Introduction to Safety in the Chemical Laboratory

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Preface

In the first twenty or thirty years of this century laboratories were normally found only in the chemical industry, in hospitals, or in educational establishments; now they are commonplace. Few industrial locations are without laboratory facilities of a size compatible with the range of operations and the substances being handled or used. Rapid changes and advances in the scientific fields of research and development call for ever larger, more modern, and better equipped laboratories if enterprises are to keep pace with, or outstrip, competitors. Moral and legislative requirements now impose on the manufacturers and suppliers of products heavy responsibilities with regard to consumer protection. The health and safety of a company's own employees have always been important considerations, but the users, manufacturers, shippers, and importers of chemicals must now not only safeguard those in their own work environment: their duty extends to the employees of customers and to the public in general. This extension of responsibility has been accompanied by an increasing concern with, and awareness of, the quality of life in general.

Industrial chemists and technicians, through their work in laboratories, provide, and will continue to provide, a platform from which the discharge of these increasingly onerous responsibilities can be facilitated. As the scope, size, and equipment of industrial laboratories become larger and more sophisticated so too must that in educational establishments in order that the skills of emergent laboratory workers keep pace with progress. Hospital, pathological, and forensic laboratories now operate on a scale unthought of a couple of generations ago.

This upsurge in activities has been accompanied by useful literature intended to raise levels of health and safety. Generally this has taken the form of helpful and voluminous lists of hazardous substances, threshold limit values, compatible and incompatible chemicals and so on. We have dealt with the general approach to safety—how to design accident prevention into the laboratory; coping with hazards which arise almost every working day; dealing with actual or potential fires and disasters, and similar matters. It was an apparent lack of collected information of this kind which inspired the authors to write this book, which should be taken as a guide rather than a manual of procedures. The aim is to provide a book of reference for everyone who works in, or uses the facilities of, laboratories.

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DISCLAIMER

The authors of this book have each been involved in laboratory safety activities for more than thirty years. The sources used to supplement their own practical experience are believed to be reliable and to represent the best opinion as at 1981. The book is intended as a guide rather than a manual of procedure. No warranty, guarantee, or representation is made by the authors and publishers as to the correctness or adequacy of any information contained therein. No responsibility or liability is accepted in any manner whatsoever for any errors or omissions.

Contents

1 Laboratory Design and Layout

It is beyond the scope of this book to deal with special-purpose laboratories such as those designed for radio-chemical work, animal studies,or toxicological investigations, and the references at the end of this chapter should be consulted for detailed information of this type. It is intended that this chapter will include discussion on basic principles of laboratory design with particular emphasis on safety. A laboratory is defined as a building set aside for experiments in natural science and, as such, may involve work in many scientific disciplines of which chemistry, physics, mathematics and engineering are examples. The general-purpose chemical laboratory contains a wide range of potentially hazardous situations. Flammable solvents introduce the risks of explosion and fire; toxic chemicals the risk of death by poisoning which can be almost instantaneous or take many years to happen; corrosive chemicals can cause serious injury and disfigurement, and extremely lethal sources of electricity such as those used to power X-ray tubes can bring about electrocution. Considerable progress has been made in the last few years in the development of new materials for use in laboratory construction and there is now a very wide choice of finishes for walls, floors, and benches. In selecting materials, particular attention must be directed towards eliminating hazards and ensuring the safety of personnel working in the laboratory.

Overcrowding is one of the significant causes of accidents in laboratories. Adequate space must be allowed for each worker but clearly the exact amount will depend on the type of work done. The British Standard Specification entitled Recommendations on Laboratory Furniture Fittings (BS 3202 1959) gives some guidance, suggesting that a space of under 9 m^2 per worker results in inefficient cramping whereas over 23 m^2 is seldom required. In the case of school laboratories, between 2.75 and 4.5 m^2 per pupil is considered adequate. For an analyst carrying out classical methods of analyses a bench length of 3 m is adequate. An examination by CSIRO (Australia),[1] however, indicated that in eight of their laboratories the average space available ranged between 41 and 50 m^2 and in another four, between 57 and 61 m^2. They conclude that a figure of 50 m^2 should be used but added a rider justifying a greater area for some types of work. In the case of ventilation, BS 3202 1959 recommends that at least 57 m^3 of fresh air per person per hour should be provided.

