LABORATORY HANDBOOK

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Edited by

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FOREWORD

The rapid growth and diversification which is so evident in science and technology today is inevitably reflected in the equipment and techniques employed, and in turn the development of yet more refined tools and methods can often open the way to new discovery.

It is the purpose of the present work to act as a guide to this complex and extensive territory. In the first place, it is hoped to provide a useful source of information for those already engaged in any given field to techniques and equipment employed elsewhere which may be relevant and capable of adaptation for the solution of their own problems. The second, and equally important, aim is to offer those at the outset of a career in laboratory work a broad survey of the fields open to them, so that they may choose their direction of work in full knowledge of the possibilities.

From the foregoing it must be evident that the content of such a book will in the main be generalized, that it must be so if it is to fulfil its ends, and that highly specialized treatments would indeed be out of place. It is hoped, however, that superficiality has been avoided, and the authors (all of whom are practising specialists in their fields) have provided reference lists of more detailed work in each subject for the guidance of those who wish to explore further.

The arrangement of a work like this poses considerable problems of organization. The plan finally adopted has been to proceed from what is fundamental and almost universal in the laboratory world, through specialized techniques, to examples of the functioning of special types of laboratory. Thus the reader will find first the sections dealing with basic equipment and fundamental techniques, then come more detailed descriptions of special techniques built on these foundations—for example, low-temperature techniques, radioisotope techniques, material testing, techniques of chemical analysis, etc. These chapters lead on to accounts of laboratories engaged in highly specialized investigations—in pathology, microbiology, metallurgy, forensic sciences, and plastics, for example. In the concluding chapters, attention is once again turned to topics of universal applicability—hazards and the health and safety precautions devised to counter them, the recording of results of one's own work, and the utilization of the results obtained by others.

No book, of course, can communicate the practical skills which are so essential, and so satisfying, a part of laboratory work, but it is hoped that this volume will be a helpful companion to those either engaged in acquiring or already using those skills in their daily work.

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PART 1

LABORATORY DESIGN, ORGANIZATION AND ADMINISTRATION

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1—LABORATORY DESIGN, ORGANIZATION AND ADMINISTRATION

The laboratory world is intriguing both to those who view it from a distance, and to those who are actively engaged in its various aspects. A laboratory can be described simply as a place designed and equipped for careful observation, manipulation, measurement and logical interpretation. Laboratories can, however, vary greatly in scope, from single rooms to large organizations employing workers drawn from various teams of well integrated disciplines supplemented with administrative and other supporting staff. Laboratories exist for research, technological development, education, and control, and the term is even used loosely by some manufacturers to describe the environment under which certain commodities are prepared under special conditions of precision or cleanliness.

The planning and staffing of a laboratory is primarily governed by its objectives, but it must always be ready to re-adjust itself to changing circumstances. Furthermore, it is frequently the laboratory's own responsibility to project itself ahead and to make provision for the study of entirely new ideas and processes. Enterprise and effort in the true scientist is partly self induced, but undoubtedly pleasant surroundings and the availability of efficient services and modern equipment can play an important role in achieving maximum productivity.

It would be impossible to arrive at hard and fast rules for laboratory design and construction, not only because laboratories differ in scope and purpose, but because allowances must also be made for the various approaches to scientific research. On the one hand there is the visionary research worker who equips himself with his own handmade apparatus as he advances, and frequently prefers to make his own observations and measurements, while on the other, certain investigations require the combination of highly developed equipment and the skill of specially trained operators. In the latter case, adequate financial resources are usually essential, but even so, these are not a substitute for perseverance and tenacity of purpose. Undoubtedly, the chief asset of a laboratory is the scientific attitude of its staff, and this frequently stems from inspired leadership.

It will be appreciated therefore that any attempt to draw up a precise specification for laboratory design and organization would be

imprudent, and so the following suggestions and recommendations are given in the broadest of terms. It is hoped, however, that some of the ideas will be found to be of use to those employed in, or about to construct, a laboratory.

Location

Although most laboratories have many common features, it will be convenient to consider them either as being complementary to a larger parent organization, or as constituting an individual unit. In the case of the first-mentioned, the laboratory is usually located near to, or closely integrated with its parent organization, unless of course it serves a number of organizations such as a group of companies. Where this is the case it may be more important for the laboratory to be located nearer to centres of other scientific activity. Modern transport and communication make dispersion more possible, and recent years have seen a removal of many industrial research organizations to less populated areas. Nevertheless, there are certain factors which must not be overlooked when considering a policy of dispersion. For instance, recruitment and technical education of junior laboratory assistants must continually be borne in mind. Similarly, it is very necessary to have a local source of other supporting staff, such as laboratory technicians, clerical assistants, cleaners and so on. The existence of adequate local social amenities is another important requirement.

