing to the manufacturing techniques involved, metal laboratory furniture is generally of unit construction, and since it cannot be readily 'cut to fit' in the event of site dimensions being changed, ample clearances should be left between such equipment and the building structure, such clearance being made good by the fitting of scribes in a suitable non-metallic form. Similarly, since steel units cannot be scribed to fit an uneven or irregular floor, it is preferred that each unit should incorporate a suitable levelling device, so that units can be levelled relative to the bench top and structure, and to each other.

2.602. *Quality of material.* The most practical metal for the construction of laboratory furniture is found to be cold reduced, general purpose quality mild steel sheet, free from rust or scale, and the gauges of component parts should be not less than the following:

- Carcases, 18 B.G. (except for non-exposed backs, which may be 20 B.G.)
- Shelves, 20 B.G. with adequate stiffening channel bends at back and front.
- Doors, 20 B.G. with 20 B.G. filler panels at rear.
- Drawer bodies, 20 B.G.
- Drawer fronts, 20 B.G. with 22 B.G. filler panels.
- Drawer backs, 22 B.G.
- Drawer suspension channels, 16 B.G.

NOTE. Equivalent dimensions are given in the following table:

16 B.G. = 0.0625	in. = 1.588	mm
18 B.G. = 0.0495	in. = 1.257	mm
20 B.G. = 0.0392	in. = 0.9957	mm
22 B.G. = 0.03125	in. = 0.7938	mm

Aluminium or stainless steel are possible alternative materials, but their cost makes them uneconomical for most purposes.

2.603. *Construction.* Carcases should be of a rigid welded construction, so designed that they will remain square under all normal conditions of handling and use, and all welds should possess a strength at least equal to that of the components being joined. All exposed welds should be properly cleaned off prior to finishing processes. All folds should be so arranged that there are no exposed raw edges on the interior or exterior of the carcass or assembled components.

2.604. *Additional requirements.*

- a. Overall dimensions of carcasses and components should be strictly maintained, so that any required interchanges may be easily effected.
- b. The internal and external surfaces of all carcasses should be as flush and free as possible from ledges, folds, screw or bolt heads, or other projections.
- c. All drawers should be fitted with releasable back stops.

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d. Drawer runners should be so designed that wear on painted or enamelled surfaces is prevented, and noise and friction are reduced to a minimum.

e. All doors and drawers should be fitted with rubber buffers, or similar sound-deadening devices.

f. All steel should be thoroughly degreased before fabrication and treated by a suitable primary rust-preventative process after fabrication, and such degreasing and rust-proofing should extend to the whole surfaces of the steel, whether internal or external, exposed or concealed. All visible internal and external surfaces should be finished with at least two coats of enamel, efficiently stoved to produce a hard non-chip surface, and the enamel should possess adequate corrosion-resistant qualities.

SECTION 3. RECOMMENDATIONS ON FUME EXTRACTION IN LABORATORIES

Sub-section 3.1. General.

3.101. Scope. This section deals with the design and construction of the main types of laboratory fume-cupboards and hoods. It also includes notes on the so-called glove boxes or dry boxes which, for certain purposes more particularly in the radiochemical field, are being increasingly used to supplement or replace fume-cupboards.

3.102. Relation to general ventilation. Attention has been drawn (see Clause 1.213) to the need for the fume extraction system in a laboratory to be taken into account in considering the general arrangements for ventilation and space heating. The objective should be to achieve a satisfactory balance between efficient functioning of the fume-cupboard, comfortable working conditions in the laboratory, and economical running costs.

3.103. Definitions.

a. A fume-cupboard is a confined working bench space (with or without movable front or side sashes) equipped with services and provided with an efficient means of removing objectionable fumes, gases, vapours, etc. admitted into, or generated within the confined space.

b. In Britain the term 'hood' is usually applied to what is basically a fume-cupboard without a front sash.

c. A glove box or dry box is a box or cabinet completely enclosed and gas tight, equipped with means, including mechanical and electrical services, for carrying out a variety of manual operations, chemical, radiochemical, physical, bacteriological, etc. in a controlled atmosphere under conditions of complete visibility and with a high degree of safety from a wide range of hazards.

