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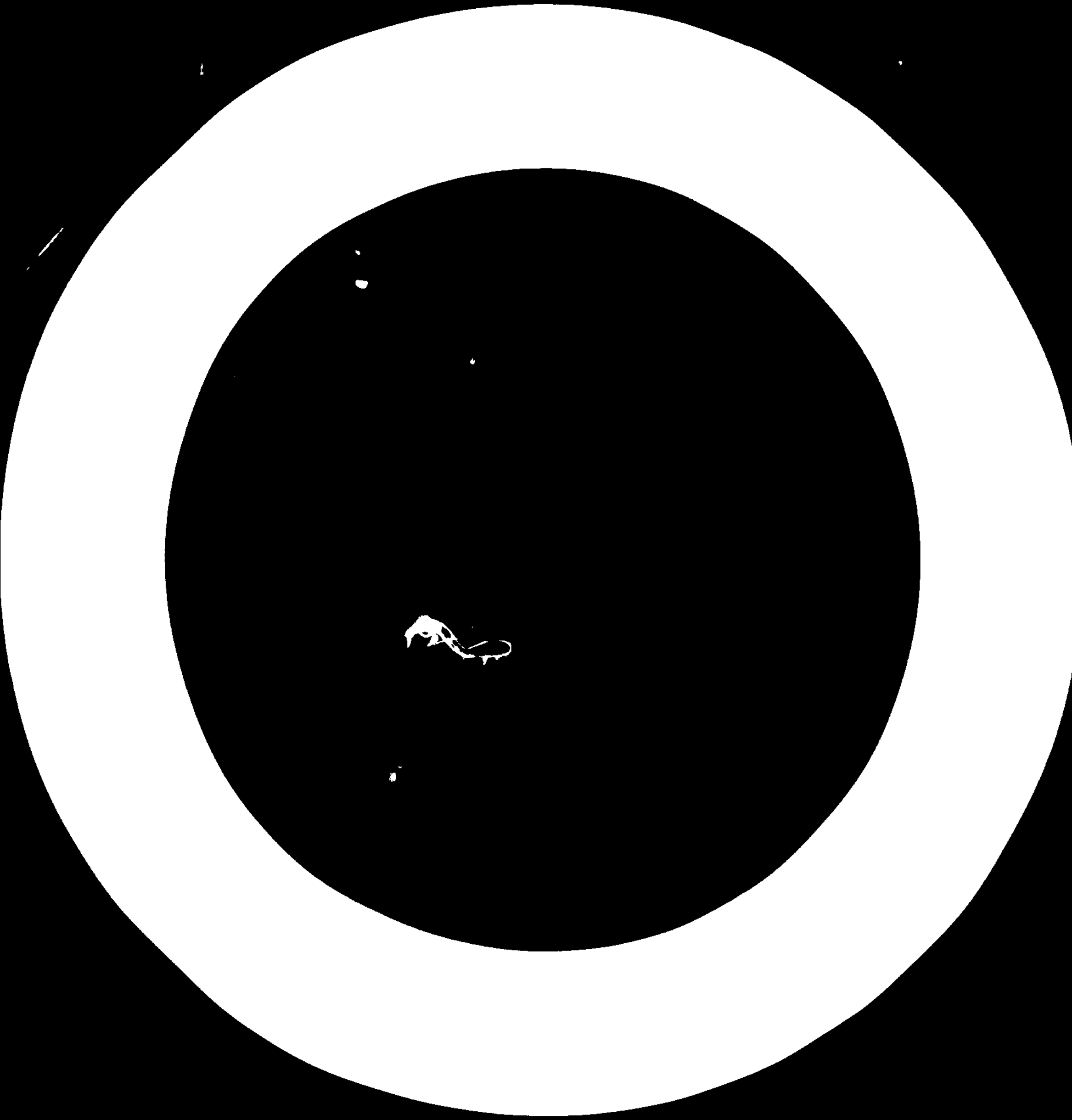
Industrial Research and Development News

VOL. VII No. 3

IRDN

UNITED NATIONS



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UNITED NATIONS PUBLICATION
Price: $U.S. 3.00
(or equivalent in other currencies)

United Nations Industrial Development Organization
Vienna

Title

Industrial Research and Development News,

VOL. VII No. 3.

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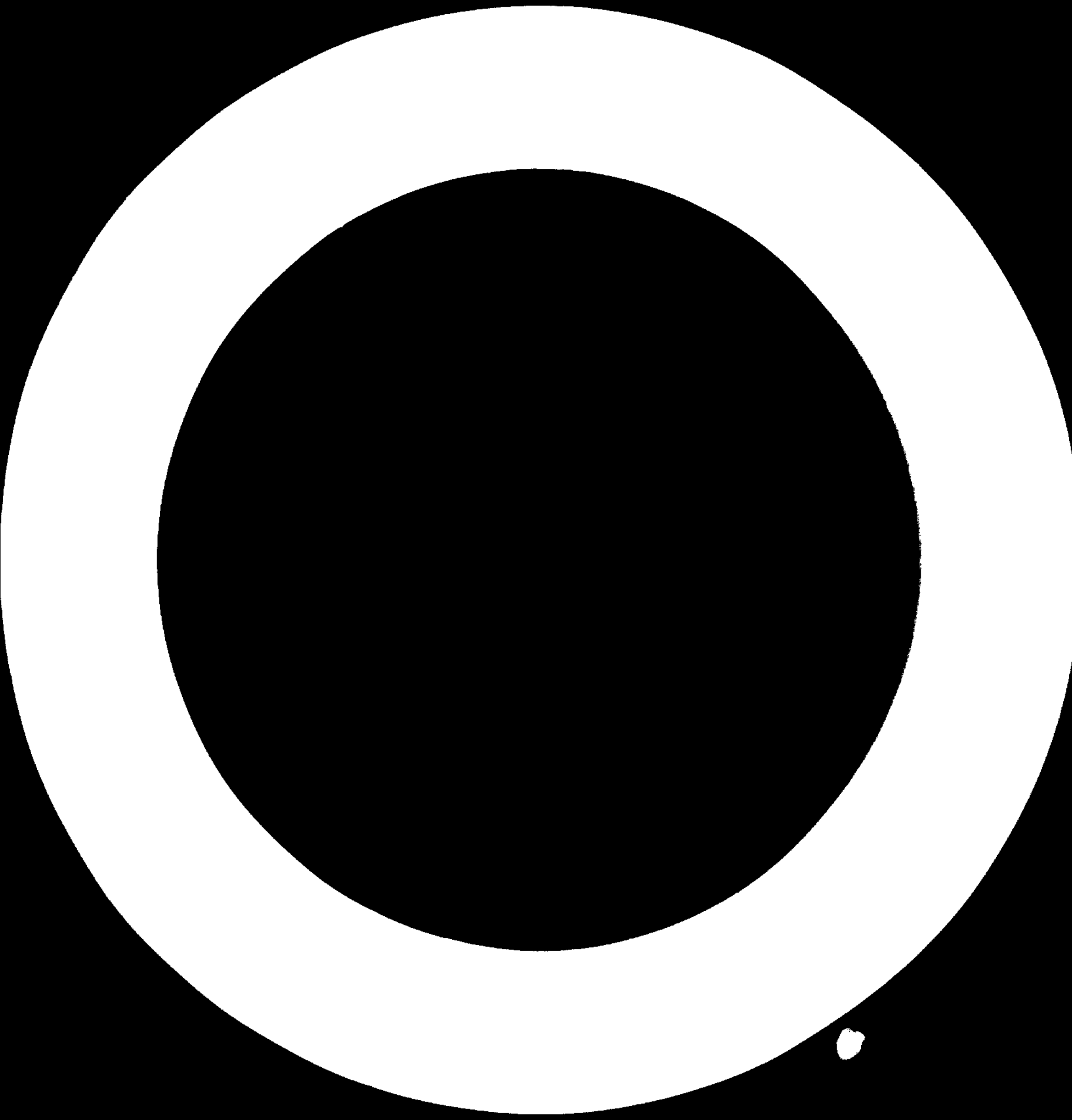
New York,

UNITED NATIONS
New York, 1975



Foreword

Industrial research and development centres provide various services to Goverments, to domestic and foreign business enterprises, and to other bodies engaged in industrial development. The services include: carrying out applied research; testing and analysing raw materials and industrial by-products to identify their industrial uses; testing and analysing industrial products for quality control and quality certification purposes; carrying out techno-economic feasibility studies on the establishment of new industries or the expansion of existing ones; assisting industry in trouble-shooting, standardization and quality control, selection of industrial processes, equipment and appropriate technology, market research, cost accounting, plant lay-out, product and productivity improvement, and diversification of production; advising Governments on technological matters; and providing assistance related to national standardization and quality control programmes. The centres are staffed by multidisciplinary technologists whose main aim is to accelerate industrial growth.

The Governments of several developing countries have recognized the need to establish such industrial research and development centres and attach great importance to them. With few exceptions, the centres are financed by the Government, which is also usually the main client. The number of professional staff in centres in most developing countries varies from 10 to 30, depending upon the level of development of the country and of the centre.

At the initial stages of a centre's development most of the funds allocated to the project are utilized in setting up its buildings and facilities. Often, however, owing to the limited expertise available in developing countries, the buildings and facilities are conceived and planned without proper regard to their end function. There is clearly a need to advise these countries in the economic utilization of their funds, and to assist them to set up buildings and facilities that can easily be adapted to meet the ever-changing technologies and requirements of science and industry.

In recognition of this need, the United Nations Industrial Development Organization (UNIDO), in co-operation with the Kongresshaus, Innsbruck, Austria, organized an expert group meeting on "Building and Facilities, Design and Lay-out for Industrial Research and Development Centres" at Innsbruck, 23-27 September 1974. This issue of *IRDN* presents edited versions of six of the expert papers prepared for the meeting.

PLANNING AND DEVELOPMENT RESEARCH

Introduction

ONE OF the most difficult planning and design problems to confront the architect in the present day is that of designing the industrial research centre a complex organism that must lend itself to a myriad of uses and be responsive to changes as they occur in the unpredictable world of science. The facility must provide access to the fundamental services and skills necessary to make it operative, but it must also respond to the changing character of those it serves. For this reason, it is better that an architect planning a centre acquaint himself with the interdependency of activities that takes place within such places rather than study the mechanics of a specific laboratory. This article, therefore, will examine the processes by which a research centre can be converted from an idea into an operational facility with the capacity to respond to the wide range of research demands that will be made upon it by diverse sciences.

Location

Choosing the location is the most sensitive planning decision to be made as it can, to a great extent, determine the centre's potential for success. The centre should be so located that it will attract personnel of the highest quality, the calibre of the staff is critical to its success.

The choice of geographical location is often determined by the role the centre is intended to fulfil. If the centre is being set up to study ocean life or behaviour, for example, it should obviously be located on or near the sea shore. If the character of the research programme is general, however, location becomes a more complex issue. The location of the general facility is more often decided by the proximity of staff skills and services (i.e. in an area where other research or industrial centres are situated) than by the proximity of research materials. The proximity of other organizations also provides for healthy interchanges and competition among staff, and the availability of supporting facilities. Nearness to potential clients is one of the least important criteria as the research process does not involve continual or intimate interaction between clients and research participants.

Working environment is also an important factor in the choice of location. It must not place a restraint on the seriousness of a scientist's endeavour or interfere with his creativity. Distractions caused by difficult commuting, poor housing, lack of cultural activities, and insufficient recreational facilities can significantly reduce the willingness of competent personnel to locate in developing areas. Staff are drawn to centres where they believe the general atmosphere is creative, the facilities up to date, and the attitude of the administration progressive.

Utilities are one of the primary location criteria. Most of the services required for laboratory operation present problems of scale. The tremendous demand for electricity, for example, can create drains on power equal to those of a small city. The demand for gas, on the other hand, is low. A fairly abundant supply of water is necessary, even if the quality is poor; it can be treated if there is sufficient power available.

The control of air pollution is an important factor in the siting of a centre. Air currents can sometimes sweep pollutants discharged by a centre back into the facility or into neighbouring buildings or sites. When considering a location, a wind tunnel test, using scale models to analyse the effect of air currents or thermal inversions known to exist in the area, is strongly advised. The treatment of sewage is not as critical as the treatment of pollutants from chemical and physical research processes.

Design factors

Social aspects

The centre should provide ample opportunities for personnel interaction on various levels. In the field of science, individuals are the final measure of potential. Their capabilities and their willingness to co-operate and pool their efforts are essential to effective performance. Great efforts must be made to create comfortable areas that can be used for the social aspects of the scientific programme and for informal meetings. These areas should be equipped with chalkboards and limited snack facilities. They should have an atmosphere of comfort, relaxation and diversion.

The author is director of the research and development facilities and a partner of Gruzen and Partners, New York City, New York. His article originally appeared as UNIDO document ID/WG.181/9.

CRITERIA FOR AN INDUSTRIAL CENTRE

by **Paul Silver**

Costs

It is difficult to define the advantages of one system over another, in different localities, in terms of cost. The availability of material, local economics and indigenous techniques are important determining factors. In general, it is important to consider not simply the construction cost of a system but the life-cycle cost, the initial cost is not the only, nor is it the most important, factor. If modifications are going to be carried out frequently it is important that the system be capable of adaptation at reasonable cost.

Climate

Climate need not be a major consideration in the design of a general research facility, apart from determining its exterior architectural character. The climate can be construed as a factor that means certain additional expenditures to provide for cooling in warm countries and heating in cold ones. Control of natural light, temperature and humidity is a requirement under any climatic circumstances. The laboratory environment should be thought of for the most part as being "climate-free", shutting out the exterior world so that it is possible within the laboratory to maintain a fairly rigid set of climatic conditions.

The modular concept

A centre intended for general scientific research requires a certain degree of adaptability in order to respond to the variety of uses to which it may be put (fig. I). Systems having the lowest frequency of anticipated change would be designed with little potential for modification.

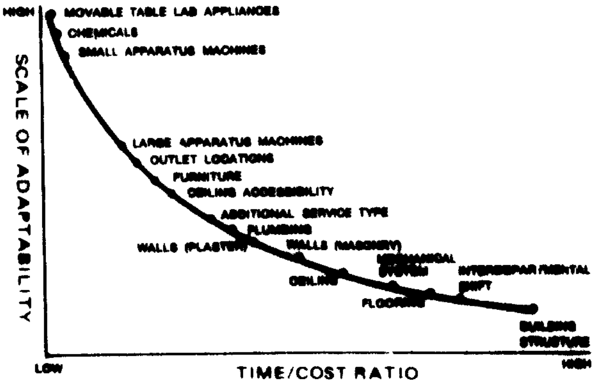


Figure I. Scale of gradient adaptability graphically shows relationship between cost and incidence of adaptability. Items at top of chart are highly adaptable at comparatively low cost

Ideally, the research areas should be modularized that is, they should be built of elements that can be arranged to form spaces of varying sizes, as required.

A properly designed laboratory begins with a planning module. The size and shape of this module is probably the most difficult single decision with which the planner is confronted. The module must be flexible enough to meet a wide range of laboratory uses and size requirements. It must not be so small that it is necessary to group it together with other modules simply to make it function, conversely, it must not be so large that it cannot be subdivided into smaller spaces when required. As elaborate geometry tends to lead to plans that are confused and difficult to modify, simple geometry should be used simple rectangular geometry allows for easy groupings.

This concept was developed for the Graduate Physics/Mathematics building at Stony Brook, New York (fig. II). The centre is so designed that the size of any laboratory can be increased or reduced without modification of the basic system. Up to five laboratories can be grouped together to form one uninterrupted serviceable area (fig. III).

The relationship between the office of a scientist and his laboratory is an important one. Proximity is of the essence, it is often desirable to use part of the office as laboratory space. This means that the laboratory and the offices should be located adjacent to each other so that both can utilize the same service system. The arrangement should make it possible for the scientist or researcher to move between the office and the laboratory without using public corridors. A conventional office is more appropriate to the needs of the theoretical scientist who does not require laboratory apparatus. The offices of such personnel are often best grouped together and in proximity to the laboratory facility, but not necessarily within the laboratory area.

The service distribution pattern makes it desirable to establish, at an early stage, a minimum-size "transport module". At Stony Brook, the facility was developed around the capability of transporting the "module" an eight-foot cube weighing five tons to any laboratory in the building. The corridor width, height and layout, the design of the entrance to the laboratory, and the location of verticle transport equipment were determined by the size and character of the "module".

Figure II. Graduate physics/mathematics building at Stony Brook, New York

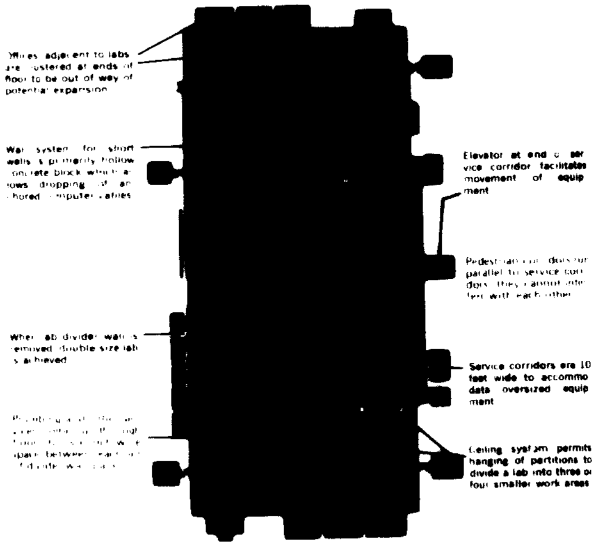


Figure III. Floor plan organization and service concept at Stony Brook

Construction technology and materials

The construction technology of a general research laboratory is seldom decided by the kind of experiments anticipated as much as it is by available construction systems. Laboratories with electronic sensitivity requirements, however, should be constructed of materials that will not develop the inherent electrical shortcomings that are characteristic of steel-frame buildings. As the trend nowadays is towards multidisciplinary scientific facilities, care must be taken that the materials selected will not interfere with the operation of the sensitive apparatus that is used in a variety of scientific fields. The choice of materials must take into account the need for control of vibration, noise, fire, smoke and dangerous chemical fumes. Soft materials with sensitive finishes are not appropriate for research facilities. Materials that can be repaired, replaced or relocated without significant effect upon the operation of the building are far more suitable.

