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Planning of metrology and testing laboratories

Planification de laboratoires de métrologie et d'essais

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PLANNING of METROLOGY and TESTING LABORATORIES

This brochure was written at the request of the OIML Development Council with the aim of guiding national organisations which intend to establish new laboratories for metrology.

As many such organisations, to a more or less extent, may deal with testing of products and materials it also briefly treats problems affecting the planning of premises for such activities and their links with the metrology laboratories.

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1. BACKGROUND for the PLANNING

The first step to be taken is to make an inventory of the needs for metrology and testing activities in the country taking into account the scope of the organisation, the requirements laid down by existing and possible future laws and regulations and already available facilities within the same or within other organisations with which cooperation arrangements may be established. The latter point becomes more and more important in view of the development of technology and the evolution of industrial and commercial practice and also due to the fact of continuously increasing expenses in running such laboratories.

It should in this connection be borne in mind that whatever may be the cost of even very advanced equipment installed in the laboratories, the cost of qualified staffing and operation will in the long run be dominant from the economic point of view.

We would like to particularly stress this fact in the light of the experience of laboratories in some countries which at their construction or expansion were provided with adequate funds but which afterwards were deprived of necessary funding to cover operational and development costs. Such laboratories may become inefficient after some years and no longer contribute to the development of the country.

If an adequate operational budget cannot be foreseen from regular government or other contributions and/or from incomes for the services rendered it is far better to limit the extent of activities by cooperation arrangements with other bodies in the country and to do the best possible from the operational point of view within a limited field of testing activities not covered by other bodies. Briefly, the activities and laboratories and the running budgets shall be so planned as to allow an efficient operation which can follow the evolution of technology in both equipment procurements and suitable staffing.

1.1. Metrology planning

Metrology is certainly a "must" not only from the point of view of legal requirements for trade, health and safety but also for practically all fields of industrial activities. Measurement standards (etalons) are thus a basic point of departure for testing activities in all countries.

The type of basic measurement standards chosen for a country shall depend more on practical factors than on theoretical considerations based exclusively on definitions of the SI - units of measurement. In other words, and with few exceptions, it is generally better to build the house starting with the foundation which in our case is represented by the direct needs of trade, health, industry and transport.

This way of planning equipment for metrology i.e. from the bottom end of the standards hierarchy scheme does however usually not mean that the costs for equipment and other facilities will be less, on the contrary : a single truck equipped for verifying weighbridges may for instance cost more than many high accuracy metrology standards!

The goal of the planning should be to render the expected services. A careful inventory of the needs in all the fields concerned is thus necessary not simply from the point of view of the kind of instruments and the accuracy required but also as concerns the yearly amount of verifications and their geographical distribution taking into account that a large number of instruments requiring regular verification cannot be brought to the central laboratory.

The number of instruments subjected to legal control has thus to be estimated for each category from available records, declarations by bodies involved in trade, transport$_4$ hospitals etc. etc.

As regards instruments not subject to legal control or declaration it is more difficult to make estimates. Some metrology services in fully industrialized countries may receive a surprisingly low number of such instruments for calibration due to the fact that the industries concerned make use of their own facilities (or sometimes even that they do not pay sufficient attention to metrology aspects). Some other industrialized countries produce large numbers of measuring instruments in which case they usually only have the factory reference standards calibrated by the central metrology organisation. (This is in particular the case where the manufacturer's own metrology laboratory has received some form of official recognition).

For a developing country it is strongly advised to base its planning of official metrology facilities on a scheme which includes metrological supervision to a slightly larger extent by verification of instruments which would not be subject to regular control in some developed countries.

The reason is that the official metrology organisation of a developing country must frequently provide services which are needed for other operations such as those related to quality control of imported and exported goods or of products manufactured for local consumption. The approximate extent of such operations must therefore be known at the planning stage. Another reason may be the necessity for purely voluntary calibration assistance to local industries in line with promotion by government. This latter part must be subject to a particular inventory comprising the type of calibration or verification needed, its location etc. Industries may on such enquiries occasionally give extensive lists, but it will be found that there are usually not many instruments$_>$other than mechanical gauges and some electrical or electronic instruments, which can really be calibrated without dismantling installations.