TYPE OF BUILDING

Although this chapter is devoted primarily to the internal construction and design of laboratories, some details on the important points in the construction of the actual building are included. Clearly, during the design stage consultations will take place with the relevant statutory bodies concerned with building construction and fire hazards to ensure compliance with the appropriate regulations. Discussions should also take place with the insurers of the property as they may enforce additional special conditions before they will provide cover. (Construction details in relation to fire protection are dealt with in Chapter 9.)

In defining areas of special hazards, such as in radiation laboratories, access to the roof space above the laboratory must be restricted. Laboratories in high-rise buildings are usually placed on the upper floors in order

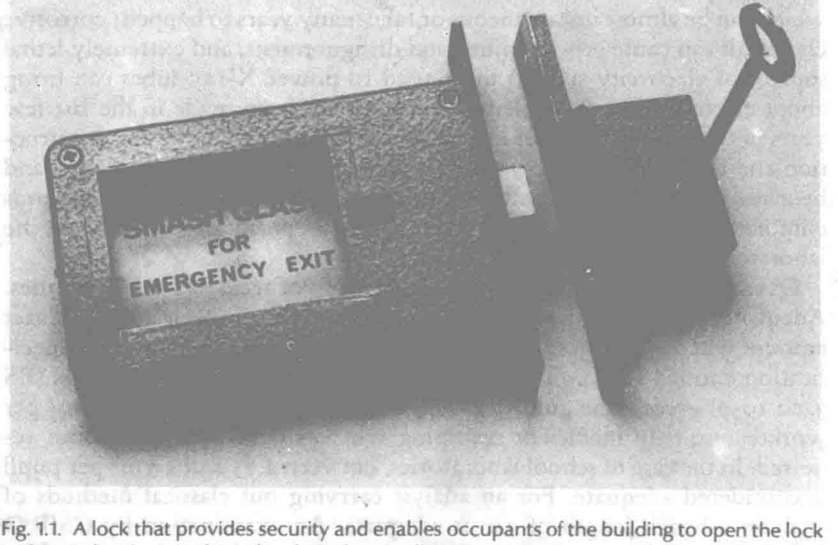

Fig. 1.1. A lock that provides security and enables occupants of the building to open the lock without a key by smashing the glass plate. It allows strong springs to withdraw the bolt thus enabling the door to be opened. The door cannot be relocked until another glass panel has been inserted. Routine opening of the door is possible using the key locking strike. (Photograph courtesy of Albert Marston & Co. Ltd).

to reduce the length of fume extraction ducting and the risk of fumes entering the building; in the disposal of liquid effluents the containment of liquid is simpler and the risk of contamination less. There are, however, problems in transporting corrosive and toxic materials to an upper floor, and the latest UK legislation on the housing of compressed gas cylinders may lead to a reconsideration of the siting of laboratories in multi-storey buildings. In view of their exposed position, additional precautions concerning such fire-fighting equipment as compressed air breathing equipment, are desirable, and at least one of any lifts installed should be large enough to take a casualty on a stretcher. Emergency exits must be available for use at any time and not be permanently locked. Various devices are commercially available for securing such exits (Fig. 1.1) and of these the easily-operated pushbar type is preferred to a locked door where the key is housed nearby in a glass-fronted case.

Other points concern the siting of stores to facilitate access and distribution, and the width of corridors, which need not exceed 2 m even in the largest laboratory block as greater width encourages storage in them. Detailed points regarding materials of construction, furniture, fume cupboards, lighting, and services will be included in later sections.