An examination of the Stony Brook facility shows the kind of construction technology that is most appropriate to a laboratory system (fig. IV). As the sheet

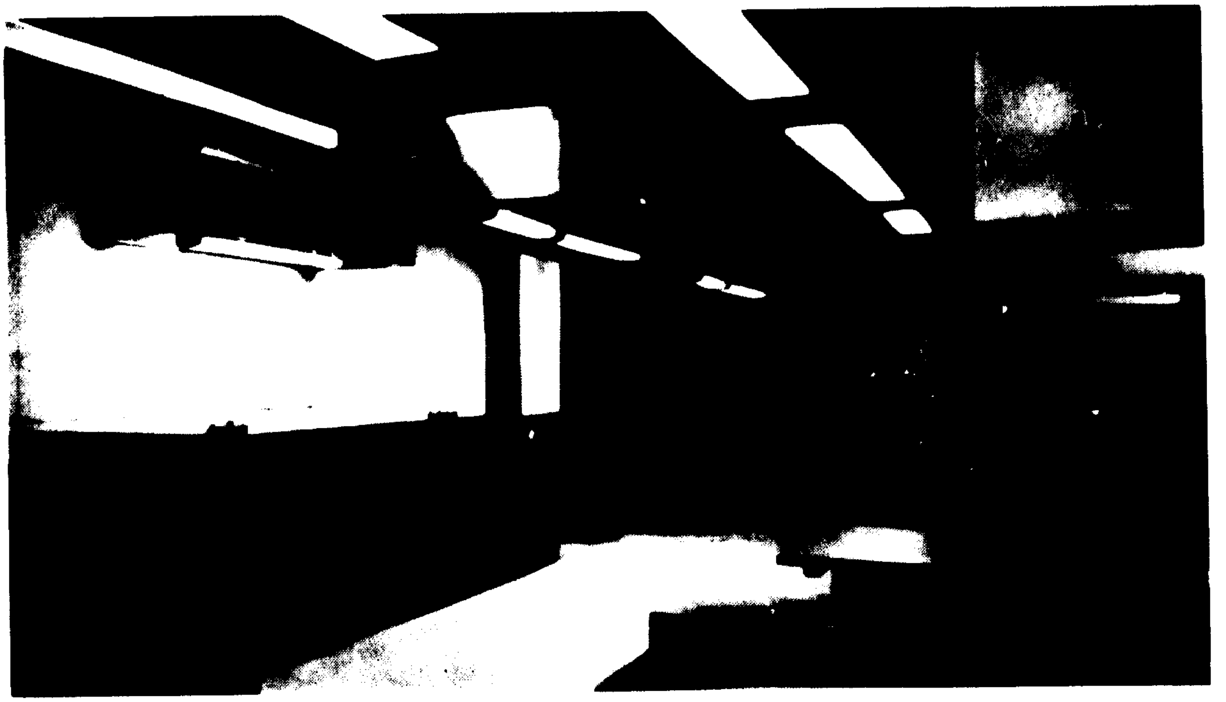


Figure IV. Specialized laboratory at Stony Brook

metal interior partitions can be dismantled and relocated, it is possible to modify the shape and size of a laboratory quickly and simply with little noise or debris. The fire areas of the corridors are formed by concrete block. Within the laboratory itself, the floors, walls and ceilings are of natural, relatively unadorned materials, leaving the interior to be finished in scientific detail by the user.

It is usually in the technical aspects of laboratory construction that the proof of a facility's ability to respond to changing requirements is indicated. The thrust of a design must emphasize the idea of the laboratory as a series of elements, whether they be planning modules or furniture modules, capable of adaptation in a reasonable period of time with a minimum of noise, waste and cost.

The materials used in laboratory construction are determined more by the operations that will take place within the laboratory than by the availability of building materials in the area. Laboratories using chemicals require surfaces that are capable of resisting chemical reaction. The choice of structure and structural materials must be based on a careful examination of the following factors: electro-static properties' conductivity; resistance to fuel damage; resistance to breakage; loading capability; and changeability and adaptability. It is a complex problem and cannot be simply described in terms of a few short parameters.

The design of the structure (and therefore the furniture) is closely related to the planned utilization of the facility. If a small number of laboratories develop a special set of difficult problems it is best to isolate them from the main building.

Laboratories are not limited to specific types of structure. Sometimes long-span structures are desirable, at other times short-span structures are adequate. Some structures use interstatial spaces, others do not require the potential flexibility that the interstatial concept permits. The degree of adaptability of the systems and subsystems best define the type and character of the structure.

To a great extent, the decision regarding the choice of structure depends upon the resources available. Structures that are basically steel-frame may require special consideration from the point of view of fire safety, conductivity of materials and interference of large quantities of steels with radio frequency and non-shielded equipment. Concrete, of course, has the disadvantage of weight, but concrete structures tend to be more rigid and vibration-free than steel ones.

The external and internal finishing of the structure should be resistant to the chemical and corrosive properties generally associated with the fumes and waste generated by laboratories.

The external walls are a matter of architectural preference, but the internal partitions, which subdivide laboratories into module groupings, should be highly adaptable. They should be capable of being moved and reinstalled in a minimum of time, with a minimum of noise and interference in the operation of the laboratory. Walls that enclose laboratory groupings need not possess this kind of flexibility.

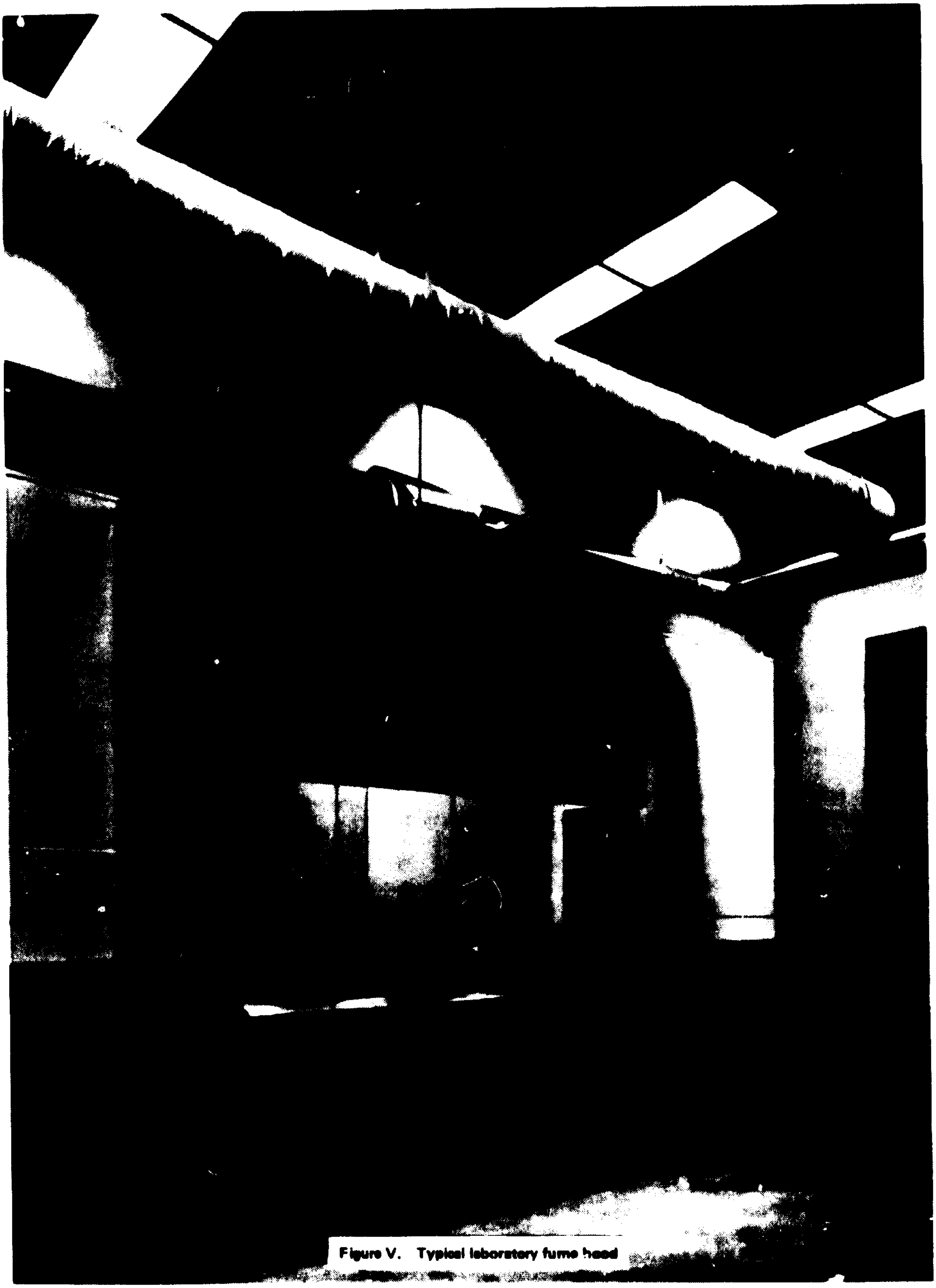


Figure V. Typical laboratory fume hood

Layout considerations

Safety

The planning of a laboratory involves designing for safety against fire and dangerous fumes generated by experiments. The traffic flow, the egress pattern and the proportions of the laboratory are all safety considerations. The greatest need for safety planning is, of course within the laboratory itself, where the greatest degree of danger exists. Obviously, research involving explosives, radiation or dangerous substances should be housed in appropriately built separate facilities. Such isolation is not only desirable but essential to the safety of an institute.

Serious thought must be given to the number and location of fire extinguishers and stand pipe systems, and to the availability of sprinkler systems, both conventional water and carbon dioxide. Designing a laboratory that would afford protection against every kind of hazard would be almost impossible; the aim should be to determine the level of safety for the most general applications and to provide supplementary systems in areas of higher hazard.

Pollutants generated within the laboratory must be removed safely, quickly and efficiently. In particular, toxic or noxious substances must be removed expeditiously through a conduit system that will prevent intermingling with pollutants from other laboratories. A small number of laboratories may be grouped together and their exhausts of harmful pollutants run through the same basic system; great care must be taken, however, to make certain that these laboratories are adjacent to one another and that it is possible to control any process that might produce explosive or combustible conditions.

If a centre is built according to the modular concept, the smaller modules should be reserved for activities that present fire hazards. In all cases, centres should have at least two forms of exit, independent of one another and set up in such a way that access to them is not hindered by laboratory expansion.

The building must be planned for security. Restriction of access is of considerable importance because of the extremely valuable and sensitive equipment used in laboratory work.

Air conditioning and ventilation

The air-conditioning system for a given laboratory will probably be chosen on the basis of local technology, local preferences and traditions rather than on whether or not it is the most suitable for the particular case. A separate system for each laboratory grouping is not normally required, except in cases where the experiments being performed are so sensitive that even a slight interruption in the air-conditioning could destroy their accuracy. Obviously, computers and other heat-generating equipment must be given special consideration. This can be done by supplementing the basic system with a secondary system.

Natural ventilation which may provide large quantities of air without cooling, is not generally suitable in laboratory areas.

The fume hood (fig. V) is the focus of operation in most chemical and natural science laboratories. Fume hood exhausts must be grouped together in order to prevent the mixture of substances that might be explosive. The choice of material and the construction of the hood and exhaust system are very important. In keeping with the flexible approach to laboratory space the fume hood should be considered as movable furniture.

Storage

In addition to the main storage areas, where equipment awaiting distribution is held, the availability of second-level storage facilities, within the laboratory groupings, is important. Goods being brought into and moved out of the centre must be protected against pilfering and loss. Storage capability within the laboratory itself should be limited; closets and below-counter cabinets should be kept to an absolute minimum. A furniture system with endless cabinets that remain underutilized is not only expensive but becomes a tidying-away place for valuable material that is eventually forgotten about; the result is unnecessary restocking.

Conference halls and meeting rooms

A research centre requires facilities for the holding of in-house and inter-institute meetings. Reception, registration and dining areas should be available and, ideally, limited overnight accommodation. Meeting rooms are best dispersed throughout the facility, though a concentration is acceptable if the facility is not too large. Small conference or assembly rooms that can be used either as lounges or for small gatherings should be located within the laboratory groupings.

Reception and telephone exchange

The reception area or lobby of the centre should act as a control point restricting movement into the remainder of the building.

The telephone exchange may be located at whatever place within the building is most appropriate from the technical point of view. In most cases it is independent of the reception area, but if the building and the telephone system are small they may be combined to advantage.

Workshops

Workshops are necessary for the preparation of the experimental apparatus used in the laboratory. They may include shops for glass-blowing, metalworking, woodworking, electronics testing and equipment storage. They provide the backbone services required by the laboratory. Some have specific requirements; for example, glass-blowing shops need excellent natural lighting.

Staircases and elevators

Staircases and elevators should be used as little as possible. Tall buildings with small floor areas depend very heavily upon vertical transport and are therefore highly undesirable for laboratory purposes. Small floor areas minimize the effectiveness of the module system by isolating research groups on separate floors. Movement within the building can be kept to a minimum by providing large floor areas. Staircases should be primarily conceived of as fire exits. The utilization of staircases for intra building traffic requires very subtle planning.

Determining the required number of passenger elevators for a tall building is a sensitive planning problem. It should be assumed that the arrival time of the staff will be during a relatively short period in the morning and that movement into and out of the building will be consistently high during the day. Elevators should not serve the dual purpose of passenger and service use. The service elevator must, of course, be designed to accommodate the "transport module" that has been decided upon.

Utilities

The water supply, both hot and cold, should be pure and of a relatively neutral quality. It need not be available in distilled form at the laboratory desk, except in laboratories that have a consistent and high rate of utilization.

The biggest single service to provide for is electricity. The voltages should be over a sufficiently wide range and the amperages set so that the total wattage is about four watts per square foot of laboratory area. Supplementary distribution capability must also be provided in order that the electrical power available in any one laboratory may be increased significantly when needed.

Centralized distribution systems for gas supply are no longer very necessary as more and more gas systems are being replaced by electrical systems. Cylinder sources are just as good as central systems.

Laboratories should be provided with telephone systems that allow interconnection with other laboratories and non-laboratory areas as well as with the outside. An intercom system is very useful if it is properly designed and integrated into the telephone system.

Furniture and furnishings

Laboratory furniture must be sturdy in order to withstand the heavy use to which it is put. It must also be capable of easy modification (fig. VI).

Desks

Desks should be considered as part of the laboratory table system. Drawers should be fully extendable and preferably self-retracting.

Desk covers and similar protective devices are not desirable features in a laboratory. The desk top should itself be a protective surface, capable of resisting chemical damage and heavy use. A good practice is to provide the same tops for the laboratory desks as for the laboratory furniture.

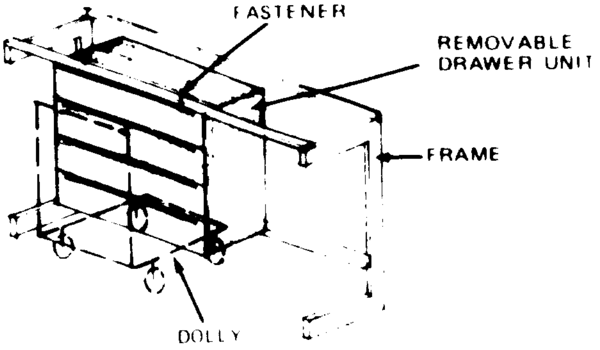


Figure VI. Typical laboratory furniture system

Sinks

Sinks can be divided into two basic categories: cup sinks and regular counter sinks. Cup sinks are highly suitable for laboratory use and can be built into the wall, leaving the furniture system free. This makes it easier to move the furniture about. Sinks of cement asbestos, stainless steel, and "duriron" (a highly chemical-resistant material) are the most suitable for laboratory use.

Water and gas taps

Taps are best built into the wall system, free of the furniture. This allows the water distribution systems to remain in operating order even when the laboratory's equipment is being rearranged.

Floors

Deciding on the floor finish for a laboratory is often a very difficult problem for the architect, as everyday laboratory use does considerable damage to the surface. Experience has proven most systems to be inadquate. Generally speaking, it does not pay to invest in good floor materials. A minimum-investment flooring such as concrete will give satisfactory results, if the aesthetic limits can be accepted (concrete shows irregular finish markings and pathways develop in painted concrete). In areas where more expensive tile and epoxy are desired, the cost implications should be understood.

Windows and doors

Laboratories often function poorly when natural lighting is used. Natural light does not enter in a manner that is easily controlled and it is generally not uniform throughout the room. Windows in a laboratory are not considered an asset. For offices or laboratory-office combinations, however, natural light may be considered.

Door materials need not be rigidly defined; any material that can take the heavy use normally associated with a research facility may be considered. Kick plates and bumper rails are important features. Lever handles are very practical for laboratories because they make it possible to open the door with an elbow when necessary.

LOCATING RESEARCH CENTRES

by **J. Nekarda**

IN THIS article, an industrial research and development centre means a complex of offices, laboratories, training and other premises and installations intended for the carrying out of applied research, which involves the practical application of basic research and technical and technological knowledge. In many developing countries, research centres play an important role in the training of personnel for research and development work.

Location

Decisions concerning the location of a new centre must take into account both macro-economic and micro-economic factors.

From the macro-economic point of view, the aim should be to determine location on the basis of the desired relationship of the centre with its potential clients and on the desirability of achieving close working contacts with related organizations. Experience has shown that it is preferable to locate in areas of intense concentration (existing or planned) of industrial, social and cultural activities, which means, in effect, areas in or near capital or major port cities.

From the micro-economic point of view, the aim should be to determine, in the given area, the most appropriate building site. When selecting a site, the following factors should be taken into consideration:

- *Size*. The site should be large enough to allow for future expansion of the centre or for the construction of houses for personnel;
- *Topography*. Ground soils should have good bearing capacity and the highest level of underground water should be more than two metres below the surface.
- *Situation*. The site should be chosen with regard to the social and aesthetic impact of the centre on neighbouring houses and other buildings and with regard to transportation accessibility.
- *Utilities*. An important locational factor is the availability of drinking and other water, sewerage, gas and electricity. To avoid the considerable financial outlay involved in building a separate installation, advantage should be taken of the utilities offered by existing industrial areas.
- *Environment*. It is necessary, when selecting a site, to bear in mind the need for clean air and a quiet working environment.

The micro-economic factors described above are by no means the only ones involved in reaching a decision regarding location; they are, however, factors which should not be omitted when selecting a building site.

An example

The following description of a successfully operating research and development centre in Czechoslovakia shows how some of the arguments advanced above are applied in practice.

The Institute for Research and Utilization of Fuels, which is controlled by the Ministry of Fuels and Energy, is located at Běchovice, some 15 kilometres from Prague. It has a branch at Brno, the second largest city in Czechoslovakia, and an important industrial centre.

The author is the Deputy Director of TERPLAN, the Czechoslovak Institute for Regional Planning, Prague, Czechoslovakia. This article originally appeared as UNIDO document ID/WG.181/6.