In some cases sensors may be of such construction that a calibration outside the measuring environment may not give results applicable to the desired measurement process.

If too high fees are charged for calibration this may also constitute an obstacle for good cooperation with the central metrology laboratory.

If a realistic inventory of the calibration needs of the local industry can be established and it appears from this list that some very particular metrology or testing instrumentation has to be specially procured for only a few potential Users or industries, it is advisable to establish some form of agreement with the parties concerned whereby the metrology service will calibrate or test equipment for those parties at specified intervals. The prospects of such voluntary calibration contracts constitute in fact a much better basis for planning of equipment, buildings, staff and transport facilities than the "Wait for it to come-in" method presently applied in many calibration laboratories [(*)].

In addition, the "calibration contract" method allows cost previsions to be made beforehand both for the customer and the metrology organisation concerned. In line with possible promotion action the government may choose to bear part of such costs.

In developed countries maintenance and calibration contracts for certain types of instruments are frequently conferred to the private sector. In the case of instruments subjected to legal requirements the maintenance companies then usually are supervised by the legal metrology service. However, experience at least in some countries seems to show that adjustments on instruments made by maintenance services have to be followed-up closely. In other Words the metrology supervision at least for some types of instruments (such as flowmeters) has to be planned to be rather strict if it cannot be 100 % or reasons of lack of staff or budget.

Returning to the basic national standards (or where applicable local reference standards) : It is on the basis of the needs fairly easy to select a range of suitable standards from those listed in various publications [(**)] and to draw up the requirements for buildings, budget and staff as regards such standards. It is far more difficult to plan the facilities required for an efficient operation of the whole metrology verification service taking into account the amount of work needed and the local conditions. Here again descriptions of the equipment may be found in literature but the amount required, its suitability to local conditions and difficulties in procurement [(***)] may have to be subject to careful preliminary consideration.

[(*)] Note : Some countries (for instance LCIE in France) have organized yearly calibration campaigns to bring in reference standards for calibration within certain periods of the year so as to enable better planning of work.

[(**)] See for instance the brochure established under the auspices of the OIML Development Council : "Verification equipment for national metrology services".

[(***)] The BIML unofficial brochure "Suppliers of Verification Equipment" may be of some assistance.

Summarizing this point we advise as a start a careful inventory of the local needs as regards the quantity and types of instruments to be verified or calibrated including their capacity .accuracy and location. This inventory can of course only be approximate for some types of instruments but it will have to be as complete as possible for instruments such as weighbridges (*) and heavy materials testing machines.

1.2. Planning for testing activities other than metrology

Official testing of materials and products is in many countries distributed among several organisations depending on activity or for administrative and sometimes historical reasons. It is not the intention here to discuss any particular appropriate organisational scheme for a developing country. However, we would like to stress that for the efficiency of the implementation of metrology in a country and for the quality of its production, it is necessary that the testing of materials and products maintains a very close link with the metrology service.

It is usually advisable that these two activities are kept separate from the point of view of premises and staff. There are of course border areas such as official mechanical testing of materials where related calibration tasks may form a part of the other testing activities. In such cases the prevailing factor for the best solution should be the efficient use of qualified staff.

In many developing countries the situation is different from that of industrialized countries with free trade and competition :

- lack of foreign currency or employment may induce governments to favour local production by high customs duties or import restrictions
- government may take special action for promotion of export industries.

In both cases it may be necessary to create some form of government control on products licensed for local production in view of maintaining the quality above reasonable minimum levels and avoid abuse of protection arrangements or facilities granted by the government. Even when no particular export promotion scheme is established by the government it may have to intervene directly or indirectly to avoid the export of low-quality products which due to low prices may find their way into the international market but which in the long run will destroy the country's name as producer and later diminish the export volume and reduce employment.

All protection and promotion systems will generally call for the establishment of minimum quality requirements (standards), agreed-upon test methods, factory inspection systems and in many cases laboratory testing of samples of production.