3.104. Siting. In general it is desirable to reduce, as far as possible, the length of ducting between the fume-cupboard and the point of discharge into the atmosphere, and where a large multi-purpose building is involved, this may be a reason for siting a laboratory on one of the upper floors. On the other hand, some extract systems make use of the ducting as a 'settling area', for example for small particles which it would be undesirable to discharge into the atmosphere and difficult to retain by filters, and for such purposes a certain minimum length of ducting is essential. On the whole it may be said that the main consideration in siting fume-cupboards should be the convenience of the user, so that for example they should be readily accessible from the bench, and easily supervised in the case of a teaching laboratory. If the ducts are long, a more powerful fan will be required to ensure an adequate air flow through the fume-cupboard.

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3.105. Classification. For convenience in considering fume-cupboard dimensions, air velocities, etc. the following classification is made. Apart from Type E, however, the types are closely related and their requirements may well overlap to a considerable extent.

Type A. Fume-cupboards for teaching laboratories in schools.

Type B. Fume-cupboards for academic and general industrial laboratories.

Type C. Fume-cupboards for special requirements, i.e. operations involving corrosive, toxic or radioactive materials in dangerous concentrations.

Type D. Movable fume-cupboards and bench hoods for use in any of the above three classes.

Type E. Glove or dry boxes.

3.106. Dimensions. Recommended dimensions are given in Table 5 for Types A and B but no dimensions are given for the other types nor for glove boxes as these may vary between wide limits depending on the special requirements.

Dimension	Type A (School laboratories)	Type B (Academic and general industrial laboratories)
Height of base (working surface) from floor	2 ft 9 in. (84 cm)	3 ft (91 cm)
Clear width of front opening*	2 ft 6 in. (76 cm) to 4 ft (122 cm)	Min. 3 ft (91 cm)
Height of front opening	2 ft 6 in. (76 cm)	2 ft 9 in. (84 cm) to 3 ft (91 cm)
Height of top of cupboard from base (working surface)	Not less than 3 ft 6 in. (107 cm)	3 ft 6 in. (107 cm) to 6 ft (183 cm)
Depth of clear working space	2 ft (61 cm) to 2 ft 6 in. (76 cm)	2 ft (61 cm) to 3 ft (91 cm)

* This does not apply to hoods, the widths of which are independent of sash considerations.

Sub-section 3.2. Design of fume-cupboards.

3.201. Basic requirements. The aim in fume-cupboard design is to ensure the efficient removal of noxious fumes, etc. admitted into or generated within the

cupboard, by extracting air from the cupboard at a rate and in a manner such that the fumes are prevented from escaping back into the laboratory.

The basic types of fume-cupboard are illustrated diagrammatically in Figs. 12 and 13.

3.202. Considerations determining air flow. It is desirable to avoid too great an air flow, as the greater the air flow, the greater the heating loss in the laboratory.* On the other hand it is important in any fume-cupboard to have the possibility of an air flow sufficient for all purposes for which the fume-cupboard may be used and this may necessitate installing a fan capacity appreciably greater than that required for the bulk of the operations to be carried out in the fume-cupboard. In order to minimize the loss of heat which this might cause, some control of the air flow through the fume-cupboard is desirable. This may be effected, *a.* by means of dampers in the fume-cupboard, in the ducting, or in both, and these dampers may be either manually or electrically controlled, *b.* by regulating the fan, or *c.* by a combination of both these methods.