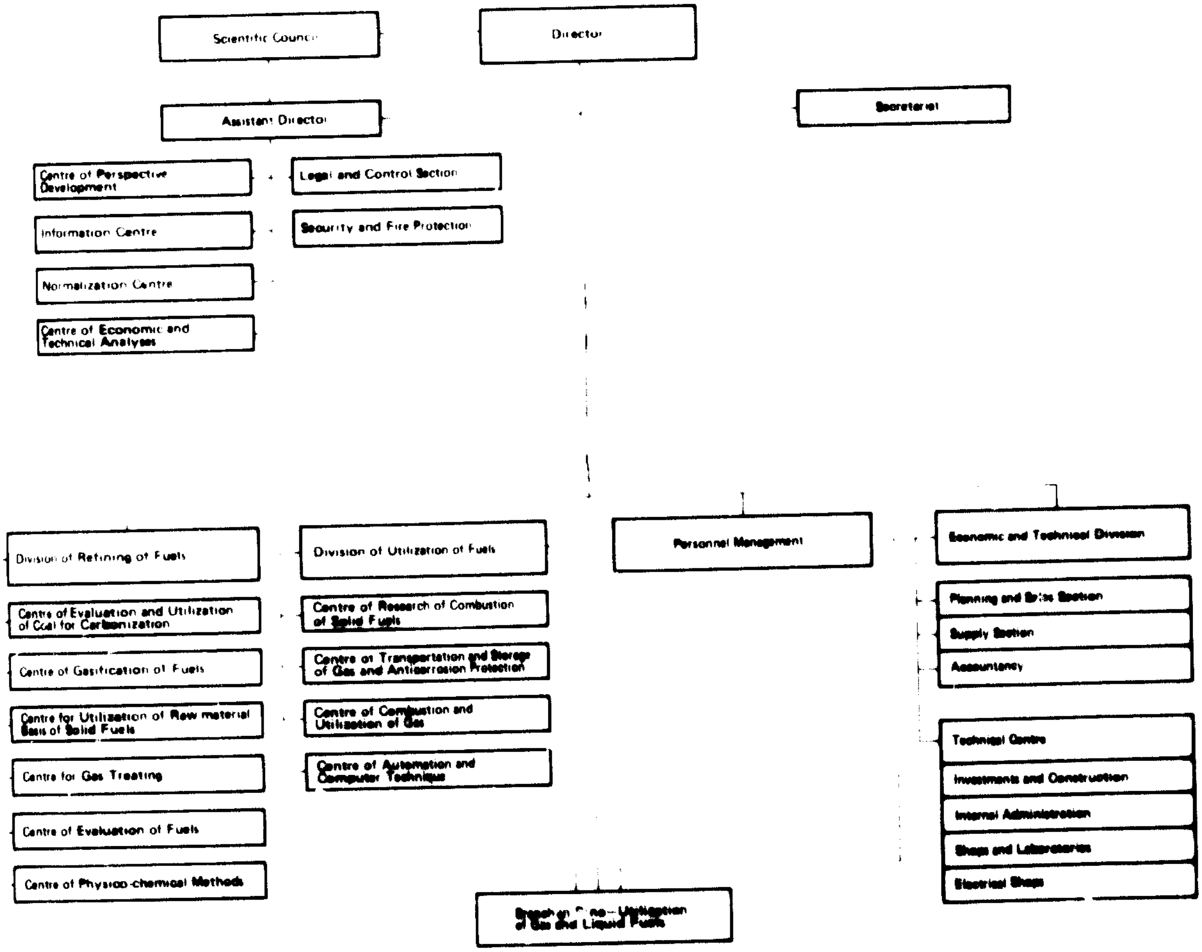
The main objective of the Institute is to contribute new knowledge in the field of processing and use of solid, gaseous and liquid fuels and to assist in putting this knowledge into practice. The Institute also carries out surveys, renders expert assistance to industrial enterprises and co-operates with local and foreign research institutes and international organizations active in its particular field.

The Institute is composed of a number of divisions which in turn are divided into sections, as shown in the accompanying chart. It has about 400 employees.

The total area of the site is 2.5 hectares but buildings cover less than 5 per cent of this. The consumption of electrical energy is about 420,000 kWh which represents a power input of some 0.2 MW. Water consumption from public utilities is about 28 m^3 per 24 hours and the quantity of waste waters discharged to the public sewage system is about 20 m^3 per 24 hours.

The Institute is located in an area set aside for research and development centres on the outskirts of the city. The Research Institute of Materials, Research Institute of Machine Construction, Institute for Motor Car Research and Research Institute of Electrical Engineering, are among other important centres located in this area.

The main advantage of concentrating several industrial research and development centres in one area is that a high standard of utility services can be achieved through investment in common interests: sewage disposal plant, water sources, electrical energy and gas. A further advantage is the possibility of pooling resources for the creation of a suitable living and working environment for the personnel of the centres, i.e. social and health care services, gardens, restaurants, recreational facilities and fire protection.



Organization chart of Institute for Research and Utilization of Fuels, Běchovice, Czechoslovakia

EQUIPPING LABORATORIES IN DEVELOPING COUNTRIES

by Helmut Maier

Selection of equipment

THE SELECTION and specification of laboratory equipment, together with the planning of space requirements for all departments (including flexibility for future expansion) and supporting sections such as workshops, darkrooms, pilot plants, conference rooms, libraries, administrative offices and staff facilities should always precede, or at least go hand in hand with, building design.

Apart from the basic equipment that is found in all laboratories, it is almost impossible to say what equipment is "standard" for an industrial testing, research or development centre. The work being carried out may vary considerably from centre to centre and from country to country. Specialized equipment and accessories therefore have to be carefully selected if they are to meet the requirements of the intended laboratory procedures.

National and international agencies that extend support to developing countries in this field usually employ experts on a short term contract basis to advise on the selection of equipment. Although this system has proved to be successful in many instances, it has one drawback: the expert's short association with a particular project and his possible lack of experience of local conditions may not allow him to appreciate the many intricate problems involved in the operation and maintenance of sophisticated instruments or the possible difficulties in obtaining regular supplies of the equipment he is recommending.

Developing countries often lack laboratory supplies and equipment, technical assistance and maintenance services. The limited over-all marketing potential, however, and the large variety of laboratory and scientific instruments available from foreign suppliers and manufacturers make it generally uneconomical for local businessmen to establish stocks or to employ qualified service engineers. The problem in many countries is compounded by foreign exchange and import restrictions which often do not even permit the commercial import of spare parts. As a result, scientific laboratories in developing countries cannot, or can only to a limited extent, find technical assistance locally. They must rely on the support and co-operation of suppliers based perhaps thousands of miles away.

Several conclusions are to be drawn from this situation. One of them is that before selecting any equipment, a careful study should be made to determine:

(*a*) Which of the many possible suppliers and manufacturers of equipment have local representatives or offices capable of providing installation and maintenance services?

(*b*) What experience do potential suppliers have in dealing with the special conditions obtaining in developing countries?

Another important conclusion is that equipment specifications must be prepared very carefully and clearly. There are countless examples of cases where lack of detail in specifying has led to the purchase of incomplete or unsuitable apparatus. It should be understood that supplementary equipment or accessories, if not specified, will not be quoted for in the supplier's bid.

Most brochures or catalogues published by equipment manufacturers give only general information, without complete order specifications. A selection based

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The author is the Managing Director of a scientific technical supply house at Buchschlag, Federal Republic of Germany, which specializes exclusively in equipping laboratories in developing countries. This article originally appeared as UNIDO document ID/WG. 131/13.

[illegible] and literature will lead to misunderstandings. [illegible] specifications usually given of essential accessories not included in the basic instrument, of optional accessories with explanations for their particular application or of essential operating supplies and recommended spare parts. Scientific institutions in developing countries have had the experience that because of insufficient specifications or lack of experience on the part of the suppliers they were supplied with, to give some examples, testing machines without specimen clamps, a climatic testing chamber without a vacuum pump or at least without the parts connecting the two pieces of [illegible] mercury [illegible] thermo[illegible] [illegible] spectrophotometer without a thermostat and a distillation apparatus without stand, clamps or tubing. The list could be continued indefinitely.

While the supplier may believe that non-specified equipment is readily available, the scientist or the laboratory may be suffering serious and annoying delays in putting the equipment into operation. New orders have to be processed, and up to a year may be required to obtain the necessary additional supplies.

Most manufacturers restrict their supplies to the parts they produce in their own works. They are used to operating within their own country where minor accessories such as stands, clamps, tubing, glassware and [illegible] instruments like pH meters, balances and thermostats commonly found in a laboratory are either available immediately or may be obtained quickly from a local dealer. When dealing with developing countries, however, it is frequently wrong to assume that the same conditions obtain.

Large laboratory supply companies offer a more comprehensive range of supplies than individual manufacturers, as their delivery programme usually includes a full range of instruments and auxiliary equipment.

Another advantage offered by the large companies is the economy gained by dealing with only one source rather than having to deal with a number of individual manufacturers. Service facilities for installation and maintenance of the equipment can also be coordinated and provided much more easily by a large organization. If experts have to be commissioned for each individual piece of sophisticated equipment, the expense becomes prohibitive.

The fact ought not to be overlooked that sophisticated apparatus requires special training for the operators. Engineers performing the installation usually provide some basic training. Depending on the experience of the scientist who is to work with the equipment, however, a more far-reaching programme of training may be necessary, which cannot be imparted by the engineer in the field. In such cases special training programmes should be arranged at the centre or at a recommended scientific institution, preferably before the equipment is delivered. Such training programmes can of course be arranged through the supplier, but the extra expenditure involved in travel, accommodation and possibly other fees should be supported out of the project funds. This very important aspect of development assistance is a suitable field of activity for international aid organizations.

Equipment maintenance

A particularly important aspect of equipping laboratories in developing countries is the incorporation of fully equipped electrical, electronic and fine mechanical workshops. In institutes that use sophisticated instruments worth perhaps millions of dollars, a well-equipped workshop is essential. Even more important is the recruitment of highly qualified staff for the workshops. It has frequently been observed that the grades fixed for workshop heads only attract technicians. Considering the fact that very expensive and highly technical instruments must be handled, it is not far-fetched to suggest that the status and pay attached to these jobs should be increased in order to attract qualified engineering graduates. The grade of such personnel after training and qualification in instrument maintenance should be comparable with that of an assistant head of a laboratory department if not with that of the department head. Training courses in instrument maintenance should be arranged in suitable local educational institutes or abroad under the aegis of international organizations. Suppliers of equipment sometimes provide training on specific instruments in their own laboratories.

It becomes obvious that an investment in workshop equipment and well-trained personnel is worth while when it is considered that any maintenance service performed by the supplier's engineers beyond the guarantee period has to be paid for. Equipment should be installed by the supplier and maintained for a guarantee period of up to 12 months. Quite often, however, equipment is not maintained after the guarantee period because the scientific institutions concerned do not have a budget to pay for instrument repair. To avoid such a situation, a certain percentage of the original purchase price should be set aside for service and maintenance.

A well-equipped workshop, in addition, can produce many special devices and instruments for the various departments of the institute.

Finally, for reasons of economy it may be thought in developing countries that air conditioning systems for research centres can be dispensed with. Much more than the human being, who has learnt to adjust even to adverse climatic conditions, sophisticated electronic or electron-optical and analytical instruments require protection against heat, humidity and dust. Sophisticated instruments also require an emergency generator to supply electricity in case of power failure or fluctuation.

Criteria for procuring equipment

Procurement rules demand, almost everywhere, that the cheapest offers be accepted. Applied to the purchase of scientific equipment, strict observation of such rules may turn out to be a very expensive way of equipping a laboratory. As discussed earlier, precise specifications are a good means of obtaining correct and reliable offers. Only such offers allow a just comparison of the scope of delivery and the prices of different bidders.

In order to obtain an undistorted picture of comparative data, only technically experienced and commercially capable manufacturers and suppliers should be invited to submit offers. A procedure is recommended whereby only a limited number of firms that can satisfy every requirement as to quality, experience in handling comprehensive supplies, reliability in connexion with delivery schedules, technical assistance and maintenance service are invited to tender. Such a procedure may even lead to individual firms being selected as suppliers for entire laboratory outfits, equipment lots or specialized instruments on a proprietary or single tender basis.

Invitations to bid should always give clear indications of the currency and terms in which offers are to be submitted, if individual prices are to be quoted ex works, f.o.b. port of shipment, c & f or c.i.f. port of destination, if shipment is desired by air or sea, and whether or not the cost of packing should be included. It is worth pointing out here that North American firms have a different interpretation of the term "f.o.b." (free on board ship) from European suppliers. The latter observe the internationally accepted definition of the term, according to which f.o.b. prices include cost and all charges of delivery, including packing, up to "on board ship" in the seaport or airport of shipment. In the United States of America, however, "f.o.b." is normally understood as f.o.b. factory, and prices do not include packing, inland freight, loading charges, documentation or export handling, all of which are charged separately.

If a bidder deviates from the terms laid down in the tender invitation, his offer should be carefully examined as it may have been intended to obtain a superficial advantage in price comparison only. A careful technical scrutiny of the specifications given in a bidder's offer and a comparison with the illustrated literature attached to the bid will, in many cases, eliminate quotations which at first glance look cheaper. Accessories may have been purposely left out to gain an advantage over other bidders. Sometimes minor but important differences in performance data cause considerable price variations.

Many national and international organizations invite offers from original manufacturers only, demanding that the commission usually allowed to agents be offered as a discount. The disadvantages of this procedure are that orders are quite frequently placed with firms which readily accept these conditions but which have neither experience nor agents in the purchasing country. Thus, the scientists in the developing countries are denied the benefit of any kind of technical assistance. When comparing price quotations, the offer of an international laboratory equipment supplier may occasionally be found to be substantially higher than that of a manufacturer. In such cases it can only be recommended that the experience and after-sales service incorporated in the offer should be carefully considered.

One aspect of equipment purchase that causes problems is the time given for the submission of offers; often it is far too short. It should be realized that long lists of specifications prepared for a project over an extended period of time cannot normally be quoted for in a space of only two or three weeks. If the time that might be left to a supplier after delays in mail are taken into account, the quality of offers might be considerably improved if more time were allowed. Decisions on bid acceptance should not be delayed beyond the normal validity of offers, particularly at the present time when worldwide inflation necessitates frequent adjustment of prices.

Another serious problem that is often encountered concerns damage in transit and the insurance covering such damage. Extensive damage and even total loss can result from the rough handling of consignments in ports where no mechanized means of transport, such as fork lift trucks, is available. Delays may be encountered in clearing consignments through customs, and sheltered storage facilities are often absolutely inadequate. Cases containing expensive equipment may be subjected to the most adverse climatic conditions: humidity, heavy tropical rains, extreme heat and dust. No economically justifiable method of packing can prevent damage to equipment under such conditions.

Sometimes, because of customs formalities and administrative delays in having the consignments unpacked and examined, insurance coverage has already expired by the time the equipment arrives at its destination and a claim can be lodged. Then, more time and effort is usually spent on fixing responsibility than on how the situation might be avoided in future. An effort should be made at the international organization level to solve this problem. The reduction in damage or loss would pay for the necessary investment in a very short time.

A final suggestion may be made here. Replacement parts required to repair transport damage should be obtainable with a minimum of delay and administrative red tape. Research and development centres should have the authority, in an emergency, to place small orders direct with suppliers.

With or without such emergency order facilities, however, scientists usually depend on and prefer co-operation with the experienced and flexible supplier who is in regular and not sporadic contact with his customer, who extends unbureaucratic help and who even provides, when necessary, free replacements and repair facilities in order to contribute to the prime objective in the establishment of a scientific institute: useful and effective work and uninterrupted operation.

LABORATORY FURNITURE AND FITTINGS

by **F. Geyer**

THE MAIN criteria for the construction of laboratory furniture are laid down in a number of standards, specifications and publications, many of which are listed at the end of this article. Particular mention may be made of British Standard 3202:1959 "Laboratory furniture and fittings" [14] and the publications of the United States Department of Health, Education and Welfare [17]. At the present time, the Federal Republic of Germany has a number of DIN standards which, together with the directives for laboratory work published by the Berufsgenossenschaft for the chemical industry and the Berufsgenossenschaft for public health, have influenced the construction of laboratory furniture [2, 16].

Laboratory furniture for chemical and similar work consists of a few repetitive units that vary in shape and style but are uniform in their arrangement and basic design. They include island benches, wall benches and fume cupboards (fig. I), cupboards (fig. II), sink units (fig. III), balance desks (fig. IV), titration desks, and microscope desks (fig. V). The supporting elements for the bench tops may be either a steel or wooden framework in which the underbench components can be mounted (figs. I and VII) or fixed carcass units of different types (fig. VI).

It is recommended that only the first type be used and that a foot space 20 centimetres deep be allowed for comfortable standing and cleaning. All these units, in particular the benches with lengths of 3 metres and more, and the fume cupboards with front lengths of 1.2, 1.5 and 1.8 metres, and a height of 2.8 metres, are space consuming items that must be shipped dismantled, then reassembled on site and joined to the piping systems of the building by skilled craftsmen.

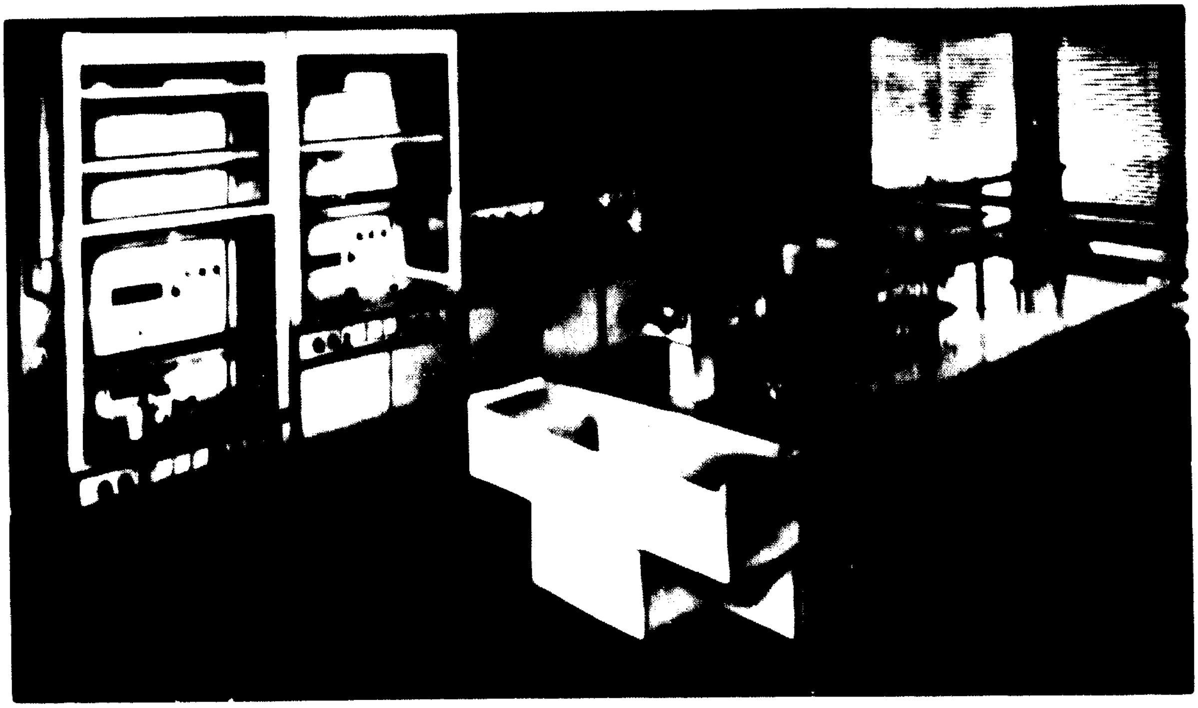

Figure I Island and wall benches with service shelves, ceramic sink unit, steel framework for carrying the bench tops and the carcasses made of plastic-laminated timbers. Standard and low-bench fume cupboards

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The author is Secretary of the Technical Committee Laboratory Apparatus and Furniture of the DNA (German Standards Institution). This article originally appeared as UNIDO document ID/WG.181/5.