Such systems already exist in most industrialized countries as regards materials and equipment involving human safety (electrical, mechanical, radiation etc). In such fields it is generally possible to find international (and national) standards and detailed test methods including descriptions of equipment. Publications by the International Electrotechnical Commission (IEC) may typically form a basis for planning of laboratories for electrical testing of materials.

(*) See BIML brochure "Mobile Equipment for the Verification of Road Weighbridges".

In other fields which do not directly involve human safety it is frequently difficult to find a basis for establishing minimum requirements on products, though a few national "quality mark" standards may probably be useful but not always well adapted to local needs. The situation is however better as regards test methods, many of which may be found in the standards of the International Organization for Standardization (ISO) or in standards issued by other international or national bodies or associations.

Whereas metrology calibration equipment can be selected rather freely taking into account mainly needs for accuracy, convenience , stability, maintenance requirements, cost and available suppliers it will be found that equipment for product testing will have to correspond exactly to the accepted test method. Documents describing test methods do in fact frequently specify characteristics which are not met by all commercially available equipment and particular care in its selection will therefore have to be taken from the very beginning. The planning phase shall start by selecting the test methods and then the necessary equipment and not the reverse which may lead to unnecessary expenditures (and lack of space in the stores !).

The study of test method standards and manufacturer's catalogues will give an idea of the requirements for the laboratory premises as regards necessary space and conditioning.

1.3. Requirements for operations in the field

It will also be found that a certain amount of testing can (or even has to) be made in the manufacturer's premises whereby the official testing authority will have to be equipped with means for verifying the correctness of the manufacturer's test equipment using transportable standards (such as mechanical gauges, temperature, force pressure or electrical measuring instruments, etc). This will thus constitute a useful link between metrology and product testing and advocates a close cooperation between the two disciplines. The staff concerned with product testing will many times also have to be equipped with suitable reference materials or reference products, the characteristics of which can be monitored using the equipment of the central testing laboratory.

The supervision of practically all schemes of quality certification will also need unannounced visits to manufacturers accompanied in many cases by the taking of production samples. The testing laboratories as well as the metrology laboratories must therefore have at their disposal suitable means of transportation (cars and trucks).

We would here like to stress that the effectiveness of any metrology or testing activities in developing countries depends on the availability of adequate means of transportation exclusively used for this purpose and the provision of a (large) budget to cover the operational costs of such cars and trucks.

The laboratory buildings provided must thus also include suitable garages for these cars and trucks and a minimum of maintenance facilities for these vehicles.

2. GENERAL LAY-OUT of METROLOGY LABORATORIES

Though the requirements as regards conditioning (temperature stability, low vibration level, etc)are usually stringent for metrology laboratories, they are in other respects easier to plan than those for materials testing where more space and flexibility may be necessary taking into account unforeseeable changes in the kind and volume of activities.

We are in this chapter trying to specify the needs and propose lay-outs for small and medium sized measurement standards laboratories and for connected activities likely to be undertaken in a centralized laboratory.

2.1. Division of activities

The fields of measurement likely to be covered by official metrology laboratories may, without going into details, be divided into the following groups :

- mass
- volume (and flow) of liquids
- length and angle (dimensional metrology)
- force and hardness
- pressure
- temperature and humidity
- gas measurements (volume and mass)
- electrical measurements
- frequency (and time)
- photometry
- physico-chemical measurements (density, viscosity, sugar content, etc.)
- ionizing radiation
- acoustics.

The last two fields should preferably be located in separate independent buildings, the planning of which has to be done so as to incorporate all calibration and supervision needs required by health authorities and, for acoustics, of those dealing with building construction and testing of materials. The special requirements for such buildings are not covered in this brochure.

It is customary in planning to draw up a chart showing the distribution of the activities in various divisions. Such a chart may not be advisable to construct before knowing more precisely the amount of each of the metrology activities but also the amount of other testing activities to be covered by the organisation as well as the availability of suitable staff to direct the various divisions. Thus, as previously mentioned, the activities force, hardness and pressure can be dealt with by laboratories handling mechanical testing of materials but they may also be connected with the division dealing with mass measurements (as mass standards are used as the starting point in such calibrations)

If it is assumed that industrial calibration activities (voluntary or contract) will be important one may create a special division or department for engineering metrology grouping dimensional metrology, force, hardness and pressure measurements.