STRUCTURE

Walls should have a slow flame-spread characteristic, be smooth and readily cleaned, and not have any ledges that would form dust traps. A plastered finish brick or breeze block wall painted with an alkyd resin paint is ideal, although if extreme toughness of finish is required a polyurethane paint may be used. For general use, PVC floor covering is a long-lasting durable material which has a high resistance to acids and alkalis. It is, however, attacked by solvents such as acetone and chloroform and is unsuitable if large amounts of these solvents are in use. In this case, ceramic tiles would be a satisfactory, if more expensive, alternative. There is an increasing tendency, particularly in laboratories with expensive instruments such as electron microscopes and X-ray equipment, to use synthetic fibre carpeting. This can be vacuum-cleaned, thereby reducing dust which can give trouble if it gets into delicate instruments. Whatever the material, the undersurface should preferably be of a rigid finish such as concrete, and the floor covering should be seamless with coves formed at the junction with the wall to help contain spillages. There is some merit in floor tiles instead of sheeting since worn patches can be easily and economically replaced. In laboratories where heavy equipment is being handled a stronger floor finish is desirable and a concrete floor treated with one of the proprietary two-pack epoxy coating materials for sealing concrete is advantageous. Floor loading tests are needed for laboratories above ground level. Suspended tile ceilings using materials of acceptable flame resistance are attractive in appearance and aesthetically pleasing. Services can be hidden behind them, but the possibility of undetected incipient fire is then created. Alternatively, a traditional painted plaster ceiling can be used. Doors to laboratories should be fitted with observation panels of a type selected with regard to the fire and impact risks in the area.

BENCHES

Benches are of three types: wall, peninsula, and island. Most laboratories have a combination of wall and one of the other types of bench. The type of bench selected depends on the work being carried out in the laboratory, the available space, and the financial budget. Where work of a high hazard rating is being performed, island benches are to be preferred because they avoid the cul-de-sac areas created by peninsula benches. However, the latter reduce the number of people passing by, which can be an advantage when delicate work is being performed. The dimensions generally used for benches are: height, 0.91 m; width, 0.75 m for wall type and 1.5 m for island or peninsula types. Materials used for the tops of the benches include teak or a similar hardwood such as iroko, afrormosia, oak, formica, ceramic tiles, stainless steel, and pyroceram. Selection of the type of material to be used depends on the type of work being carried out in the laboratory. For general purposes, the ceramic tile finish is excellent and details of a typical bench are shown in Fig. 1.2. Particular attention is drawn to the lip on the edge of the bench which retains any spilled liquids. The services to the bench are preferably led along a central spline which is easily seen in Fig. 1.2. The traditional high reagent shelf has been dispensed with; this eliminates the risk of bottles falling off the top shelf and also increases the feeling of spaciousness in the laboratory. The type of bench illustrated is supported on a rigid wooden base with either drawer or cupboard fitments. The drawers should be fitted with stops to prevent them being withdrawn completely. In cases where instrumentation is used extensively, it is difficult to service the instruments if access to their rear is necessary. In this case a special split bench has been designed by the laboratory staff (at Tioxide International Ltd) to facilitate all-round access to the instruments as shown in Fig. 1.3. The illustration shows a bench which has been specially designed for atomic absorption spectrometry. The service outlets, which comprise cold water, electricity, compressed air, vacuum, acetylene, nitrous oxide, nitrogen, and argon are situated at each side of the centre aisle. Acetylene is led to the bench from the cylinders external to the building via the exposed downpipe—four outlets with flash arrester units can be seen on the top of the benches. The distinctively shaped handwheel for the acetylene valves can also be seen. Special localized fume extraction equipment is placed above the bench to remove the heat and fume from the flames. The rack on the wall holds the hollow cathode lamps which are used in this method of analysis. Sinks are usually placed at the ends of benches, tun dishes being used to receive water from taps situated along the length of the bench. These are preferred to central troughs running along the bench which are difficult to keep clean. Choice of material for the sink is dependent on the chemicals most in use in the laboratory. If substantial amounts of hydrofluoric acid are used then stainless steel is preferable to porcelain. Draining boards should be placed alongside the sinks; a typical sink installation at the end of a double bench is shown in Fig. 1.2. The draintrap is placed below the sink