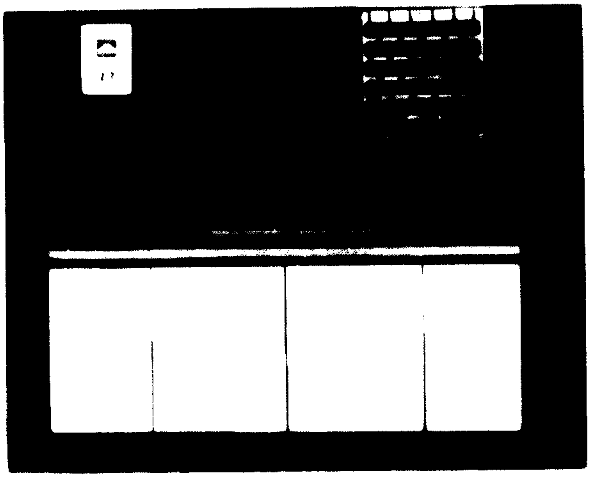

Figure II. Laboratory cupboards

Figure III. Laboratory sink unit with draining boards

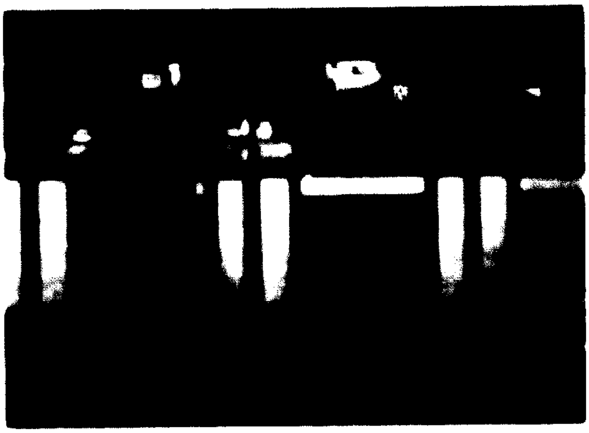

Figure IV. Balance desks with built-in anti-vibration mountings

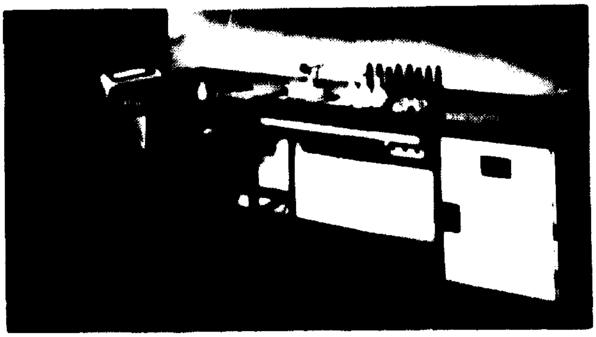

Figure V. Desk for sitting work

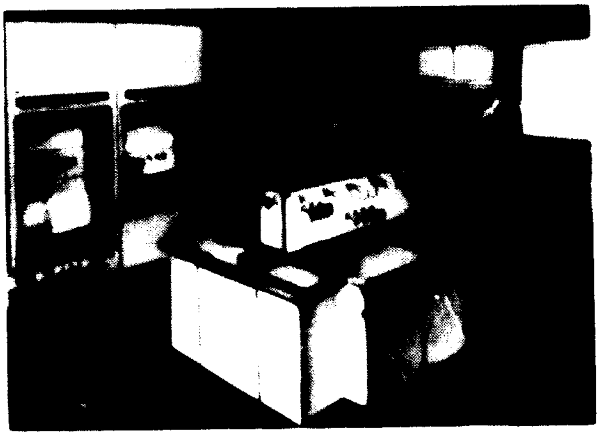

Figure VI. Island and wall benches, with service cell on the back, bench tops of large acid-proof stoneware tiles mounted on fixed carcass units

At the earliest stage of planning, it should be taken into account that the design of the furniture and the essential dimensions of length, height and depth will largely govern space planning, the design of the building, plumbing and ventilation systems and the choice of materials for floor and wall covering. During the past 20 years, additional laboratory furnishings, such as the plumbing cell (figs. VII, VIII and XI) and movable desk units (figs. IX and X) which are better adapted to present day physico-chemical methods of analysis, have been developed. They can replace the conventional fitted-furniture type of bench. The prefabricated plumbing cell mounted in the axis or on the wall of the laboratory includes all pipes and outlets for the various services and must be connected to the service piping system of the building. The easily dismountable or, in some cases, independent and movable desks are placed adjacent to the plumbing cells. These instrumentation desks with different top coverings may be used as bases to carry special electrical equipment assemblies to be joined to the plumbing cell. Such adaptable laboratory furniture is to be preferred if the purpose of the laboratories cannot be specified in detail at the planning stage.

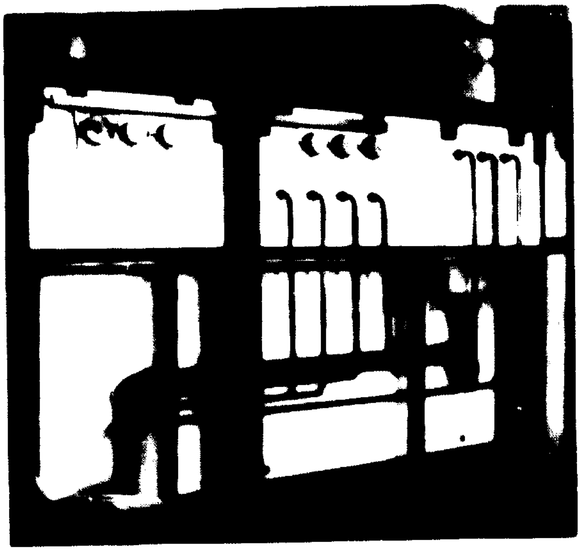

Figure VII Prefabricated piping system made from copper tubing and plastic pipes

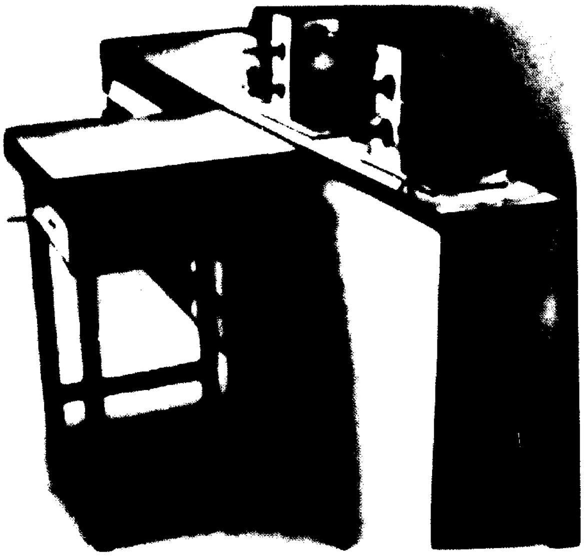

Figure VIII Island plumbing cell with gas, water, compressed air taps, electrical sockets and cup sinks

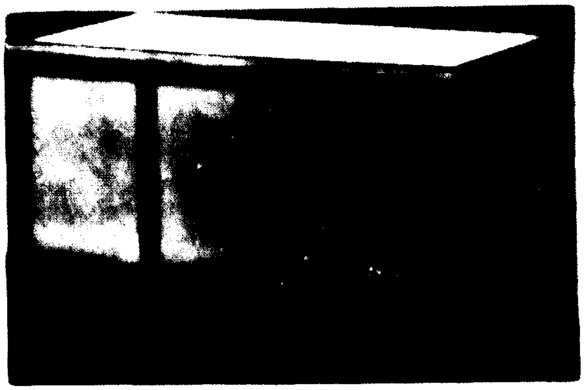

Figure IX Instrumentation desk

Figure X Instrumentation desk on casters

In the industrialized countries a number of companies specialize in the manufacture, supply and assembly of laboratory furniture. They also supply the plans and indicate the location and size of the piping, exhaust and electrical terminals in the building. The increasing demands and the modulation and elementation of laboratory furniture has stimulated production, in series, of timber, plastic laminated wood and epoxy resin coated steel carcasses (fig. XII).

The equipment of industrial research centres in developing countries should not depend entirely on imports. Transporting laboratory furnishings from abroad involves the additional costs of dues, packing and delegation of specialists. Moreover, the complete installations of laboratory furniture being produced in the industrialized countries may not be necessary. In many industrialized countries, however, laboratory benches are still mounted on site by using the co-ordinated work of carpenters, tile layers, plumbers and other craftsmen. Their work is regarded as secondary building work. In this case, fitters or carpenters build the supporting framework on top of which tiles are embedded in acid-proof putty on a concrete base. The plumbers execute the necessary piping work. A furniture manufacturer subsequently supplies the carcasses to be fitted into the framework of the benches (fig. XIII and XIV). This method has proved satisfactory for many years and could also be applied to the furnishing of industrial research centres in developing countries. The contractor charged with constructing and equipping the building could also order and co-ordinate the subcontract work for the laboratory furniture as he would have the necessary contacts with local specialized tradesmen. The building contractor could also prepare the tenders for supply and assembly and supervise the progress of work on site.

Figure XI. Island plumbing cells for laboratory servicing, housing in addition the vertical main lines, electrical distribution boards, and waste and exhaust ducts for use with movable instrumentation desks

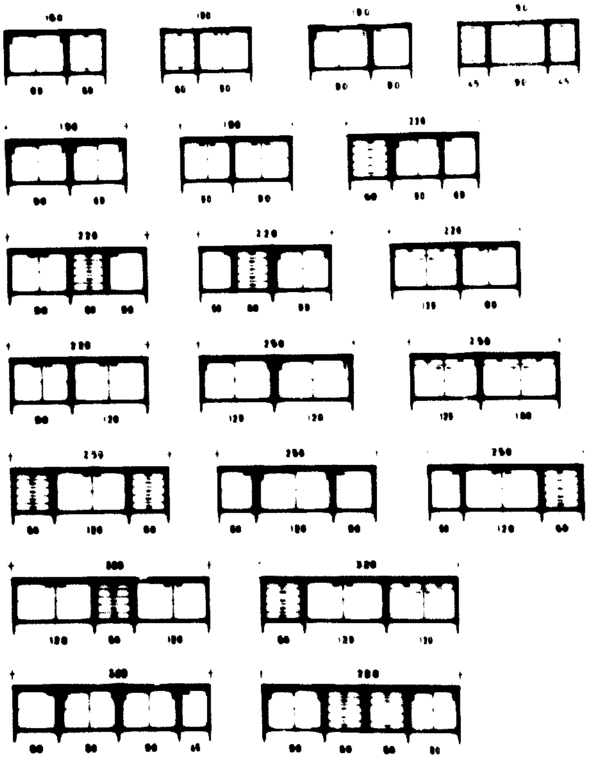

Figure XII. Bench assemblies of various modular carcasses (widths in centimetres)

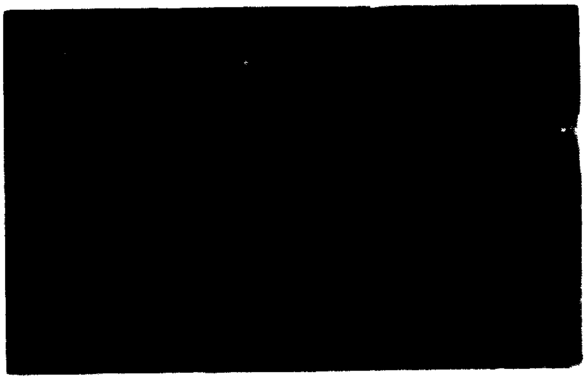

Figure XIII. Assembling of laboratory bench on site

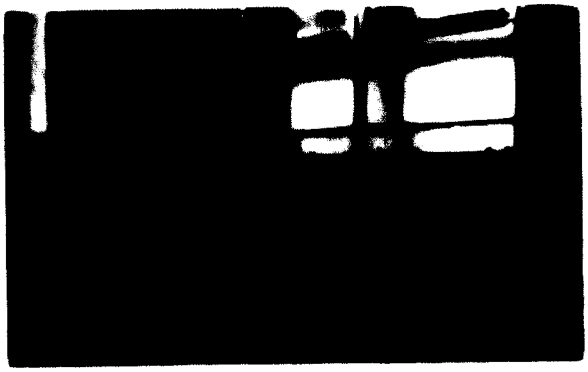

Figure XIV. Assembling of fume cupboards on site

Essential dimensions

The optimum working depth of benches for standing work has been found to be 60 cm clear of the working surface, plus 15 cm for the accommodation of above-bench fitments such as gas stands, electrical sockets and shelves. The total depth of 75 cm is specified in DIN 12 922-1972 "Laboratory furniture; benches; dimensions" [9c] (see table 1). The catalogues of important manufacturers of laboratory furniture in the Federal Republic of Germany, France, the United Kingdom of Great Britain and Northern Ireland and the United States of America as well as the British Standard 3202:1959 [14] also show an overall depth of 75 cm for most of the apparatus. Figure XVII shows the influence of the dimensions given in table 1 upon space planning.

Observing the heights given in table 1 has always caused some problems because of the variety of bench tops available. Their thickness varies with the different coverings and supporting bases used: 6 cm for ceramic tiles, 4 cm for Pyroceram, 3.7 cm for acid-proof stoneware and 2.8 cm for plastics. Height differences in adjacent bench units cause inconvenience to the user.

Tenders should therefore expressly indicate that desks and benches with different coverings must have uniform heights. (Differences can be compensated for by underlaying the bench tops.)

Table 1 shows modular lengths that have found general acceptance. The basic length of 1.2 m is frequently applied and the 60-90-120 cm series and its multiples have been derived from this length in the course of manufacturing laboratory furniture. This modulus of length in 30 cm steps (M 300) allows satisfying adaptations to local conditions and the utilization of elemented units (fig. XII).

Materials

The materials used in the construction of laboratory benches and fume cupboards are required to possess a variety of properties. This requirement applies in particular to bench-top coverings. The various possibilities are set out in BS 3202:1959 [14]. In both the Federal Republic of Germany and France, ceramic tiles, stainless steel, Pyroceram (a thermal shock-resistant flat glass), large stoneware plates as standardized in DIN 12 916-1972 [9g] and plastic-laminated wooden panels are used. Wooden boards, natural stone, inlaid teak or similar hardwood, and concrete covered with ceramic tiles are available in most countries, but bench tops made of stainless steel, Pyroceram or large acid-proof stoneware plates (figs. I and VI) usually have to be imported. The time involved in transport, customs clearance and delivery can cause considerable delay in completing the work of equipping the laboratory. Locally available timbers should be used for the manufacture of cupboards, under-bench units and carcasses.

The surface finish of wooden parts should meet the special requirements of laboratory furniture. Chlorinated rubber paint coatings have yielded satisfactory results. Steel carcasses, spray-coated with powdered epoxy resin in an electrostatic field and subsequently stored, have proved to be highly corrosion resistant for many years. These usually have to be imported into developing countries, however.

Service piping

The planning of the plumbing system of a research centre is governed by the outlets of water, gas,

TABLE 1. BENCH DIMENSIONS
(mm)

				American				*British*		*French*	*German*	
				Manufacturers								
		DIN 12 922	*BS 3202*	*Fisher*	*SH*	*Hamilton Metal*	*Hamilton Wood*	*Gallenkamp*	*Grundy*	*Cattin*	*Köttermann*	*Waldner*
Height	**Standing**	900	910	914	940	940	915	914	900	900	900	915
	Sitting	750	760	760	710[a] 735[b] 790[c]	760	760	760	750	760	775	745 765
Clear depth		600	610	610	610	610	610					600
Over-all depth		750		785	760	760	760	760	750	750	750	750
(service space included)		1500		1395	1370	1370	1370		1500	1500	1500	1500
Length of units (see fig. XII)		600 900 1200		465 620 890 1195	465 610 900 1195	465 610 900 1195	465 610 900 1195		500[e]	600[e] 1150[e]	600[e] 900[e] 1200[e]	600 900 1200

[a] Microscope desk

[b] Chemists' desks

[c] Titration and balance desks

[d] Former German Standard height: 780

[e] Bench top projecting not included (see fig. XII)

compressed air, steam and electricity used on the laboratory benches and in the cupboards. The services and number of taps, cocks and valves to be provided should therefore be specified at an early stage (table 2).

TABLE 2. RECOMMENDED NUMBER OF OUTLETS, SINKS AND SOCKETS

	Bench tops of 0.6-0.75 m width			
Services *Length (m)*	*3*	*3.6*	*4.2*	*4.5*
Gas taps	2	2	3	3
Water taps	2	2	4	4
Above cup sinks	1	1	2	2
Compressed air valves	1	1	1	2
Fused electrical circuits with	2	2	2	3
Two-phased sockets	4	4	4 (6)[a]	6 (8)[a]
Three-phased sockets	1	1	1	2
	Bench tops of ≈1.5 m width			
Gas taps	4	4	6	6
Water taps	4	4	8	8
Above cup sinks	2	2	4	4
Water taps	3	3	6	6
Hot water taps above	1	1	2	2
Sinks with overflow	1	1	2	2
Compressed air valves	2	2	2	4
Fused electrical circuits with	4	4	4	4
Two-phased sockets	8	8	8 (12)[a]	12
Three-phased sockets	2	2	2 (4)[a]	4
	Fume hoods			
Length (m)	*1.2*	*1.5*	*1.8*	
Gas taps (front controlled)	2	2	3	
Water taps (front controlled)	2	3	4	
Cup sinks	1	2	2	
Compressed air valves (front controlled)	1	1	1	
Fused electrical air valves with	1	1	2	
Two-phased electrical sockets	2	3	4	
Three-phased electrical sockets	1	1	1	

[a] **For physical or physico-chemical laboratories.**

The three standard types of bench fittings, i.e. stands, wall-fixing and front controlled patterns, are made of brass. In air-conditioned rooms, chrome-plated surfaces are usually sufficiently resistant. Acid-proof coatings are used in German laboratories carrying out wet chemistry work, however.

Colour coded lever handles and handwheels of cocks and valves facilitate the identification of the fluids they control. BS 3202 recommends an alphabetical identification system, but the position of the handle sometimes makes readings difficult and, besides, such letter symbols are not universally comprehensible.