For an efficient fume-cupboard the air entering the cupboard should pass across the whole area of the fully open front in a flow which is as uniform as possible and at a velocity depending on the character and quantity of fumes to be removed or by the nature of the hazard (see B.S. CP 352*, Clause 3.312). Most ordinary fume-cupboards are not designed in accordance with aerodynamic principles and the air velocity across the open fronts can vary considerably, but this is not usually a serious disadvantage provided the velocity at any point does not fall below the minimum appropriate to the particular type of cupboard.

3.203. Recommended air velocities. Recommended limits for air velocities are given in Table 6.

TABLE 6. LINEAR AIR VELOCITIES THROUGH THE FULLY OPEN FRONTS

Type A	Fume-cupboards in schools	20-40 lineal ft/min (6-12 m/min)
Type B	Fume-cupboards in academic and general industrial laboratories	40-100 lineal ft/min (12-30 m/min)
Type C	Fume-cupboards for special requirements involving toxic hazards	100-200 lineal ft/min (30-60 m/min)
Type D	Movable fume-cupboards and bench hoods	As for Type A, B or C depending on requirements

* It should be borne in mind that under certain circumstances where operations producing dangerous or objectionable fumes are involved, it may be more satisfactory and cheaper to provide local extract (see Clause 3.509 and Fig. 21*d*).

† B.S. Code of Practice 352, 'Mechanical ventilation and air conditioning in buildings'.

3.204. Indication of air flow. Some indication of an air flow through a cupboard is desirable. In the case of Class A or Class B cupboards a simple lamp energized through an auxiliary contact on the fan motor starter is sufficient.

For Class C cupboards the lamp should be controlled by means of a relay installed in the extract duct, actuated by air flow.

3.205. Arrangement of ducts. Whether fume-cupboards are individually ventilated, or linked together and connected to one main exhaust duct, must depend on a number of factors such as cost, the layout of the building, particularly the relationship between discharge and fresh air intakes, and the nature of the work being done. In general, individually ventilated fume-cupboards are more convenient, but in all cases the same air flow considerations apply for efficient working.

3.206. Sashes. Most fume-cupboards are fitted with vertical sliding sashes suitably balanced for smooth movement, but glazed panels sliding laterally across the face of the fume-cupboard are also used, though more often with long open hoods than with the conventional type of fume-cupboard. Typical designs of sash are illustrated in Fig. 14. In the case of the vertical sliding sash the suspension is achieved by means of sash cords, chains and weights, spring balances or spring tape balances. The two latter have the advantage of occupying very little space. The spring tape balance in particular occupies a few square inches only, but the types available at present are not suitable for sashes weighing more than approximately 30 lb or 14 kg. With all vertically moving sashes, however supported, safety pegs or safety catches (Fig. 14) should be fitted in the front stiles of the fume-cupboard so that in the event of the suspension breaking the sash is prevented from falling lower than about 6 in. or 15 cm above the level of the fume-cupboard base. In general it is preferred that fume-cupboards should be made so that the sash does not close completely. The minimum opening should be sufficiently large to prevent, for example, a bunsen flame being extinguished by the increased air velocity when the sash is lowered rapidly.

3.207. Services. The main services required in fume-cupboards are gas, water, waste and electricity. Other services which may be required are steam, compressed air and vacuum. All services should be plainly identified by the use of colours, distinctively shaped taps, and labelling (see Clauses 4.401-4). All mechanical services should have outside controls with the outlets arranged in the front corners of the base, in the front pilasters or along the sides of the fume-cupboards. If for any reason it is not convenient to arrange the services in one or another of these positions they may be placed at the back of the fume-cupboard, either on the base or in a row on the back vertical face. Electrical outlets should be arranged outside the fume-cupboard and it is desirable that they be kept as far away as possible from the water service. They can often be arranged along the front rail below the base of the fume-cupboard or adjacent

to the sides of the fume-cupboard. In the latter case a small opening with a sliding cover should be made in the side of the fume-cupboard (6 in. (15 cm) or so above the base level) through which to pass the electrical leads to equipment inside the cupboard.