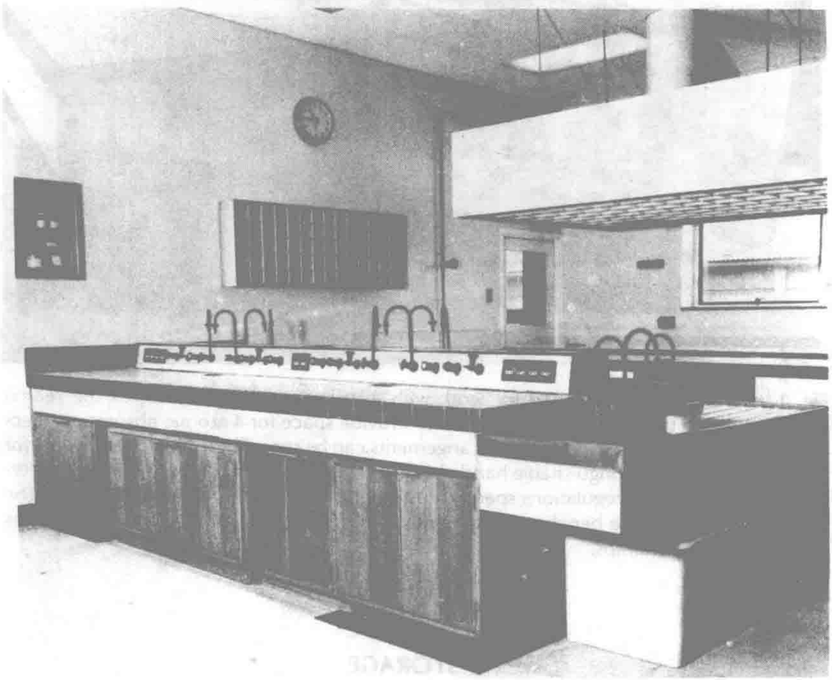

Fig. 1.2. A typical modern laboratory bench. Services are led from the wall side along the central spline. The sink unit is stainless steel and the drain trap is easily accessible at the end of the bench. Ceramic tiles are used for the bench top and cupboards or drawers can be placed underneath. A rubbish bin is housed under the sink.

where it is readily accessible, and the space below the sink is used to house waste-bins.