It frequently happens that more service piping is installed than is really necessary for the activities of a laboratory. Measurements carried out in some laboratory buildings have proved that the compressed air service utilization rate was not even 6 per cent. If compressed air must be provided on the benches, ¼ in valves will be sufficient for a gauge pressure of 1 bar and for a maximum supply of 0.15 standard m^3/min [3].

Vacuum service for suction of 0.15 m^3/min at a pressure below 400 Torr[1] at each point can also be an expensive and uneconomical installation. Water operated ejector pumps and even motor-operated small rotary pumps are more practical and more efficient because they deliver a vacuum below 20 Torr and their pressure does not depend on the varying load of a piping system.

The necessity of supplying steam to benches and cupboards is doubtful, although steam as a heat source can certainly be helpful in evaporating inflammable liquids. Steam heated laboratory apparatus is now rarely manufactured as temperature-controlled electrical appliances, some explosion proof, are easily available and are much more practical to use.

The necessity of a general supply of high-pressure gases such as nitrogen, oxygen, hydrogen, helium and carbonic acid to the benches should be carefully examined at the planning stage. The alternative systems are:

(*a*) Service piping running throughout the entire building from a central space for the storage of high-pressure gas containers to needle valve panels on the reagent shelves of the benches;

(*b*) Short tap pipes running from exhausted decentralized storage boxes for high pressure gas bottles on the floors to needle valve panels on a limited number of benches, for example in chromatography laboratories (fig. XV).

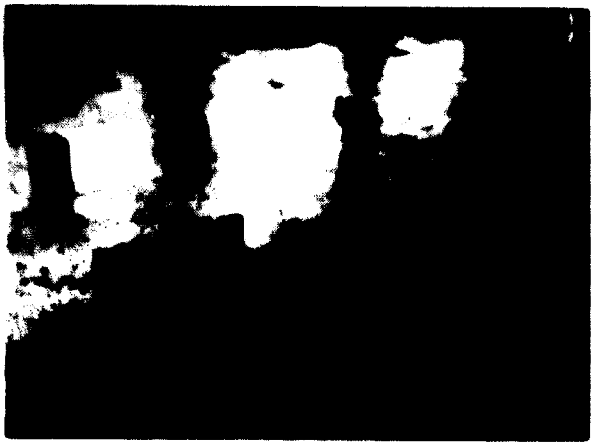

Figure XV. Service terminals provided for connexion to the piping system of a bench

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[1] The Torr is a unit of pressure equal to 1/760 of an atmosphere and very nearly equal to the pressure of a column of mercury 1 millimetre high at 0 °C and standard gravity.

(c) Clamps on laboratory benches and cupboards for fastening high-pressure gas cylinders fitted with reducing valves: this is undoubtedly the most economic solution [8].

It must be taken into consideration, however, that alternative (c) will increase fire load, and explosion hazards in case of fire. German guidelines for accident prevention recommend the removal of high pressure gas bottles from the laboratory overnight [2, 12].

In an industrial research plant, separate services for potable (town) and industrial water should be provided for the laboratory work areas. The handwheels of valves for potable and non-potable water supply must be clearly distinguishable, e.g. by colour coding or by conspicuous and durable labels. The supply of non-potable water to the benches can considerably diminish the consumption (water jet pumps 180-550 l/h) of potable water. The drinking water piping system must also be protected against backflow resulting from the connexion of laboratory hose to water taps [3, 5a, 7, 14 and 17].

The American National Institute of Health suggests [17] the use of an industrial water system serving all laboratory work areas. Such a system would be independent of the potable domestic system and only the few potable water taps would have to be marked or labelled.

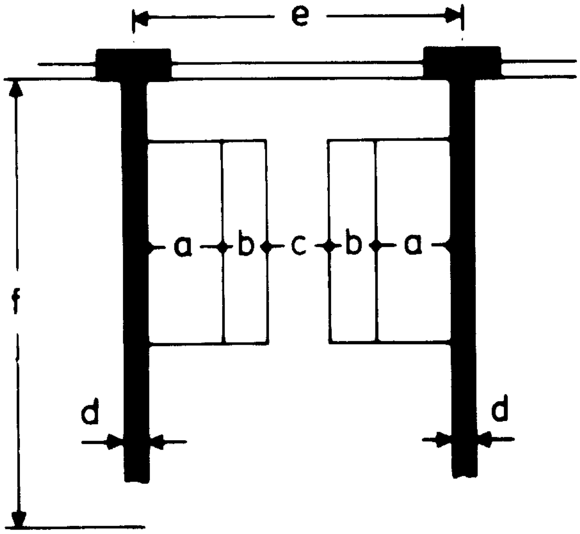
The provision of hot water through local electric heaters placed above the laboratory sink units could be more practical and more economical than bench taps fed from a central system.

Plastic taps for distilled or demineralized water should not be provided for all benches [14, 17]. In general, it is sufficient to provide one tap, fed by a central plant, in each laboratory of a certain type, or on each floor, and this only if the activity of the institute necessitates a permanent supply of distilled or demineralized water. In all other cases, distilled water can be used from bottles stored on the reagent shelf of the bench.

The number of gas taps on the benches and in the fume cupboards cannot be taken as a criterion for the evaluation of gas consumption. A 3/8-in. gas tap delivers 1,200 ℓ/h at the usual pressure of 90 mm wc.[2] A Bunsen burner consumes about 100 ℓ/h [3, 5b, 5c, 14 and 17].

The diversity factor of 0.4 or 0.5 mentioned in BS 3202 should only be based on 100 ℓ/h gas consumption and not on the maximum possible supply of the tap. Gas stands or other types of gas fittings are installed on all benches and cupboards, although the utilization of gas heated laboratory apparatus is steadily decreasing in favour of electrically driven appliances.

Figure XVI. High-pressure gas cylinder in exhaust cabinet



(a)	Width of bench tops	
(b)	Width of operating area	
(c)	Width of passage way	
(d)	Thickness of partition	
(e)	Optimal distances	0.6 m and 0.75 m
(f)	For laboratories	0.45 m
	For offices	0.55 m

depending on its structure

3 m	3.3 m	3.6 m
6-7.0 m	6.6-8 m	7.2-9.0 m
3-4.5 m	3.3-5 m	3.6-5.5 m

Figure XVII. Width of working areas and space dimensioning

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[2] Water column.

Instead of common town gas (90 mm wc), natural gas (200 mm wc) is now being used in the service systems of many laboratories. The higher pressure requires adequately designed burners and bench fittings with greaseless stuffing box valves. For safety reasons, an outdoor location is required if high-pressure gas bottles for propane/butane supply are utilized.

The terminals of the piping system to which the benches, cupboards and prefabricated plumbing cells are to be connected (fig XVI) should not exceed the following sizes

Water	1 in.
Gas (town)	¾ in
Gas (propane/butane)	½ in.
Compressed air	½ in.
Vacuum	½ in.
Waste	50 mm NB

Copper tubing and welded or soldered connexions are used for prefabricated piping in benches and plumbing cells. Gas, vacuum and compressed air bench piping, mounted on-site, are usually made from black steel with malleable iron banded fittings, and water piping from galvanized steel tubing and galvanized iron fittings. The supply line terminals should have shut-off valves

Cup sinks and sinks with overflow are made of acid-proof stoneware, fire clay, stainless steel and plastic. In the Federal Republic of Germany, their dimensions are standardized in DIN 12 914-1973 and DIN 12 915-1973 [9e, 9f]. Glazed ceramic sinks of brown, white and grey colour and ceramic S-traps are highly corrosion resistant and therefore extremely suitable for laboratory furniture. Stainless steel sinks are less resistant, for example, against air containing small amounts of halogen, particularly chlorine, which frequently circulates in chemical laboratories. For the waste lines, iron pipes with spigot and socket connexions made from fine-grain spun cast iron can be used [14], or PVC and PE waste lines with welded connexions, which experience has shown to be sufficiently corrosion resistant and shock-proof.

Bench waste lines made from acid-proof stoneware and glass are highly corrosion resistant, but have low impact strength.

For research centres in developing countries, the use of cast iron pipes, which are available anywhere, is recommended for the main ducts as well as for the piping in benches mounted on-site.

Consumption of fluids

Croissant [3, p. 49] measured steam, water, gas and compressed air consumption (figs. XVIII and XIX and table 3) at five minute intervals in twelve laboratories of an industrial research centre (two analytical, three research, two application engineering, three routine, one agriculture and one teaching). After recording the consumption peaks and the mean values for 24 h covering also the maximum values when multiplied by 1.5 he came to the conclusion that exact values guaranteeing a solid basis for planning in all types of institutes could not be stated, but that the results of the measurements gave a realistic impression of the order of magnitude to be expected in most of the cases. The measurements yielded the results shown in table 3.

TABLE 3 CONSUMPTION PER BENCH LENGTH AND PER WORKER

	Consumption			
	Per m bench length	*Scatter range*	*Per worker*	*Scatter range*
Steam	0.07-2.2 kg/h	1:3.1	1.9-6.6 kg/h	1:3.5
Water	0.03-0.12 m^3/h	1:4	0.12-0.36 m^3/h	1:3
Town gas	0.01-0.04 m^3/h^a	1:4	0.02-0.11 m^3/h^a	1:5.5
Compressed air	0.02-0.1 m^3/h^a	1:4	0.11-0.52 m^3/h^a	1:4.8

^{a}Standard m^3

Conclusions

When planning an industrial research centre, the laboratory furniture should be considered as an integral part of the building and its details specified in the project.

In the past, planning, tender and supply of laboratory furniture and its assembly on-site started only after completion of the building and resulted in considerable additional costs and much loss of time. If, however, the assembling of laboratory furniture can be co-ordinated with the progress of the construction, the necessary labour will be available at all stages to carry out the additional work involved in the installation of benches and fume cupboards and in connecting them to the main lines.

If it is found at an early stage of planning that the contractor's engineers are unable to design the laboratory furniture and that local subcontractors cannot execute the work, an experienced manufacturer of laboratory furniture should be invited to submit information on the supply and assembly on-site of prefabricated laboratory furniture. Because of the difficulties of transportation, however, only a few specialized companies are interested in such business.

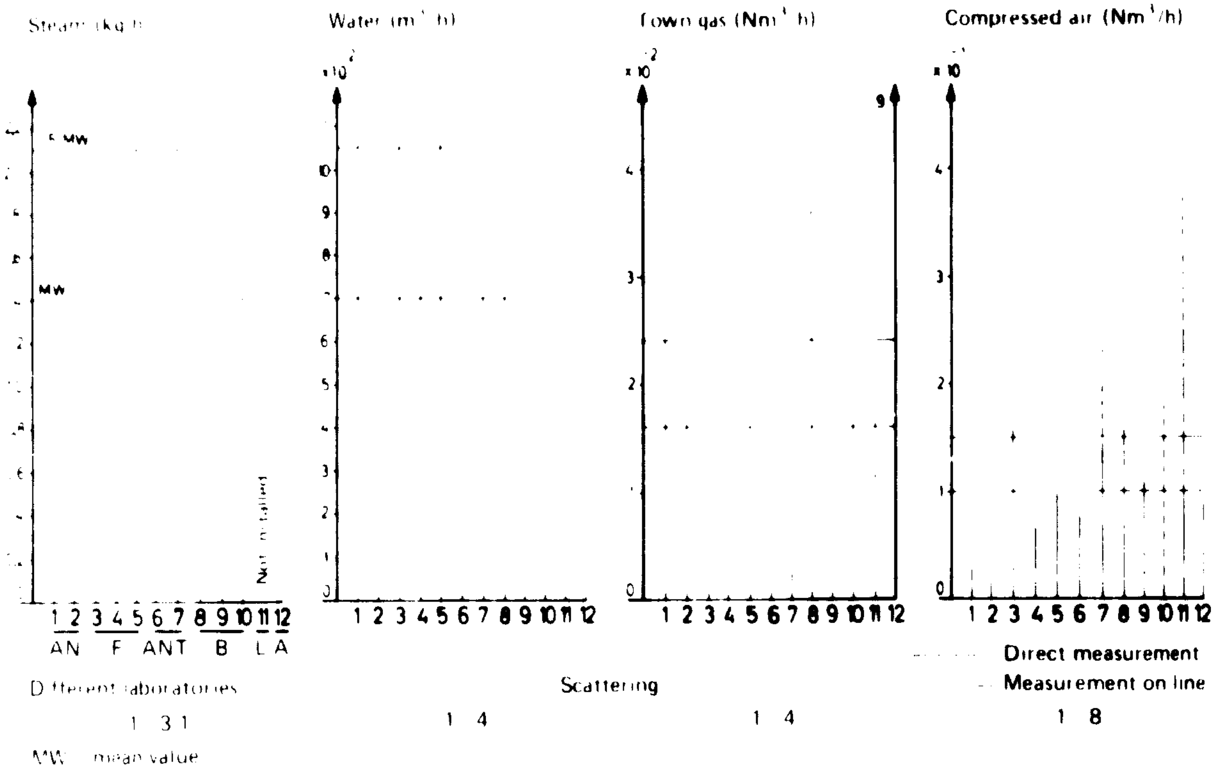

Figure XVIII. Consumption per m bench length

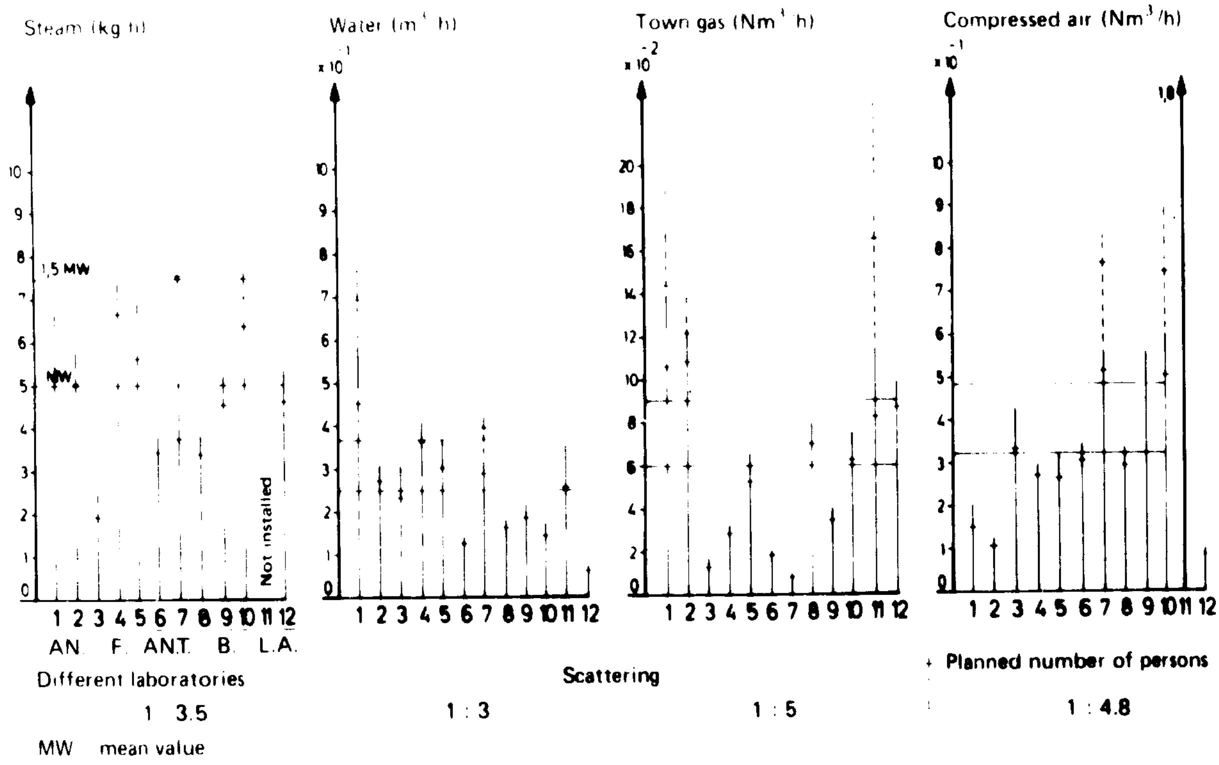

Figure XIX. Consumption in relation to number of personnel

KEYED BIBLIOGRAPHY

1. Beck, H. Lüftungseigenschaften von Laborabzugen (Ventilation power of laboratory fume cupboard). Weinheim, Chemie-Ingenieur-Technik, 1964 (No. 36)
   In German.

2. Berufsgenossenschaft für die chemische Industrie. Richtlinien für chemische Laboratorien Nr. 12 (Directives for chemical laboratories no. 12). Weinheim, Verlag-Chemie, 1972.
   In German.

3. DECHEMA Erfahrungsaustausch. Laborbau (DECHEMA sharing experience, laboratory design). Frankfurt/M., DECHEMA, 1969.
   In German.

4. Decken, C. B. v.d. and B. Hundorf. Untersuchungen uber die strömungstechnischen Vorgänge in der Kapelle eines Laborabzugs (Experiments about flow within the cabin of a fume cupboard). Darmstadt, GIT, 1968. (No. 8)
   In German.

5. Deutscher Verein von Gas- und Wasserfachmännern (DVGW) Normen (German Federation of Gas and Water Specialists Standards). Eschborn, Federal Republic of Germany.
   - 5a. Wasserversorgung. Verbrauchanlagen (Water supply, service piping). DVGW W 503-1966.
     In German.
   - 5b. Technische Regeln fur Bau und Prüfung von vorgefertigten Bauteilen mit Gas- und Wasserinstallation (Specification for construction and testing of prefabricated appliances with gas and water installations). DVGW GW 3 (1968).
     In German.
   - 5c. Technische Regeln für die Installation von Gasanlagen in Laboratorien (Specifications for gas service installations in laboratories). DVGW G 621 (1971).
     In German.

6. Druckgasverordnung (Pressure gas regulation). Köln, Carl Heymann's Verlag.
   In German.

7. Dunkl/Geyer. Rationale Lösungen von Laborbau und Laboreinrichtungsproblemen in Hochschulen, Industrieunternehmungen und im Gesundheitswesen der USA (Rational solutions of problems in the design of laboratory building and equipment for universities, industry and public health in the United States). *In* Beiträge zur Universitätsplanung (Contributions to the planning of universities). Frankfurt/M., DECHEMA, 1970. (Heft 6)
   In German.

8. Feuriel, H. Rohrnetze für Sauerstoff, Druckluft, Vacuum, Kohlensäure in Krankenhäusern und Laboratorien (Service piping for oxygen, compressed air, vacuum and carbon dioxide in hospitals and laboratories). Darmstadt, GIT, 1964. (nos. 8, 9 and 10)
   In German.