Three examples of fume-cupboard design showing arrangement of the services are illustrated in Figs. 15 to 17.

3.208. Modifications. For occasional use or where a flexible arrangement is necessary, transportable fume-cupboards may be used. In these cases a fume-cupboard superstructure is placed over part of a working bench equipped with services and is connected to an exhaust duct provided in some predetermined position. This arrangement, however, is not regarded as good practice and does not adequately replace a normally designed fume-cupboard.

In teaching laboratories small individual hoods placed directly on the working bench are sometimes used. These are usually connected to a common exhaust duct below bench level, and fumes are drawn downwards. Such an arrangement can be quite satisfactory provided the air velocity into the hood is adequate.

Sub-section 3.3. Materials for fume-cupboards

3.301. General. Conditions in fume-cupboards may be extremely corrosive, and the selection of suitable materials is made more difficult by the variety of uses to which they may be put. It is only possible, therefore, to make general recommendations, and it may nevertheless be necessary to replace corroded parts or fittings during the life of the laboratory.

3.302. Framing.

a. Hardwoods. Teak and oak are most commonly used. Normally, timber framing is protected by a good quality varnish and a waxed finish is often sufficient protection for teak. Where conditions are very severe a protective coating of paint is desirable. Suitable paints are available and those based on chlorinated rubber or epoxy resins give good protection under varied corrosive conditions. Where perchloric acid is likely to be used, timber should be avoided owing to the danger of spontaneous combustion.

b. Metals. Mild steel with a painted (air dried or stoved) finish is commonly used. Aluminium, although a little more costly, has certain advantages where the corrosive conditions are severe but it should also be protected with a suitable paint finish. Stainless steel, nickel and certain nickel alloys, though satisfactory from a corrosion point of view, are rather costly and consequently less used for this purpose. Stainless steel, however, is particularly valuable for fume-cupboards used in work with radioactive materials.

3.303. *Transparent panels.*

a. Sheet glass. This is the most commonly used material for the panels and sashes of fume-cupboards. It has the advantage of being cheap, light, resistant to fumes except hydrofluoric acid, and able to withstand a moderate degree of heat. Its main disadvantages are that it readily breaks and, in the event of an explosion, is a source of additional hazard. For these reasons, it cannot be generally recommended.

b. Wired glass. This is manufactured in $\frac{3}{4}$ in. ($6\frac{1}{2}$ mm) thickness only. It is resistant to fumes except hydrofluoric acid and affords a good measure of protection. A serious disadvantage, however, is that it readily cracks when subject to mild heating.

c. Toughened glass. This safety glass costs appreciably more than sheet glass but in general is strongly recommended. It provides very good mechanical protection, and is much more resistant than ordinary sheet glass or wired glass to thermal shock. It is stable up to a temperature of 295°C . It is resistant to fumes except from hydrofluoric acid. The thicknesses appropriate for fume-cupboards are $\frac{3}{16}$ in. (5 mm), $\frac{1}{4}$ in. ($6\frac{1}{2}$ mm) and $\frac{3}{8}$ in. ($9\frac{1}{2}$ mm) depending on size and degree of protection required.

d. Laminated glass. This safety glass may be more expensive than toughened glass, and its only advantage is greater mechanical protection; but this depends on the combination of laminations used. Under thermal shock conditions it fractures as readily as single sheet glass or wired glass unless the glass used is itself toughened. In the event of breakage, however, the interlayer will hold the broken pieces of glass together. The effect of fumes and heat on the interlayer must also be considered, although some protection from fumes may be obtained by sealing the edges.

NOTE. For further information on the thicknesses available of the types of glass mentioned above, reference should be made to B.S. 952, 'Glass for glazing' and to B.S. 857, 'Safety glass for land transport'.

e. Plastics sheet. Polymethyl methacrylate, cellulose acetate and transparent unplasticized P.V.C. are resistant to fumes including hydrofluoric acid and they afford good mechanical protection. Their main disadvantages are that they are easily scratched, readily distort with heat and, with the exception of P.V.C. and non-flammable cellulose acetate, will burn.