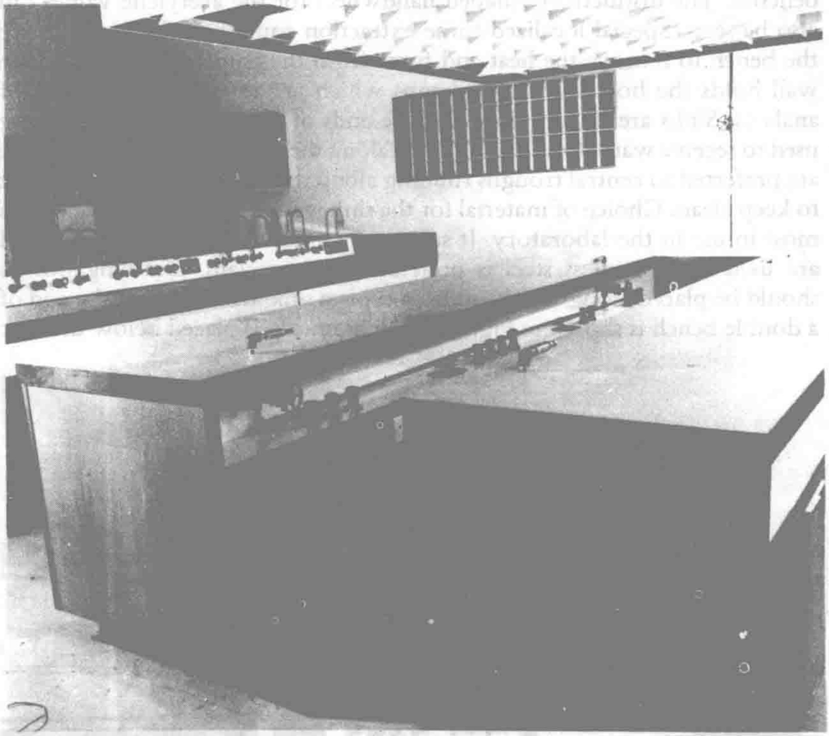

Fig. 1.3. A split bench designed for work with instruments where access to the rear is important. Here the benches are intended to provide space for 4 atomic absorption spectrometers and the special gas supply arrangements can be seen. These include acetylene for which the specially distinguishable handwheels and flame arresters can be seen. The acetylene supply which UK regulations specify must not be concealed is visible on the wall. The arrangement above the bench conceals a fume exhaust system and the wall rack houses the hollow cathode lamps.

STORAGE

Storage space is an item which frequently gets overlooked in laboratory design. It is exceptional to find that all the equipment is in use at any one time and there is usually a need to store fairly large amounts of equipment and chemicals, as well as materials that have been produced or samples that have been analysed. It is worth, therefore devoting some time to planning storage space as untidy stacking of equipment and materials in a laboratory is a frequent cause of accidents. Note that, at this point, the primary concern is storage of materials in the laboratory and external stores are not being considered here.

With regard to chemicals, the amount stored in a laboratory must be kept to a minimum. Highly flammable materials defined in the UK as those with a flashpoint of less than 32°C should be kept in closed containers (preferably metal if the quantity is greater than one litre) and stored when not in use in metal cabinets of approved design. Although UK regulations permit up to 50 litres to be stored in the workroom, efforts should be made to keep the volume well below this. Corrosive chemicals should be stored as near to the floor level as possible and in non-corrodible trays. Hand bottles containing corrosive chemicals should also be kept in trays. Toxic chemicals should be stored in well-ventilated areas and preferably in a fume cupboard or hood. Poisonous chemicals should be kept in a locked cupboard and under rigid key control. Chemicals safeguarded in this way should be those included in a UK Schedule[2] or, in general terms, any chemical having the "poison" symbol on label. Certain chemicals, e.g. powerful oxidizing agents and organic compounds, react violently together and these must be stored apart. Sodium hydroxide and yellow phosphorus in stick form are very much alike and should not be stored alongside each other.

Hazards in the storage of equipment are not so prevalent, but thought given to reserving cupboards for beakers, volumetric flasks, funnels, etc., will pay dividends in the saving of time. The drilling of holes in cupboard shelves greatly facilitates the storage of separating funnels, and specially lined and fitted drawers are recommended to accommodate fragile glass equipment such as burettes and pipettes.

Finally, the need to dispose of rubbish is frequently overlooked. The problem of designing rubbish containers into the furniture of the laboratory so that they do not look obtrusive and yet are readily accessible is not easy. One way of doing this is illustrated in Fig. 1.2 in which the bin is placed under the sink at the end of the bench; another solution is to put the container in place of a cupboard under the bench. A special bin clearly marked should be reserved for disposing of broken glass. Corridors must not be used for storing equipment other than fire extinguishers, first-aid materials, and breathing apparatus which should be placed in clearly marked cabinets, preferably inset into the walls.

SERVICES

In the event of a hazardous situation developing in the laboratory it is essential that all the services are able to be isolated at a central point which is preferably outside the door. Such an arrangement is shown in Fig. 1.4. This also facilitates maintenance of services within the laboratory. The services to the modern laboratory are numerous and can consist of: water, steam, compressed air, natural gas, acetylene, argon, argon/methane, butane, carbon dioxide, helium, hydrogen, nitrogen, nitrous oxide, oxygen, and vacuum. In fact in the authors' laboratories there are seven different types

Table 1.1a. Colour identification system for pipelines.