9. Deutsche Industrie Norm (DIN) (German Industrial Standard). Berlin, Beuth-Vertrieb GmbH.
   - 9a. Ventilation plant; principles. DIN 1946-1960, Part 1.
     In English and German.
   - 9b. Fire resistance of building materials and structural elements. DIN 4102-1970.
     In German.
   - 9c. Space lighting by daylight; principles. DIN 4034-1969.
     In German.
   - 9d. Laboratory furniture; ceramic tiles for laboratory bench tops. DIN 12 912-1973.
     In German.
   - 9e. Laboratory furniture, cup sinks. DIN 12 914-1973.
     In German.
   - 9f. Laboratory furniture, sinks with integrated overflow. DIN 12 915-1973.
     In German.
   - 9g. Laboratory furniture, large-size tiles for laboratory bench tops. DIN 12 916-1972.
     In German.
   - 9h. Color code for fluids on handlevers and handwheels of laboratory taps. DIN 12 920-1971.
     In German.
   - 9i. Laboratory furniture, benches, dimensions. DIN 12 922-1972.
     In German.
   - 9j. Laboratory furniture; fume cupboards, dimensions. DIN 12 923-1972.
     In German.
   - 9k. Heating plant, smoke stacks. DIN 18 160-1968, Part 1.
     In English and German.
   - 9l. Traffic ways in buildings. DIN 18 225-1958.
     In German.
   - 9m. Ventilation of laboratories. VDI 2051-1966.
     In German.

10. Geyer, F. Anforderungen an Laborbauten (Requirements for laboratory building) Darmstadt, GIT. (No. 12, 1967 and No. 1, 1968)
    In German.

11. __________ Richtlinien fur die Planung und den Bau von Laboratorien (Principles for design and building of laboratories) Weinheim, Chemie-Ingenieur-Technik, 1971. (No. 11)
    In German.

12. __________ "Rôle et intérêt de la normalisation dans l'aménagement et l'equipement des laboratoires" Courrier de la Normalisation. No. 228, novembre-décembre, 1972.
    In French.

13. __________ The role and significance of standardization of laboratory equipment and furniture. Laboratory Practice (London) No. 4, 1973.
    In English.

14. Laboratory furniture and fittings; BS 3202-1959. London, British Standards Institution. 112 p.
    With bibliographical data.

15. Strangmann, W. Wasserverbrauch in chemischen und biologischen Laboratorien (Water consumption in chemical and biological laboratories). Darmstadt, GIT, 1964. (No. 6)
    In German.

16. Unfallverhütungsvorschrift; Medizinische Laboratoriumsarbeiten (Prescription for accident prevention; work in medical laboratories). Frankfurt/M., HGUVV.
    In German.

17. United States Department of Health, Education and Welfare. Health Research Laboratory design. Bethesda, Maryland, NIH, 1968. (Publication 1807)
    With bibliographical data.

18. Verband Deutscher Elektrotechniker (VDE) Normen (Union of German Electrical Engineers standards). Offenbach/Main, Federal Republic of Germany.
    - 18a. Bestimmungen für das Errichten von Starkstromanlagen mit Nennspannungen bis 1000 V mit Änderungen: (c) 12.65 und (e) 12.65 (Rules for the installation of high tension plant up to nominal voltages of 1000 volts. Amendments (c) 12.65 and (e) 12.65). VDE 0100-1965.
      In German.

TECHNICAL CONSIDERATIONS

Case history 1: The B.C.

THIS ARTICLE discusses the technical considerations involved in the construction and decoration of an industrial research and development centre. It does not cover every aspect, but those discussed are of particular importance with respect to *(a)* a laboratory building fulfilling its intended function, and *(b)* keeping initial capital and subsequent maintenance costs to a minimum.

The accompanying illustrations refer to the laboratory complex of the British Columbia Research Council at Vancouver. This structure, which was completed in 1969 (fig. I), is used to illustrate the various points considered important and is presented as one example of an attempt to optimize the selection of construction materials and methods. It is not the intention here to suggest that either the construction methods employed or the materials used are the most suitable for all cases. the final design of any building involves a number of compromises because of the relationships between the various components. Its development on a systematic and rational basis, however, enables better prediction of performance and provides the best approach to an optimum solution.

Modular concepts

To some, the term "modular" used in connexion with building design means a dimensional programme in which all principal spatial dimensions are multiples or submultiples of a selected modular dimension. To others, a module is an element of a building which may be used repeatedly to make up substantial sections of the whole structure. Both views, however, embody the notion of design standardization (fig. II). The modular approach leads not only to efficient design but to cost

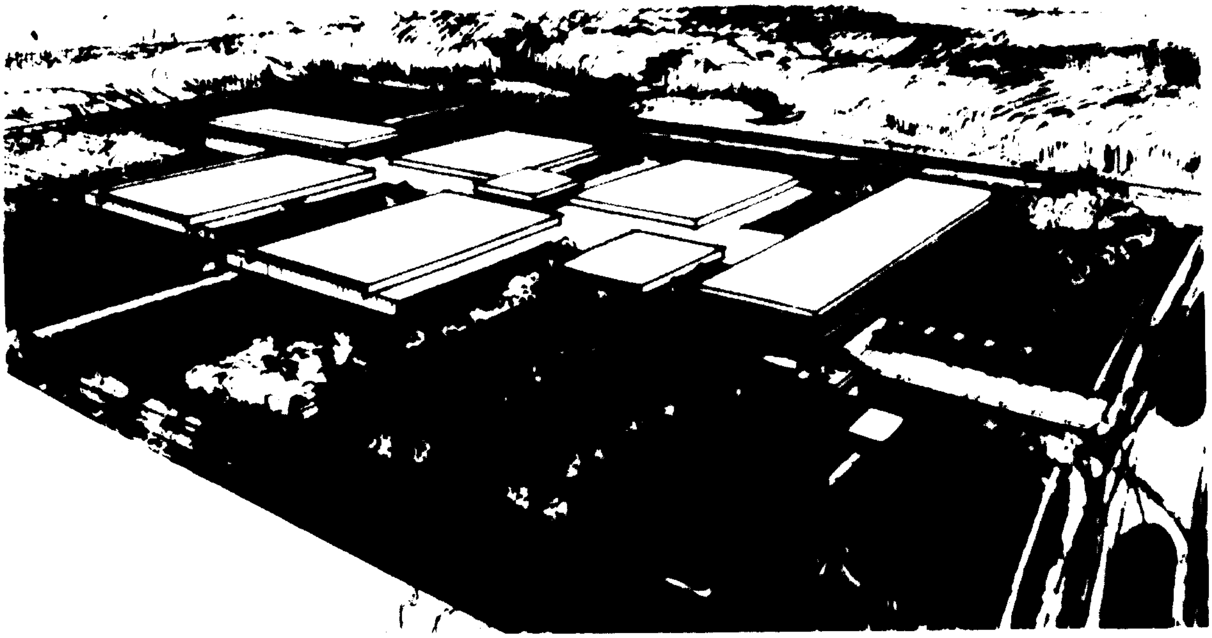

Figure I. Artist's impression of B.C. Research building. The entire project cannot be shown from any one point at ground level. Over-all visual therefore not essential. Future additions will change the building perimeters but all building elements are arranged so that additions do not destroy the original design. The interplay of building elements adds variety and interest

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IN CONSTRUCTION AND DESIGN

Research Council Building

by J. E. Breeze

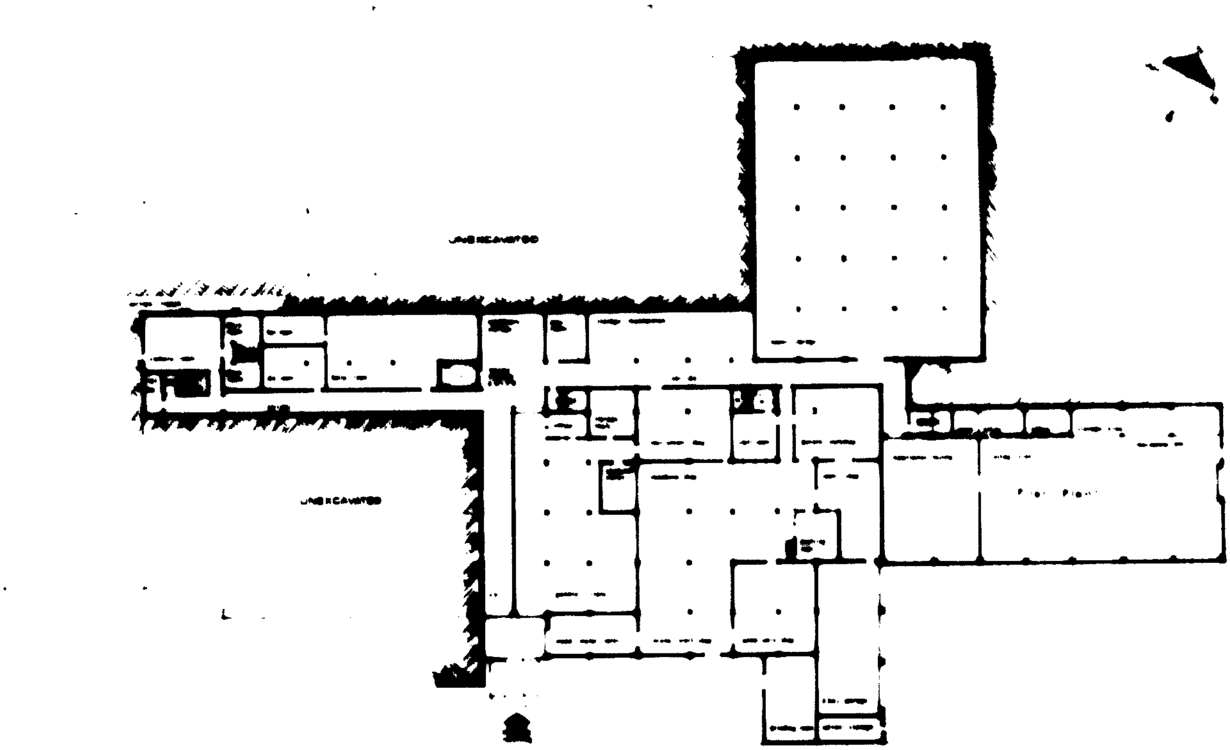

Figure II. Modular design. The natural slope of the grade made location of the lower floor workshops and stores economical and central. The areas are fireproof and soundproof. Floors, ceilings and walls are reinforced concrete

savings through the use of common components. In the structure itself, many components may have standard dimensions that can be repeated many times throughout the building. The fact that they are repeated identically time after time leads to cost economy, no matter whether they are constructed on-site or factory built. In poured-concrete construction, for example, the modular approach can lead to the repetitive use of high-quality forms at considerable cost saving. In the interior of the building, repeated modular dimensions lead to common sizes and spacings for partitions, millwork and furnishings.

One of the most convincing arguments for the adoption of the modular approach in laboratory construction, however, is the flexibility it allows for future adaptation and modification. Interior partitions can be added without upsetting the basic module and materials removed can be reused later.

Types of structures

Many types of structure have been found to be satisfactory for research centres. The simplest is a rectangular building having one or more storeys. Such a structure can be extended by the addition of wings at either end or at the centre. The B.C. Research structure features a central spine used to connect wings that might otherwise be separate rectangular buildings (fig. III). The most significant criterion in establishing the type of structure is probably the need for expansion. The simple rectangular building can be expanded by adding storeys or wings. If independent expansion of various sections of the laboratory is envisaged, a structure along the lines of B.C. Research is more suitable. Generally speaking, maximum flexibility for change and expansion is obtained through the use of a one- or two-storey building.

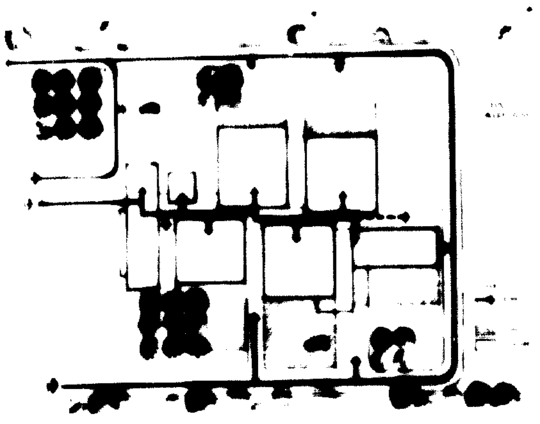

Figure III Spine and wing layout of B.C. Research building

The building enclosure

The most important building requirement is that the walls, roof and windows taken together as an enclosure not only serve as an effective barrier against the elements but provide an indoor environment that can be adjusted and maintained within desirable limits.

Just as programme and project planning must at all times be flexible and responsive to changing circumstances, the laboratory space must be adaptable. In its simplest form, a laboratory may be a single large room in which space is laid out and arranged as required. Structural walls and columns should be so located as to impose the minimum of limitations to changes in space use (fig. IV).

Walls

As a barrier between the internal and external environments while at the same time satisfying requirements of appearance, durability and acceptable maintenance limits, the wall should be composed of four principal elements: a structural air barrier, a membrane to control water vapour flow, an insulation layer to control heat flow and an exterior cladding to shed the rain (fig. V). Such a wall employing the well known 'rain screen' principle can be assembled from many combinations of materials and so long as the basic principle is adhered to will perform satisfactorily. The greater the difference between inside and outside environment, or the greater the control required over the inside environment, the greater the care that is needed in designing and constructing the exterior wall system (figs. VI and VII).

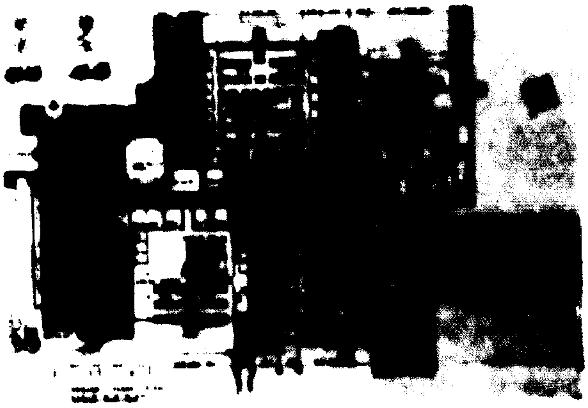

Figure IV Four large open laboratories at B.C. Research

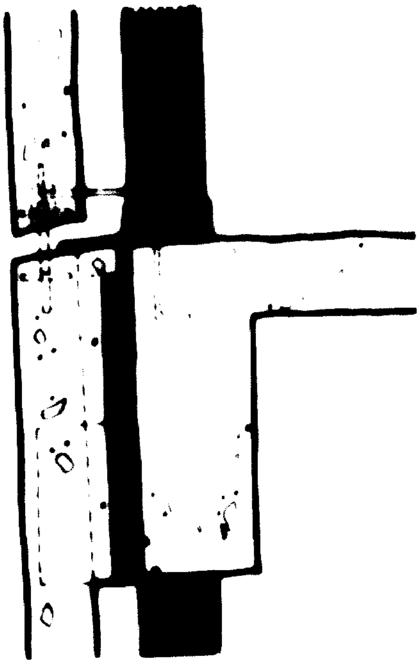

Figure V Rainscreen wall

Internal partitions have different requirements. The chief requirement in most laboratory buildings is that they be adaptable for future space changes. They should therefore be designed with a minimum of services built within the wall cavity. In laboratory areas, surface mounting of all electrical, water and other services is to be recommended. A wide variety of internal partition systems and materials ranging from walls assembled from conventional materials such as wood and plaster or masonry blocks (fig. VIII) to pre-manufactured panels that can be joined together and later separated for rearrangement, is available today. For the B.C. Research building, four-inch-thick concrete or pumice block was selected to meet the combined criteria of cost and flexibility. Such walls can readily be assembled and dismantled.

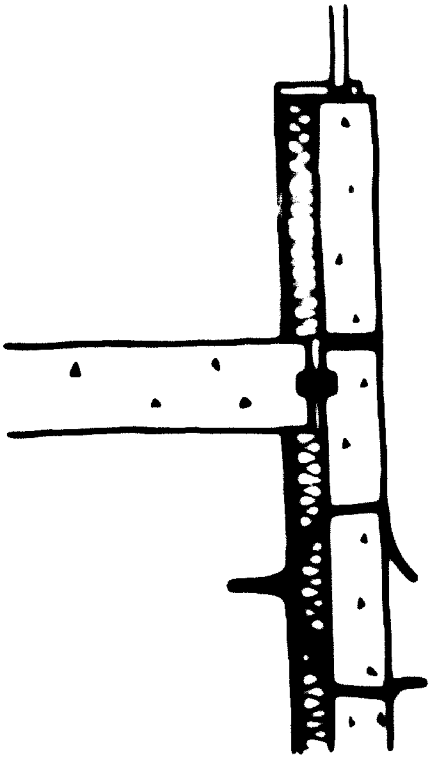

Figure VI   Wall assembly with insulation layer on interior face

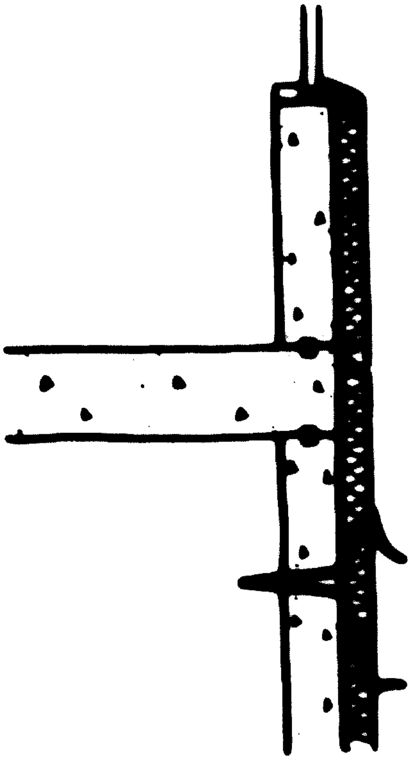

Figure VII.   Wall assembly with insulation layer on exterior face

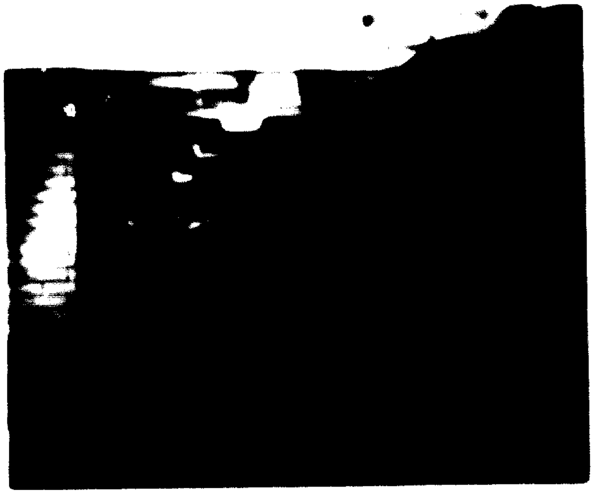

Figure VIII   Interior partitions B.C. Research building

Flexibility within a laboratory can be achieved to a much greater extent if all internal walls are non-load-bearing. Such a requirement, of course, has a significant effect on the structure of the building itself. By solving this problem at the outset, the B.C. Research building was able to use lighter materials, simplified heating and ventilation, and control the future allocation of its space in almost any way other than moving the roof and ceiling supports.