3.304. *Opaque panels.*

a. Highly compressed asbestos cement board. Materials of this type are mechanically strong and resistant to heat. In the natural condition they are reasonably resistant to a wide range of corrosive substances and this resistance can be appreciably improved by treatment with a suitable plastics varnish or acid-resisting paint. A disadvantage is that they are readily stained by a variety of chemicals.

b. Plastics sheet. Various types of laminated plastics (see Clause 2.403 *b*) are available as well as rigid P.V.C. They differ in their resistance to chemicals, but all withstand reasonably well the action of dilute acids, dilute alkalis and a wide range of organic solvents. Strong mineral acids tend to cause discolouration, and in most cases if left in contact with the plastics for long enough they will cause actual breakdown. The maximum working temperature for these plastics is in the region of 130–165°C.

c. Metals. Stainless steel, nickel-copper alloy, aluminium and mild steel may be used. The two latter, however, must be coated with suitable protective paint, and depending on the conditions to which they are subjected they may require regular maintenance. Stainless steel and nickel-copper alloy have the advantage that they do not require paint protection except when exposed to very severe corrosive conditions.

3.305. Bases.

a. General. A wide variety of materials are used for fume-cupboard bases, and selection among them depends largely on the type of work that is likely to be undertaken. Where particular hazards are involved it may be necessary to test a variety of possible materials before making a choice.

b. Highly compressed asbestos cement board (see Clause 3.304 *a*.)

c. Lead. This makes a satisfactory base for many purposes. Its principle disadvantages are that it reacts with certain chemicals, particularly mercury in the presence of acid. It is rather soft and therefore easily damaged and it is a little difficult to maintain in a clean condition. It is recommended that 'chemical lead' complying with B.S. 334*, i.e. pure lead without any added copper or other metals, should be used and that the weight should be not less than 5 lb/ft² (24.4 kg/m²).

d. Stainless steel and Monel metal. These metals have certain advantages for special fume-cupboards such as those used in radiochemistry. They are, however, costly and bases made of these metals need careful construction so as to avoid buckling.

e. Slate. This makes a satisfactory base for some purposes. Its main disadvantages are that it is readily cracked by heat and is dehydrated by water-absorbing acids such as sulphuric acid.

f. Toughened glass, clear, translucent or opaque. This makes a satisfactory base. In a thickness of $\frac{3}{8}$ in. or more it is highly resistant to mechanical impact. It is also highly resistant to thermal shock and to all chemicals with the exception of hydrofluoric acid and hot strong alkalis.

g. Vitreous tiles. These make a very satisfactory base provided they are laid well and pointed with a suitable acid-resisting cement.

* B.S. 334, 'Chemical lead (types A and B)'.

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They should be laid on a reinforced concrete base. Good quality vitreous tiles are resistant to all chemicals with the exception of hydrofluoric acid and they will also withstand a considerable degree of heat.

3.306. Sashes. (See also notes on construction and workmanship in Clause 2.503.) Sashes are normally constructed with a framing of hardwood such as teak, oak or iroko and they are usually panelled with one or another of the transparent materials mentioned above. Metal framing of stainless steel, mild steel or aluminium, suitably protected, may also be used. Toughened glass is frequently used without a framing and is quite satisfactory.

Catgut, polyester and polyamide fibres and stainless steel are suitable materials for sash cords. If spring tape balancers are used, they should preferably be fitted with stainless steel tapes.

Sub-section 3.4. Glove or dry boxes.

3.401. Basic requirements. For many laboratory operations involving the handling of radioactive, bacteriological and chemically toxic materials an increasingly useful device which in some instances takes the place of a fume-cupboard is the glove box or dry box. Basically this consists of a gas-tight cabinet fitted with one or more windows giving a comprehensive view of the interior.