The division in charge of electrical measurements may naturally include photometry and frequency.

Thermometer calibrations nowadays involve a great amount of electrical measurements and may thus be grouped with the electrical laboratories unless it is expected that other activities such as gas measurements and calorimetry justify the creation of a special thermodynamics division.

In countries where the use of gas meters is limited to laboratory or a few industrial applications it is certainly not worth to set up a special laboratory for basic calibration of gas meters. Bottled gas is generally measured by weight and thus comes under the control of inspection services technically related to the mass department (with the exception of other physical properties). See Note in 2.2.3.

Unless physico-chemical measuring instruments are manufactured in the country and thus need primary calibration facilities it is advisable that reference instrumentation for such activities is maintained by the official physico-chemical materials testing laboratory in the field concerned. However, if such a laboratory does not exist, the thermometry laboratory may be equipped with suitable reference instrumentation(*).

The need for calibration activities within the field of high-frequency electrical measurements has to be carefully examined in cooperation with the authorities dealing with broadcasting, television and telecommunications. Unless there are important local industries in this field requiring metrology supervision, it is in fact advisable that high-frequency calibration equipment be installed with the respective administrations for best efficiency and adaptation to local needs. The calibration equipment is usually very costly and must in fact be adapted to the particular user equipment as regards connectors, frequency bands etc. These problems need anyway to be considered at an early stage as it may be difficult or inconvenient to install screened rooms in buildings which have not been specially planned for this purpose.

Some form of frequency standards will however have to be provided and can easily be installed in a suitably climatized room. The dissemination of standard frequency to users in the country can be done in various ways and does not affect the building. The dissemination of standard time creates more problems as regards the necessity for continuous operation requiring emergency power, etc but needs only little space and can be arranged without special precautions as regards the buildings.

(*)Calibration of viscometers, densimeters and related reference materials requires carefully thermostated baths and very accurate temperature measurements.

Summarizing this section we may say that the metrology activities can be distributed over minimum two main divisions, mechanics and electricity, which each happen to have their particular requirements as regards building construction.

If the testing of materials and industrial products is going to be associated, in some way or another, with metrology activities it may be feasible to divide the mechanical division into two parts : one dealing with mass and volume and one dealing with engineering metrology including length, force, hardness and pressure.
As the main impact of thermal and humidity measurements in this case will then lay within the field of physical chemistry it may also be suitable to create a separate division for thermodynamics including physico-chemical measurements.

The resulting proposed broad scheme of two or four main divisions is shown in Fig. 1.

This scheme is aimed to fit both a suitable distribution of the laboratories and the qualifications of senior staff.

2.2. Buildings for metrology

Following the proposed scheme in Fig. 1 one may consider various lay-outs depending on whether new buildings are to be constructed or old buildings are to be reconditioned. It will be found that the latter is usually feasible, as concerns electrical and thermal metrology and testing activities if enough floor space is available. However mechanical metrology and testing will require suitable space on the groundfloor and calibration installations for standards of length and mass should preferably be installed in dry premises below or partly below ground level.

Furthermore a machine hall will have to be available for large mass, force, pressure and other mechanical metrology equipment.
(If applicable a separated part of this machine hall may also be used for testing of metals and non-polluting materials) . A part of the machine hall will have to allow entry of trucks and cars specially equipped for field verifications. The calibration of heavy weights and unloading of heavy goods may require the installation of a hoist or traveling crane (or the use of fork lifts).

Furthermore vibrations or shocks locally produced or from the surroundings should not affect measurements in the length and mass standards rooms.

All these considerations and the fact that it often costs more to recondition old buildings than to build new ones should induce planning authorities to seriously consider the needs, interrelation of activities and possibly necessary future extensions before undertaking reconditioning of old buildings and this especially as concerns mechanical metrology and related activities.