Pipe Contents	*Basic Identification Colour*	*BS Colour Reference BS 4800 1972*
Water	Green	12D 45
Steam	Silver-grey	10A 03
Mineral, vegetable and animal oil; combustible liquids	Brown	06C 39
Gases in either liquid or gaseous condition (except air)	Yellow ochre	08C 35
Acid and Alkalis	Violet	22C 37
Air	Light blue	20E 51
Other fluids	Black	Black
Electrical Services	Orange	06E 51

Table 1.1b. Safety colours.

Safety Colour	*BS Colour Reference BS 4800 1972*
Red	04E 53
Yellow	08E 51
Auxiliary blue	18E 53

The basic identification colour is used to identify the material in the pipe and the safety colour indicates the type of hazard, e.g. a pipe containing (a) cold drinking water would be painted green with band coloured auxiliary blue; (b) fire extinguishing water would be painted green with a red band; (c) a gas containing a radioactive compound would be painted yellow ochre, with a yellow band on which is placed the radioactive symbol. (Material from BS 1710, 1975 is reproduced by permission of the British Standards Institution, 2 Park Street, London W1A 2BS, from whom complete copies can be obtained.)

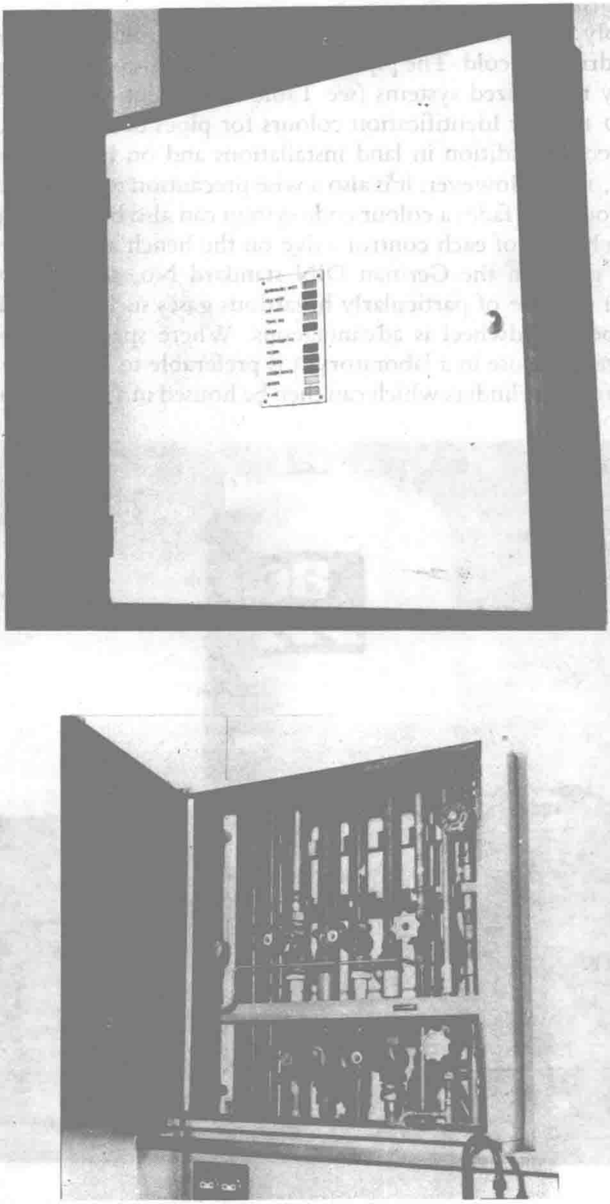

Fig. 1.4. A typical services isolation unit shown with the door open and closed. The colour code for the pipelines is attached to the front of the door.