3.402. Facilities provided. The cabinet is generally equipped with:

- a. inlet and outlet ports controlled by taps or valves through which to exhaust or replace the atmosphere within the cabinet;
- b. suitable connections for electrical and other services as required;
- c. one or more small cupboards, fitted with gas-tight doors, which form air-locks and permit apparatus or materials to be introduced into or removed from the cabinet while it is in use;
- d. two or more glove ports with attached elbow-length gas-tight rubber gloves, arranged in convenient positions in the panels forming the walls of the box.

in addition it may be equipped with:

- e. a suitable electric light; and
- f. a filter in the exhaust to remove radioactive or other contaminants from the exhaust gases.

3.403. Materials and construction. Glove boxes are made in a wide variety of shapes and sizes. Suitable materials for their construction are:

- a. stainless steel;
- b. mild steel or aluminium sheet, suitably painted;
- c. plastics veneered board;
- d. transparent or laminated plastics materials;
- e. toughened glass.

It is important that the interior finish should be chosen so as to minimize the possibility of corrosion and to facilitate drastic cleaning.

Examples of glove box design are illustrated in Figs. 18 and 19. Fig. 18 shows a general purpose glove box constructed of mild steel sheet with stoved enamelled finish and a window of polymethyl methacrylate. The base is equipped with a stainless steel tray. Fig. 19 shows a glove box used specifically for work with radioactive materials. It consists of a welded sheet metal box with plastics windows fitted into the sides and sealed by means of a special rubber gasket. All the metal parts are coated with an air-drying enamel paint. Toughened glass would also be suitable for windows or panels in glove boxes of other materials.

3.404. Transfer of hazardous materials. For the transfer of hazardous materials in and out of the glove box a simple yet effective method is to use a thin (0.004 in. or 0.1 mm) P.V.C. bag instead of the air-lock cupboard. This P.V.C. bag is attached to a port similar to a glove port and materials transferred from the box are passed to the end of the bag where they are isolated by two adjacent rows of welding across the bag. The material thus isolated is then separated from the remainder of the bag by cutting between the two rows of welding. Passing equipment into the box can be done in a similar manner.

Sub-section 3.5. Extract systems.

3.501. General. The main methods in use are described below and illustrated diagrammatically in Figs. 20 and 21.

In planning an extract system, care should be taken to ensure that as far as possible the discharge to atmosphere does not occur in proximity to windows which can be opened, because of the danger that fumes may in this way be drawn back into the internal air circulation of the building.

3.502. Natural draught. (See Fig. 20a.) This is the earliest form of extract system, based on the principle that hot gases rise. For fume-cupboards, the source of heat is commonly a small gas burner at the base of the flue. This system is comparatively little used today, as it is not easily controlled. It is very much affected by atmospheric conditions, and the amount of air that can be moved is limited, unless large and long vertical ducts are provided and a considerable degree of heat is used. These latter conditions sometimes exist in the case of a well-designed furnace or hot plate hood, but the flue construction is usually expensive.

3.503. Axial flow and propeller fans. (See Fig. 20b.) These are fans of the ordinary ventilating type. Under suitable conditions, large quantities of air can be moved at quite moderate cost, but the fans are not designed to work against any appreciable resistance, consequently ducting runs must be short and of large diameter. Preferably the motor itself should be external to the ducting. With the ordinary type of axial flow fan both fan and motor are in

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the path of the removed fumes, and in this case the motor should be totally enclosed and protected by a plastics coating or by a sprayed lead coating painted with a suitable paint.

3.504. Centrifugal fans. (See Fig. 20c.) These are the most widely used today. They are available in a very wide range of capacities, designed to suit varying types of air-flow conditions. The motor (which can be for direct or belt drive) is outside the path of fumes, but the fumes do pass through the fan, which therefore requires to be of corrosion-resistant material, or protected by a corrosion-resistant coating. This is the principal weakness of this type of fan, and for really *severe conditions* has led to its partial replacement by the following type.