Where the laboratory is a part of a larger organization, and in particular where its prime function is control rather than research, it must endeavour to integrate itself into the main activities of the organization without losing too much of its individual identity. Such a laboratory often has responsibility for the direct or indirect control of processes, with economic production and the safety of workers frequently being monitored by laboratory tests.

It is essential that the highest possible standards of cleanliness and efficiency should be maintained at all times. Free access to the laboratory by all and sundry must be discouraged, and in order to ensure continuity it may be advantageous to employ intermediate liaison officers. Freedom from noise, industrial fume, dust and vibration is also very desirable, particularly where precise measurement and quiet interpretation of results are called for. For these reasons, there are obvious advantages to be gained by siting an industrial laboratory on the upper floor of a building. A laboratory so placed often benefits from natural lighting, but will not be practicable where very intimate association with industrial operations, or for heavy foundations for test equipment are essential. In such cases it may be best to separate small working groups from the main laboratory, but care should be

taken to see that close contact with the main group is maintained, otherwise the detached fractions can easily become isolated and dispirited. Where control testing and inspection has to be an integral part of a production flow pattern, a small efficient laboratory must be provided right on the spot. Such a tiny out-station can benefit greatly from the continual backing of its parent organization by the provision of standards, improved techniques and periodic relief of staff.

Laboratories not tied to specific production have more freedom in the choice of location, and their design and siting is governed largely by the availability of land and common services. Given a free choice, however, the siting of a new laboratory must take a number of factors into consideration. These are, of course, directly related to the main purpose of the new facility, but invariably include such basic items as power supplies (which can for some purposes be very heavy), availability of adequate water, gas, and effluent disposal, nature of subsoil and surface water drainage, local bye-laws, room for expansion, accessibility for staff, visitors and main supplies, and reasonable proximity to public transport and social services. With regard to the last mentioned, the existence, or provision, of living accommodation and shopping facilities is a vital factor to the staff. It is necessary also to have temporary accommodation in the way of a hostel, or hotel, for visitors and newly appointed staff. Recreation facilities are also essential to the larger, self-contained organization, either in the form of social clubs or sports fields.

Thus, both the needs of the laboratory building and its services, and those of the workers, must receive equal consideration in the selection of a suitable site for a new laboratory. Usually, it is not possible to satisfy all these conditions, and a compromise is often found until natural development evens out early difficulties.

Design and Construction

It is not possible to evolve an ideal design which would suit all laboratories, as their function and size may vary greatly. Where a laboratory is part of a larger organization it may have to conform to a production pattern, and only a few of the basic principles employed for the design of a large self-contained research organization may apply. Certain features are, however, common to all laboratories, and the first requirement is sufficient floor space for each worker. While this too can vary according to the nature and size of equipment being used, around 300 ft^2 per worker has been found to be a normal requirement. Adequate natural and artificial lighting is essential. Air-conditioning is far from a luxury, particularly where dampness and wide temperature variations will reduce the life of, and invalidate

the results from, delicate scientific equipment. Even the local provision of temperature and humidity control can be of great benefit where available funds do not permit this service to be provided on a more general basis.

The importance of adequate services such as power, gas, compressed air, vacuum, hot and cold water, sinks and drains cannot be overemphasized, and these should be arranged for maximum convenience. Higher capital expenditure on such services in the first place frequently leads to more economic operation in the long run. Standardization of power points and taps is essential because it permits easy interchange of equipment from one place to another.

Generally speaking, laboratory buildings should have firm foundations in order to avoid undue vibration. It is sometimes an advantage to provide mobile internal walls to facilitate readjustment of floor space. Building specifications are usually a matter of economics, but fullest use of the more modern materials of construction should be made where possible. These include pres ressed concrete for ambitious load-carrying designs, soundproof inner linings, glass-brick partitions, new floor coverings and so on. Designs vary from small research rooms, with fairly humble facilities, to vast test houses equipped to deal with prototypes under close ambient-temperature and humidity control. In order to cover as many features as possible it will be convenient to examine the design of a modern research centre serving a group of companies with widely varying interests.