Roofs

The roof of a building shares with the exterior walls the function of separating the interior and exterior environments. Because of its normally horizontal position, the water-shedding requirements of a roof system are much more severe than are those for exterior walls. The requirements for air and water vapour flow control and for thermal flow are similar, however. A variety of roof systems have been found to be satisfactory in various climates but all can be rendered inadequate through faulty construction or incomplete understanding of the principles involved.

Most laboratory buildings have conventional "built-up" flat roofs. A variation on this system, the double-membrane roof, has been found to be very successful in cold climates such as that of Canada (fig. IX).

Apart from the design, probably the most important factor in achieving a successful, low-maintenance-cost roof is the care and supervision provided during the construction of the membrane and the installation and caulking of the flashings. A roof should not need constant maintenance.

Figure IX Roof assembly, B.C. Research building

Windows and doors

Windows and doors giving on to the outside of the building can be the cause of a wide variety of maintenance problems if they are made of wood. The temperature and water vapour gradient across the window membrane accentuate the dimensional instability of wood products and the problems of maintaining the finishes in the presence of changing water vapour gradients. More and more metal-clad doors and window frames are favoured for improved finish maintenance and dimensional stability. As glazing on the interior of the building can be done very simply, wooden doors are normally used. As a rule there is no difference between the environments on either side of an interior partition and consequently problems with respect to the maintenance of surface finishes and dimensional stability do not develop. Doors for special purpose rooms such as environmentally controlled low temperature and refrigeration rooms must be given special consideration.

Interior and exterior finishes

The term "finishes" covers not only the materials used for exposed surfaces such as plaster, brick, plastic tiles and wood but the final surface treatment of these materials including paint and stain. In the selection of finishes for a building, therefore, a host of technical requirements must be considered. Again materials and finishes must be selected having regard to the lowest maintenance factors commensurate with acceptable appearance and cost.

Maintaining surface finishes can be one of the most time consuming and costly elements of over all maintenance. Exterior finishes must be selected for their durability and resistance to the effects of water, water vapour, sunlight and changing temperatures. Materials such as fired brick, concrete and corrosion resistant metals have excellent durability while unprotected wood and synthetic materials such as plastic have little (figs. X and XI).

Materials for interior finishes must be selected with regard to the service conditions in each particular area. The quality of finish in a public or office area may be higher than that in a laboratory or workshop area. Three levels of finish quality were employed in the construction of B.C. Research. The highest level with concealed services and suspended ceilings, painted gypsum board walls and plywood panelling, was specified for the library and administrative office wing. The laboratories were the next level down with pumice block wall construction for all partitions, exposed services, and all exposed masonry and poured-concrete

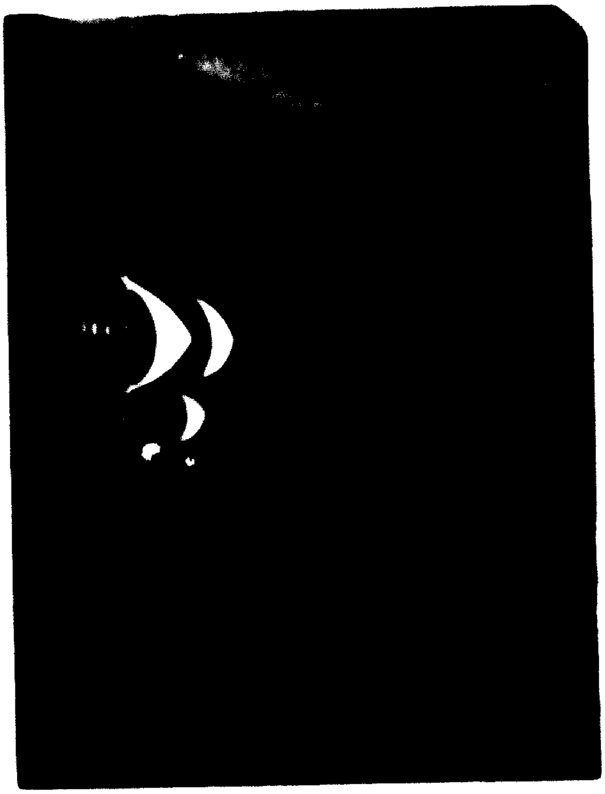

Figure X Exterior finishes at entrance to B.C. Research

Figure XI Exterior finishes near entrance to B.C. Research surfaces of walls, columns, beams and ceilings painted. Vinyl asbestos floor tiling was used throughout most of the administrative and laboratory areas (fig. XII). The

Figure XII Interior finish, library

stores, workshop and pilot areas were given the lowest level of finish. Concrete blocks were used as wall partitions and the floor was of concrete. All walls and ceilings were painted, but the floor was left unpainted. For improved dust control, however, the floors in all corridors and working areas in the stores and shop sections of the building are gradually being painted with an epoxy floor paint (fig. XIII).

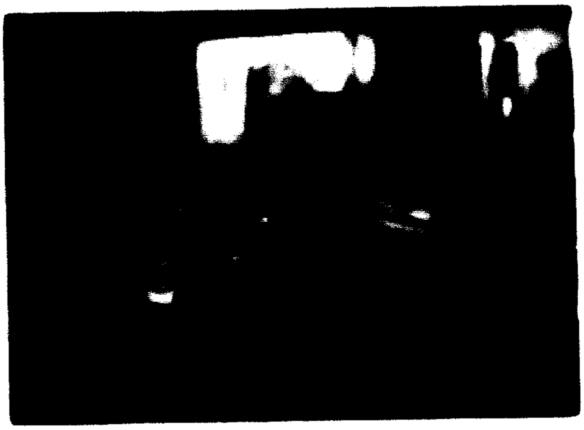

Figure XIII Interior finish, shipping and shop areas

Materials for interior finishes should be selected not only for serviceability and appearance; environmental factors such as acoustical control and light reflection must be considered. Thus, at B.C. Research, tile and carpeting are used on floors while ceilings and walls are painted in bright colours for good light reflection. Such surfacing materials as acoustical plaster and tile provide sound absorption where required (fig. XIV).

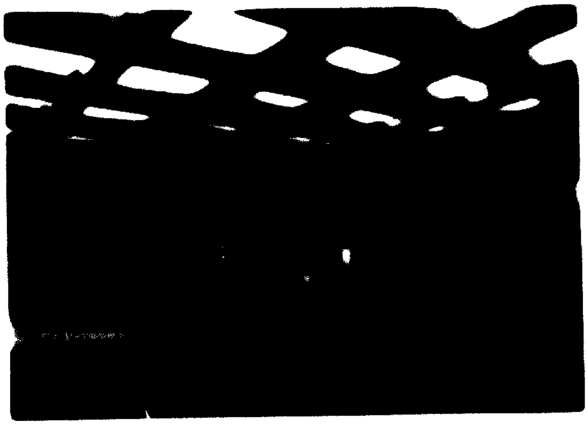

Figure XIV Interior finish, foyer

Selection of finishing materials, whether interior or exterior, should not be left until construction of the building is well under way. Rather, their technical properties must be considered as components of the wall, ceiling and floor systems at the earliest stages of design. In this way, finishes that are most compatible with the building system chosen, that will provide adequate environmental control and that will require a minimum amount of maintenance and upkeep, can be obtained at the outset and at lowest cost.

Staircases and elevators

Staircases are placed both for convenience of access and as means of exit required by fire codes. For buildings of only two or three storeys, stairs are normally used by staff to move from floor to floor. Stairways should be well lit and have non-skid treads of high durability. Where a laboratory occupies more than one floor, there is always a need for transport equipment, such as a simple freight elevator, between floors.

Safety considerations

Laboratory activities associated with industrial research and development are sometimes hazardous and this should be taken into account at the construction stage. Fire is the most obvious hazard, but most building codes provide for the protection of both personnel and structure. Some areas require the installation of sprinkler systems; for others, hose standpipes or cabinets, or portable fire extinguishers, suffice. In laboratories that use flammable chemicals, it is standard practice to have portable fire extinguishers located at regular intervals throughout the premises. Areas with high fire potential, such as the boiler room and transformer vault, should be separated from the rest of the building by a fire wall.

Generally speaking, to provide protection against all possible hazards in the design of a laboratory building would be excessively expensive and unwarranted. When the B.C. Research building was being designed, it was decided that it would not be practical to try to anticipate all hazards but to strive for a building that would respond favourably in the event of any of the more likely ones such as fire, explosion and poisonous gas leaks. Further, rather than allow the idea to become accepted that the building provided absolute protection against such hazards, project supervisors were given to realize that it was they who were principally responsible for assessing the degree of hazard of a particular activity and judging what steps were appropriate for the protection of both personnel and property. For this reason, explosion blow-out walls, for example, were not included as part of the design of the building. It was anticipated that activities requiring such protection would not be carried out within the building without special provision having been made. In addition, a working area outside the pilot area of the laboratory was provided where the more hazardous experiments could be set up and conducted.

The storage of large quantities of flammable chemicals is always a problem. This should be provided for by means of external solvent stores and by regulations within the laboratory allowing only limited quantities of any one solvent to be removed from the stores for use in any particular working area.

Decoration

Internal and external decoration of a building, including landscaping, can have a great influence on its working environment. This is particularly important in laboratories where favourable surroundings assist in promoting the creative output of research and development groups (fig. XV). Externally, the appearance of the building can be enhanced by the proper choice of materials, textures and colours, together with landscaping so designed that the eye is led to the building entrance and such service features as parking areas and shipping and receiving docks are concealed. Located as it was on the campus of the University of British Columbia, B.C. Research probably had a better than average opportunity to develop a favourable appearance through the use of these devices. The landscaping shown in the illustrations has now been installed for approximately four years and its effectiveness in framing the building and in concealing parking areas is already apparent (figs. XVI, XVII and XVIII).

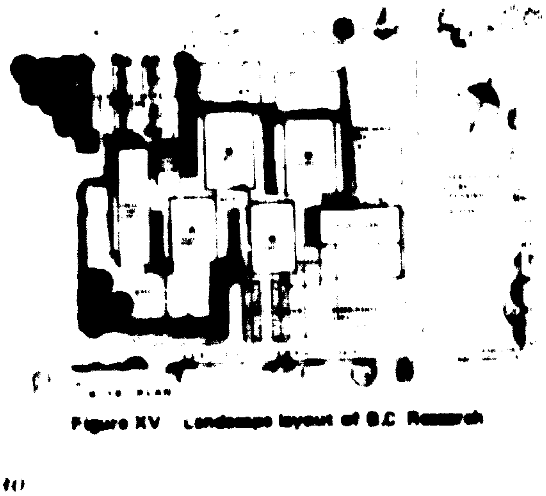

Figure XV Landscape layout of B.C. Research

Figure XVI Landscaped entrance

Figure XVII Suppressed parking area

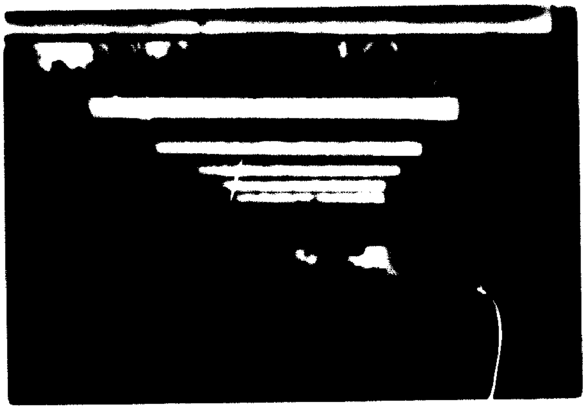

Figure XVIII Landscaping between walls of buildings

Interior decoration is also an important factor in developing a good working environment Working areas should be bright and cheerful Halls staff rooms and public areas need not be so bright however thus providing a change of mood about the building The choice of interior decoration should be made with regard to appearance factors such as colour and texture housekeeping factors such as cleanability and dust control and environmental factors such as light reflectivity and acoustical properties Where natural materials such as fired masonry or bricks are employed both the colour and the texture are permanent features For simple interior partitions these materials are usually very economical since once erected the wall faces require no further finishing

At B C Research all non fired masonry and concrete surfaces were painted primarily for dust control but also to provide colour and to improve light reflectivity In the laboratory areas the basic colour chosen for all walls and ceilings was an off white with a similarly coloured floor tile to assist in generally brightening up the areas This over all white colour was broken up by a coloured highlight strip and small patch areas of the same colour in each laboratory and all millwork and benches were given a pale green base and black moulded epoxy top A different colour for the highlight strips and patch areas was used in each laboratory wing to give variation throughout the building The floors throughout most of the building are covered with a vinyl asbestos tile of an off white colour also for good light reflectivity To give a quieter and more subdued atmosphere carpeting has been used on the floors of the staff room the boardroom the public foyer and in the typing area

With regard to lighting design a light level of about 50 footcandles was decided upon for the laboratory working areas and warm white fluorescent tubes were employed that provided a soft light and natural colour Light levels in the corridors and non working areas were much lower and the brick walls in these areas served to provide a soft warm appearance in contrast to the brighter working areas This change of mood in the decoration throughout the building was also considered to be an important and desirable feature in avoiding monotony

Case history 2:
The National Metrology Centre of Brazil

by **Fabio Becker** *and* **Luiz Eduardo Indio da Costa**

METROLOGY is one of the essential tools needed by any country striving to reach its full development potential. Such a country is Brazil, which continues to enjoy some of the highest development rates in the world and which had annual gross national product (GNP) growth of 9.3, 9.0, 9.5, [illegible] per cent respectively for the years 1968-1973.

[illegible] the demand for scientific and [illegible] phase of Brazilian development [illegible] the administrative [illegible] some agencies [illegible] metrological capacity [illegible] normalization [illegible] compliance with legal [illegible] undergoing scientific research [illegible] technological influence. The [illegible] sector and [illegible] take [illegible] appropriate [illegible] technology [illegible]

Metrology comprises [illegible] activities [illegible] weights and measures but [illegible] the market [illegible] the quality of products. Metrology [illegible] interwoven with normalization, quality control and certification, forming a continuum. It was in this context that the National Institute of Weights and Measures (INPM) of the Ministry of Industry and Commerce, appraising the rate of Brazilian development which had assumed a dynamism characteristic of developed countries, decided to expand and modernize its facilities and laboratories and to make provision for the acquisition of qualified staff to meet its new responsibilities in the area of normalization and quality of industrial products.

Serviços de Planejamento S.A. was awarded the contract, in accordance with Brazilian legislation governing public bidding procedures, to make the necessary studies and preparations for the creation of a new national metrology centre. A tract of land measuring some 1.8 million square metres and located 55 kilometres from Rio de Janeiro was made available for the purpose.

In only one year the studies and the design of the project were completed and a draft law creating a public agency (*Autarquia*) prepared. This law, which provided for financial autonomy and administrative flexibility for the centre, was subsequently approved by Congress.

The establishment of a metrology centre is a challenge for the Government of any developing country. The challenge stems not only from the fact that the centre will operate on a national scale but from the scope of the undertaking, which requires central and regional laboratories well equipped in terms of technical and scientific facilities and staffed with highly qualified personnel whose education and training represent a high level of investment. Return on capital is a long-term proposition, and operational and maintenance costs are high, with no compensating surplus in income to permit amortization of investments within conventional time spans. A good share of the return on capital invested is indirect and difficult to identify. Another important fact to be considered is that in countries undergoing rapid technological change, industrial activities increase daily and, as a consequence, the rhythm of growth required of the laboratories to keep pace with the rapid sequence of innovations necessitates a constant rate of expansion incompatible with the profit orientation of undertakings of this nature in the private sector. Finally, and this feature is well worth emphasizing, a metrology centre as conceived in Brazil goes far beyond the traditional role of legal metrology: it concentrates on research and development and on the co-ordination of normalization and industrial quality. These activities are carried out not only in connexion with products for the domestic market but for products intended for the highly competitive international markets.

Planning

The planning of a national metrology centre presents a challenge to developing countries not only because of the multiplicity of aspects to be considered, some of which are entirely new, but because of the necessity for the absorption and evaluation of all technical-scientific progress. The same types of difficulties arise when architectural plans and layouts are being prepared for the variety of options and approaches

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that present themselves as a consequence of the diversity of laboratory services and functions especially when an effort is being made to achieve for the whole complex unity of style and aesthetic homogeneity without prejudice to the operational individuality of the parts

The best planning will inevitably be outdated before it is realized constant change and adaptation is necessary to keep pace with the new conditions resulting from scientific technical economic social and political progress Planning should be based on present needs while anticipating probable changes in the near future and be characterized by a flexibility that will permit it to meet the constantly evolving requirements of staff For these reasons it would be as illogical to create a metrology centre patterned along the lines of those in the most completely developed countries as it would be to consider the most rudimentary centre as satisfactory

The fundamental factors involved in the development of the country itself must be taken into account in the planning process in order that solutions compatible with the state of the national economy and culture may be found

It is commonly assumed that by simply observing the functioning of metrology centres in the most advanced countries sufficient data can be gathered to prepare a project adaptable to the conditions of another country This however has not been the experience with the Brazilian project

No uniform criteria exist for the planning and design of metrology centres In many instances the most modern centres possess features that are advanced in some respects and conventional or even outdated in others These institutions were largely established according to the level of industrial development reached and the availability of highly skilled personnel in certain sectors In countries where laboratories are not up to standard the absence of entrenched traditions actually facilitates the immediate implementation of the most advanced solutions for expansion and modernization

Methodology

In planning the national metrology centre for Brazil it was found advisable to group all aspects to be studied into three distinct sectors each under the control of a senior officer The senior officers worked under the supervision of a general co-ordinator who was responsible for carrying out the project The sectors were termed

A Legal, institutional and financial economic
B Scientific and technological
C Engineering and architectural

This structure permitted the taking of parallel action and, consequently, reduced to a minimum the dependency of each sector on the inputs of the others Inputs were channelled through the general coordinator In meetings arranged with the contractor to discuss sectoral matters the general coordinator was accompanied whenever necessary by members of the team of the relevant sector

The global integration of the studies was achieved through successive approximations and additions until the final phase of synthesis and proposals was reached

To shorten processing time and to facilitate examination by the contractor partial reports of the sectors were presented to him as soon as they were completed

The methodology for the execution of the project was distinguished initially by the studies made by each sector When those of sector B reached the conclusive stage the elements needed for preliminary engineering and architectural plans were furnished by sector C The preliminary urbanization plans and the first architectural outlines were analysed and criticized jointly by the three sectors thereby ensuring that the projects were executed in accordance with the norms and budgets of each sector

Sector A

The essential objective of sector A was to maximize the functional capacity of the metrology centre so that it could meet the technical demands deriving from the development of the country That objective required in the first instance an analysis of all relative legislation including its constitutional basis and the legal and regulatory consequences stemming therefrom Simultaneously the conduct of research on national requirements for metrological services made it possible to sketch out the potential demand which considered in conjunction with the studies of sector B indicated the future delineation of the laboratory units provided that in addition to the type of demand the data permitted an evaluation of its volume

In the event it is found appropriate to restructure and modernize the metrological organ or to create a new one it is the responsibility of sector A to propose the directives needed to establish a national metrological policy The inclusion of questions relative to normalization, certification and quality control in the study was of the greatest importance

Sector A concluded its work by carrying out studies on the establishment of special centres for data processing, human resources development and metrological information dissemination and by formulating a financial-economic programme for the centre.