3.505. Ejector (induced draught). (See Fig. 20d.) This system operates on the venturi principle and is probably unequalled for severe conditions. Where a fan is used, it handles only clean air, and consequently it can be of plain steel plate construction, but designed to work at comparatively high resistances. The system provides a blast of high-pressure air or steam to the nozzle of a venturi system, and the fumes are extracted by the resulting vacuum action. The system is rather more expensive to install and operate than the normal centrifugal system. It is noisier, and where a fan is used to produce the air blast it must be situated where it can obtain a supply of clean air. Where conditions are so severe as to justify the installation of this system, it will outlast many direct-acting centrifugal fans.

3.506. Top and bottom extract. (See Fig. 21a.) There are a number of designs for use with either centrifugal or ejector fans. Their principal feature is the design of the ducting and baffling to extract fumes at two heights, at or near the bottom for heavy gases, and at or near the top for light or hot gases, the two levels of exhaust frequently having independent damper control.

3.507. Centre back extract. (See Fig. 21b.) This may be regarded as a modification of the top and bottom extract system, arranged to give an even draught all round the back of the hood. Centrifugal fans are used, extracting from the centre point of the hood back, immediately in front of which is fitted a baffle having narrow extraction slots at top, bottom and both sides.

3.508. Balanced extract. (See Fig. 21c.) This system may be regarded as still in its experimental stage, being designed primarily for use in fully air-conditioned buildings. It secures adequate fume removal with the minimum loss of conditioned air, which may effect a considerable saving in expense.

The system is in two parts, a straightforward extract system, with top or rear extract, and an input system, supplying clean, unheated air at appropriate positions around the open front of the fume-cupboard or hood. The inlets and outlets are so arranged that a moving 'curtain' of air is produced across the

working opening and the bulk of the air for this is supplied by the input fans which draw clean air from outside the building.

To avoid the escape of fumes due to eddy currents it is necessary to restrict the capacity of the input fan to 60–70 per cent of that of the extract fans, but even so, this represents a considerable saving of conditioned air. Many elaborate control arrangements are possible, providing automatic and variable linkages of input to suit the conditions required at any particular time.

3.509. Kjeldahl hood. (See Fig. 21d.) This is an example of a system (which might be used in conjunction with an ejector fan) in which fumes are extracted as closely as possible to their point of liberation before they are able to escape into the general atmosphere. Well designed examples are efficient, and use very little air, but they are essentially systems designed for specific purposes and are not suitable for general fume-cupboard or hood ventilation.

3.510. Perchloric hood. (See Fig. 21e.) This extract system is of straight-forward ejector type, but using *inorganic* materials as far as possible (owing to the danger of spontaneous combustion with perchloric acid), and with a water spray so arranged that the baffles and lower part of the ducting can be washed down, either continuously or at intervals.

3.511. Walk-in hood. (See Fig. 21f.) This is a form of closable hood which can accommodate tall or bulky apparatus and which allows the operator to get inside when required. Controls are often duplicated so that they can be used either from the inside or the outside. Straightforward centrifugal or ejector extract systems are generally used, but with a slightly higher extraction rate than for a corresponding length of ordinary hood.

Sub-section 3.6. Ducting.

3.601. Materials. Suitable materials for ducting are the following:

- a. Asbestos cement ducting in round or rectangular section lined with a suitable protective coating. Bituminous paint or chlorinated rubber paints are often used as the protective coating but they may not be satisfactory if appreciable quantities of organic solvent vapour are likely to be exhausted through the ducting.
- b. Chemical stoneware.
- c. Galvanized mild steel sheet with a suitable protective lining.
- d. Plastics ducting, reinforced, e.g. with glass fibre.
- e. Rigid P.V.C. or polythene ducting.