The first criterion governing overall design is the relative proportions of basic and aimed research, technological development, and, possibly, pilot-scale production. Then the subdivision between the various sciences must be decided upon, i.e. chemistry, physics, mechanical engineering, electronic engineering, metallurgy, chemical engineering, and so on. An appreciation of the overall nature and size of effort, including of course ample room for internal adjustment and expansion, will then give some idea of the extent of the supporting services that will be required. These will include the secretariat, workshops, maintenance staff, stores, library, information officers, cleaners, canteen and security, all of whom are essential to the organization and must be provided for accordingly.

Assuming that a convenient site, with adequate services and providing ample room for expansion, has been selected, it will now be possible to formulate an economic arrangement of the various sections required to undertake the research and development programme.

A double-storey building is economical on ground space, and lends itself to the segregation of heavy equipment on the ground floor, with the lighter apparatus and administrative staff on the upper floor. Even so, it may be more desirable to provide separate buildings for

workshops and pilot plant equipment in order to avoid noise, vibration and fume in the main building.

The scheme outlined in Fig. 1 is fairly comprehensive; the proportions allocated to the various activities are purely hypothetical. Room for expansion is provided in this case at each end of the building so that any number of extra spines can be added without disturbing the original arrangement or work in progress. This plan is aimed at the provision of maximum natural light, and endeavours to place laboratories with similar interests in close proximity to each other without losing overall cohesion. Small studies or offices are provided in each of the major laboratories and senior administration is in a central position close to records and secretarial staff.

Each specialist laboratory can be arranged and equipped according to its individual requirements, but uniformity of services and standardization should be achieved as far as possible. Means for internal communication is often an advantage but this should be on a personal rather than a general basis, as the loud-hailer system constantly disrupts thought. External telephones should also be provided at strategic positions.

Adequate fire-fighting and first-aid equipment and sufficient emergency exits must be located at convenient points, and a lift is essential for the vertical transport of equipment in multi-storey buildings. Generous cloakroom and washing facilities must also be provided on both floors.

Certain special features, such as local sound-proofing, biological shielding, decontamination locks, light traps, fume extraction and so on, must be incorporated in the main design. As modification and extension is the natural outcome of a vigorous reseach programme, it is economic in the long run to arrange for common services to be supplied in readily accessible ducts. Floor construction will vary according to the requirements and characteristics of each main division. For instance, the avoidance of dust in laboratories employing optical equipment calls for polished linoleum, while chemical engineering, mechanical testing, and workshops will require heavy concrete bases for machines and plant, with the provision of localized non-skid floor surfaces. For most of the remaining rooms however, wooden block floors on a solid foundation will provide a good all-round surface.

Height of ceilings should be at least 12 ft, and colour schemes should be chosen not only to give maximum reflected light, but also to stimulate an atmosphere of creative interest, to which adequate general and localized artificial lighting should contribute. Main services should be colour-coded to British Standards, though not at the sacrifice of the overall colour scheme. In this last mentioned case, small coupon colours to the standard specification

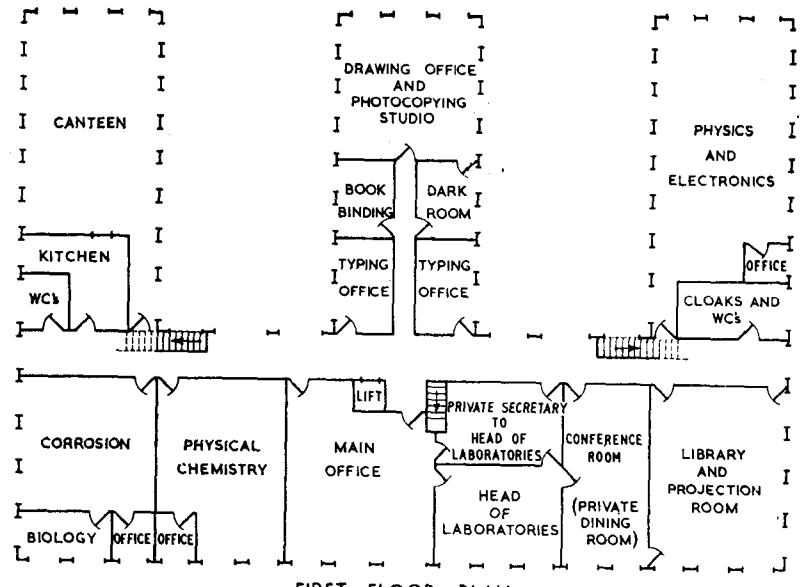

Fig. 1. Suitable laboratory designs for a research centre serving a group of companies with varying interests