The studies contributed supporting data which influenced Government approval of the creation of a new federal agency, the National Institute of Metrology, Normalization and Industrial Quality (INMETRO), and the creation of the National Council of Metrology Normalization and Industrial Quality (CONMETRO) within the Ministry of Industry and Commerce

Sector B

Metrology centres in most countries are formed by the addition of successive segments. In Brazil, however, the integral planning of a national centre in its entirety in a very short period was essential.

One of the main objectives of the project was to select and provide specifications for the laboratories and determine them as short-, medium- or long-term according to the rhythm of national scientific, technological and industrial development. (A modern and efficient metrological centre will stimulate by its very existence a greater demand for services essential to the scientific-technical development of the country.)

It was assumed implicitly that the several options or viable solutions available could not be reduced to a single basic choice. This, however, contradicted the initial idea. The example of metrological laboratories abroad was clear and informative in this respect. Even though the maximum degree of perfection could not be attributed to any of them and although they possessed different structures, they all functioned well. The experience of other countries was therefore to some degree of undeniable value in the selection and choice of the types of laboratories most suitable for Brazil.

The selection of the units was based, on the one hand, on the clear and precise definition of a series of guiding scientific criteria, and on the other hand, on the evaluation of the short-, medium- and long-term apparent and potential demand for metrological services.

As there was no obligation to follow any rigid scheme in the development of the project, and as it had been decided to start from the premise of a global planning process that would meet the requirements of Brazilian regional diversification, it was possible to adopt general and flexible criteria for the organization of the laboratories in sectors grouped homogeneously according to the technique to be utilized or to the predominant type of scientific knowledge required.

Another very important criterion was the relationship of one laboratory to another, that is, of deciding which laboratories had common interests or needs, such as equipment. This was done in an effort to reduce initial capital investment and to determine which laboratories should be separate from the others, for technical reasons.

Sector B was also responsible for establishing the objectives, functions and services, physical areas, environmental control, personnel estimates and all other prerequisites for the operation of each laboratory, including methods of measurement and the techniques and specialized equipment needed.

Sector C

The engineering group of sector C was responsible for the choice of physical location, the demarcation of areas, the surveying of geological and climatic conditions and the availability of water supplies, drainage and sewerage systems.

In the study of urbanization, preliminary identification of groups of activities which by their characteristics presented specific location and space requirements was made, special consideration being given to the access, support and laboratories sectors.

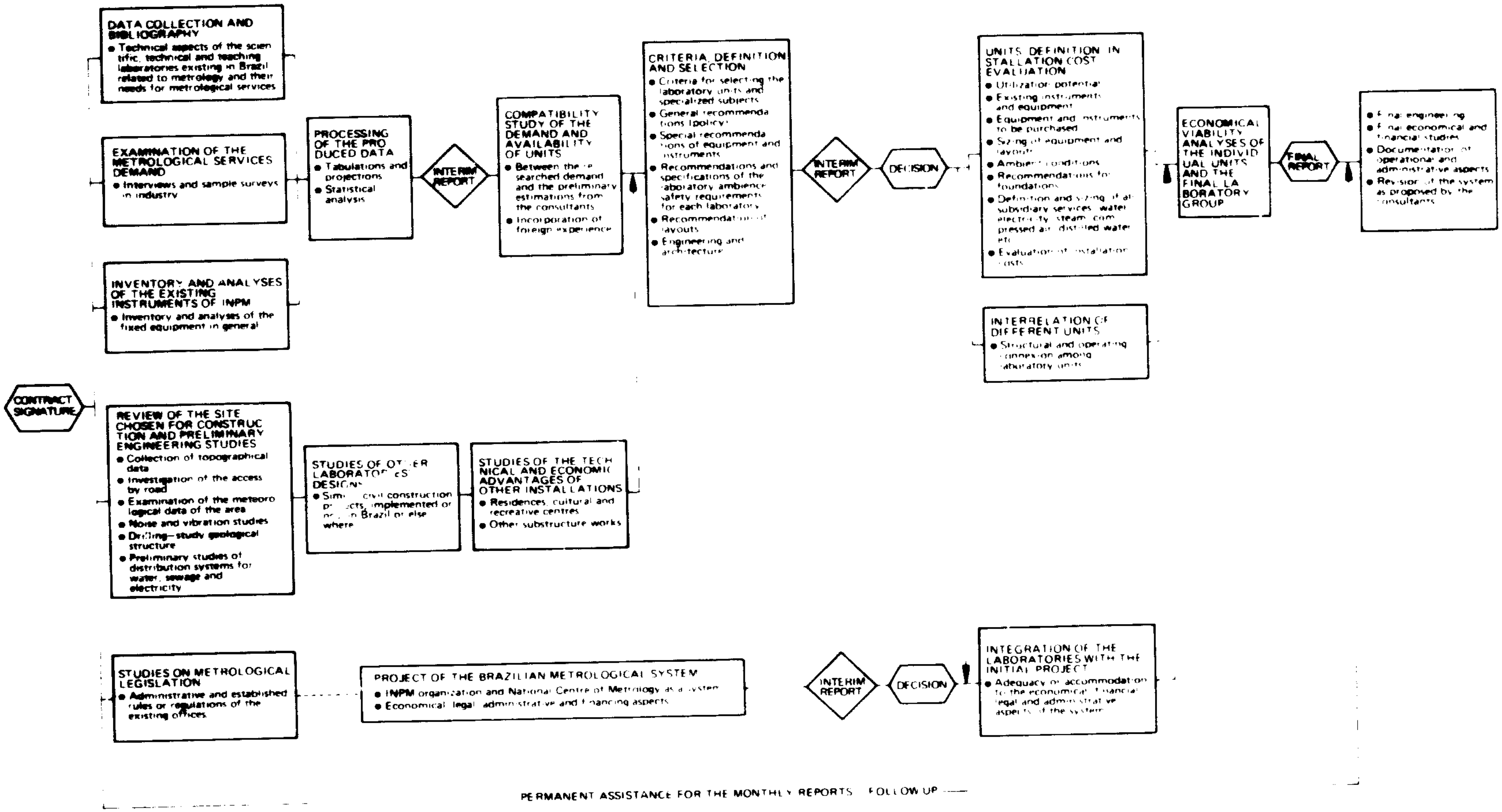
An effort was made through landscape planning to give the site the atmosphere and quality of a campus, thereby improving the well-being and consequently the work output of the personnel of the centre.

The application of the module concept in the architectural design of the centre provided the laboratories with the best operational conditions and resulted in a reduction in final capital investments. Two standard modules were adopted, one for the electricity and temperature laboratories and the other for mechanics and optics.

The work schedule of sector C was as follows:

Surveying the area where the centre was to be established
Collecting data for engineering studies (topography, soils, water, drainage, sewerage system, electric energy, noise and vibration)
Ensuring complementarity with existing surroundings
Visiting and making technical observations of national and foreign laboratories, either in operation or under construction
Making first analysis of studies and conclusions of sectors A and B
Preparing the basic urbanization and construction programme
Preparing the first draft of the urbanization project
Preparing initial outlines of the architectural projects for the laboratory units
Preparing a revised draft of the urbanization project
Reviewing sector B partial reports
Consulting with national experts in areas of specialized engineering (climatization, communications, fire prevention, lighting)
Preparing architectural designs for buildings to house support activities and laboratory units
Preparing urbanization and landscaping plans
Estimating costs
Preparing specifications and technical norms for project execution
Undertaking engineering, architectural and urbanization projects
Preparing budgets.

The accompanying illustration shows the flow chart on which the over-all planning of the national metrology centre was summarized.



Implementation of the national Centre of Metrology: flow diagram

Use of foreign know-how

The INPN decided to select consultants through public bidding, permitting foreign firms to participate in consortium with national firms. The purpose of this approach was to bring foreign experience to bear on the problem, in recognition of the difficulty of carrying out the project with only the limited resources of the INPM itself and of the inexperience of domestic firms. Serviços de Planejamento S.A., after a preliminary study of the terms of reference, established an initial working hypothesis on which the structure of the whole project was based. The principal point concerned the most suitable form of arranging for specialized know how from abroad. The hypothesis of establishing a consortium with foreign firms presented one serious disadvantage conditions in Brazil did not lend themselves to the methods and solutions customarily used by those firms in their home countries. Furthermore, Brazil possessed advanced engineering and architectural know how which it desired to use as the basis of the project.

The problem was solved by inviting the participation of individual foreign scientists and technicians specialized in metrological activities. These foreign specialists worked in conjunction with Brazilian counterparts. In this way, the drawbacks (from both the technological and economic points of view) of a simple incorporation of foreign experience were avoided.

The combination of international experience, the undeniable competence of the foreign consultants, the active participation of Brazilian technicians and the supporting data provided by the study of national and foreign laboratories guaranteed the objectivity of the over-all approach to the project.

Human resources

Among the factors that are fundamental to the implementation of a national metrological centre in a developing country are the education, recruitment and training of personnel.

In 1972, because of the small number of experts available at the time, INPM launched a project designed to create an efficient reserve of human resources. The main reason for the shortage of personnel was the low salary levels in effect in the public services. The project consisted of a course in metrology of 12 months' duration followed by an equal period of practical training in a metrological laboratory abroad. The INPM was offered scholarships for this purpose by UNIDO, the Federal Republic of Germany and France.

Specialized training was offered to the following levels:

High-level (master and doctorate degrees)
University-level (with special courses in metrology for students of engineering, physics and chemistry)
Middle-level (training in legal and applied metrology)
Assistant level (training in metrology and calibration, principally for the plants)

Recruitment and selection for the high-level and university level courses were carried out among recent university graduates. High-school students and others were recruited for the middle-level and assistant-level courses. Candidates from companies interested in training and upgrading their technical personnel were also considered.

A university body, the Co-ordination of Engineering Post-Graduate Programmes of the Federal University of Rio de Janeiro, agreed to issue a legally recognized academic certificate for scholarship holders completing specialized courses.

Training of administrative and clerical personnel is currently under way. This policy of educating and training personnel in the diverse levels and fields of metrology is closely related to the current national drive for scientific and technological development.

In order to promote scientific interchange, it is planned to invite the collaboration of foreign specialists, to establish contacts with international metrological institutions, and to send Brazilian specialists to foreign countries to work as trainees or to collaborate in programmes equivalent to those carried out in Brazil.

Market study of applied metrology services

The most dynamic element in the diagnosis of metrology problems in Brazil is the volume of demand for metrological services on the part of industries using high-level technology. In the past, indifference or even opposition on the part of businessmen to innovations involving costs and controls could be considered as resistance to industrial modernization. It was thought advisable, therefore, to identify the attitude of the most representative group of entrepreneurs (firms under State control, private firms with predominant foreign capital and national private firms), vis-à-vis the new phase into which the system of weights and measurements had entered.

It was considered that, to a certain extent, the steadfastness of the implementation of fundamental metrology (to which capital investments being applied at the centre were linked) should be related to, and complemented by, the flow of concrete demand for high-level calibration, and not only to elementary calibration practices of a fiscal nature.

Accordingly, a field survey designed to determine the preliminary reactions of hundreds of entrepreneurs and technologists to the idea of a systematic provision of services in the sector was conceived and carried out.

These marketing studies also had the following purposes:

(a) To define the sectoral structures of the industrial and related demand,

(b) To delineate the qualitative extent of services to be offered, through specification of the diverse kinds of services and the various types of equipment susceptible to calibration,

(c) To collect technical and economic data on client firms with a view to correlating these data with metrological demand;

(d) To estimate, to the extent possible, demand in each industrial sector for services that might justify the selection and dimensioning of the technical scientific laboratories composing the national metrology centre.

Simultaneously with the marketing survey, which involved approximately 600 industrial firms, informal contacts were made with scores of scientists, professors and public officials involved in technological work. All of them expressed opinions and presented suggestions on the implementation of a technological development policy in the areas of metrology, industrial quality and normalization. The results of this work have confirmed the validity of the initial course of action.

Because of the embryonic nature of the official initiative, and in spite of the lack of contact between sources of supply and demand, it was possible to detect the main types of services required, the frequency of calibration (resulting in a great number of cases from the technology itself) and the deep interest of the potential clients in the formalization of the new market. In addition, many cases were discovered of plants maintaining costly facilities for instrument calibration or, still more serious, being forced to pay for calibration services in the countries where the equipment was produced.

The main result of the survey, however, was the technical registration of the elements that generated demand, i.e. the instruments themselves, which were subject to periodic calibration norms.

This registration will be continuously updated, through direct and systematic contacts with each of the industrial firms selected.

Costs and projections

In whole numbers and as a provisional for cast, the Brazilian project may be summarized as follows:

	Thousands of square metres	*Millions of US dollars*	*Personnel*
Total area	1,000		
Area to be urbanized	700		
Area of construction	42		
Laboratory areas	15		
Programmed investment			
Construction work		16	
Equipment and instruments		10	
Other items		1	
Personnel working in the first phase			1,000
Technicians and scientists			150
Other categories			850

Activities are divided into the following sectors: Fundamental metrology (or scientific); Legal metrology; Applied metrology (or industrial); Normalization.

Fundamental metrology. Approval of programmes and estimates of funds required are the responsibility of the Government. Costs are financed from the public budget and the Government is the client.

Legal metrology. Clients are businesses that are obliged to submit their equipment or products to calibration and control, paying the price for these services. This sector is expected to earn an appreciable profit.

Applied metrology. The demand, whether voluntary or spontaneous, for this type of metrological service is encouraged by incentive policies for the promotion of technological development. A significant part of the services is carried out by other authorized laboratories.

Normalisation. Although of small significance as an element of cost normalization plays an important role as it meets the demand of hundreds of areas in the industrial economy lacking the necessary normative support.

The sectors correspond to different types of activity and to special procedures used for listing and meeting demand (if demand can be considered as the simple definition of a need or institutional requirement). Through analogy, it is not difficult to specify those directly responsible for, or those directly benefiting from, decisions that imply options regarding the use of the human and material resources of the technical office.

Business structure

A measure considered to be essential was the adoption of an economic business model for the new entity. The basis for the decision was the need to assure direct and indirect "returns" on the resources invested in the sector, along with the effective evaluation of the legal and administrative structure adopted.

Within the operational scheme of the institution, it is necessary to register and control the costs of each activity or project in each sector, and to determine periodically the business income and expense budget, which show the internal transfers of balances to cover deficits. A source of funds, in the form of public resources or surpluses from other activities, will always be available to cover a given item of cost, thereby escaping the concept according to which no task should be performed without the initial payment of the costs involved.

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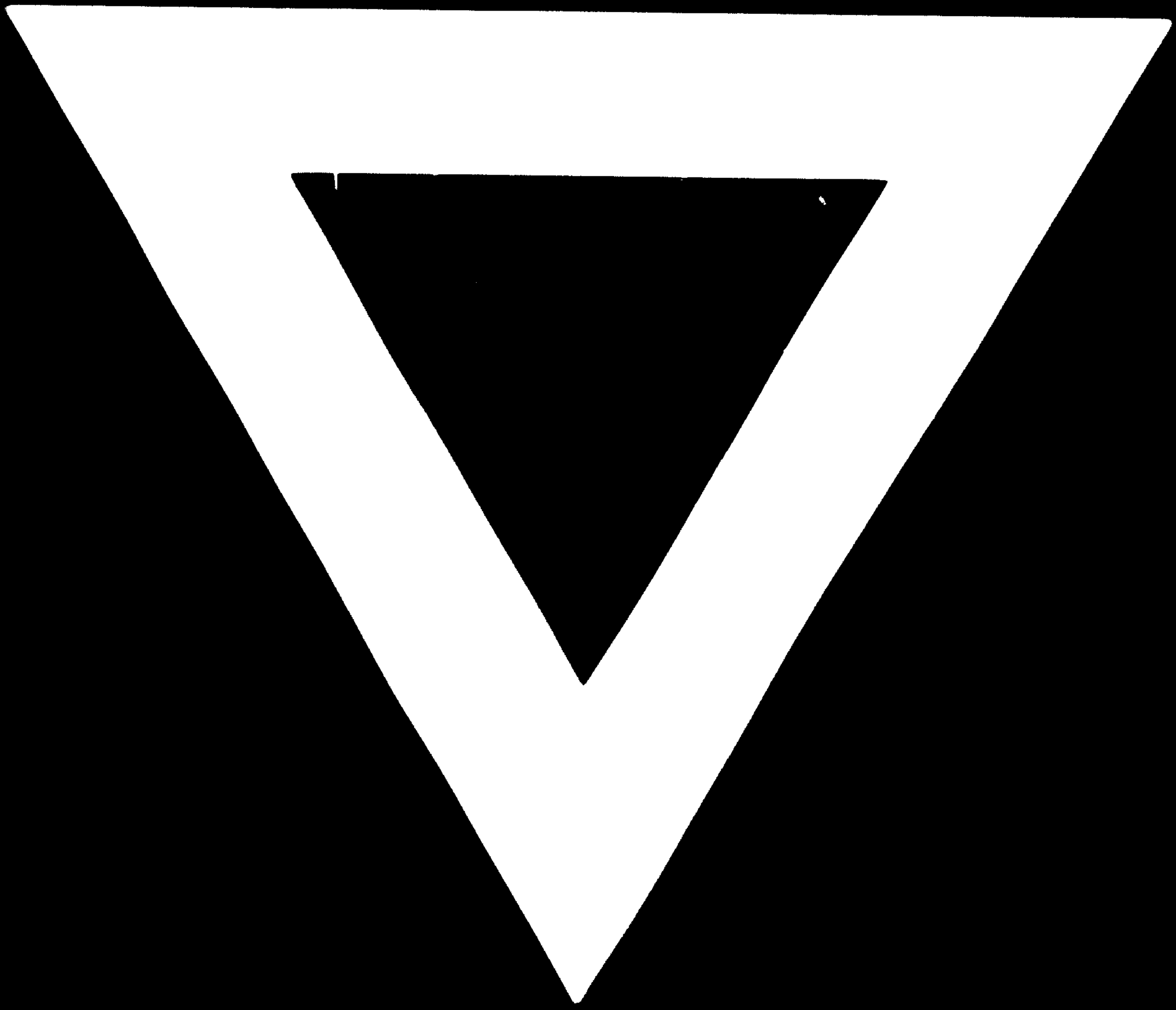
The Editor
Industrial Research and Development News

United Nations Industrial Development Organization
P.O. Box 707
A-1011 Vienna
Austria

Printed in Austria
75-1274 October 1975 3,800

Price $U.S. 3.00
(or equivalent in other currencies)

United Nations publication
ID/SER.B/21



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