Further on, we will suggest lay-outs for small and medium-sized metrology laboratories which can be modified according to needs, the available building ground and possibly already existing premises.

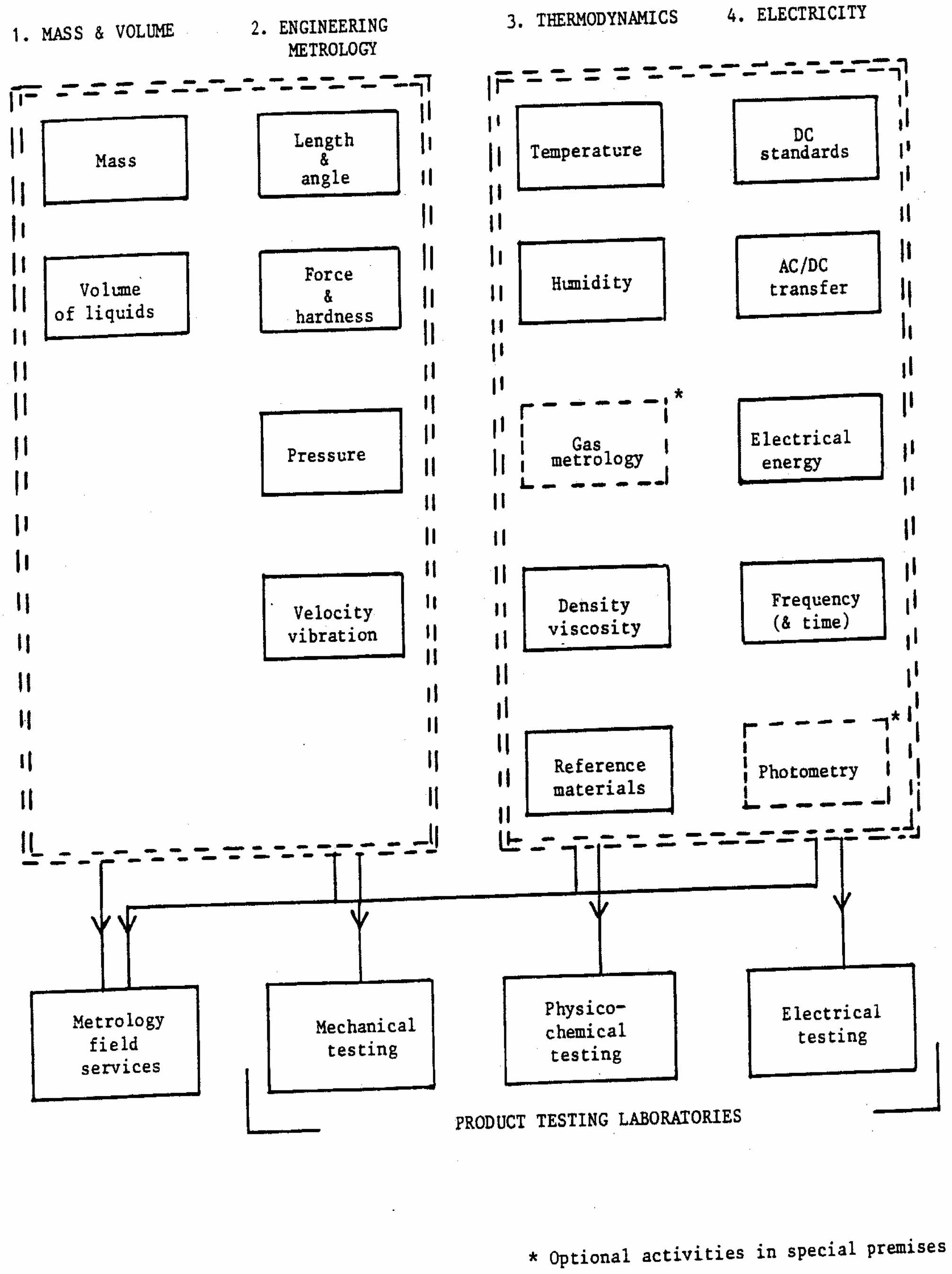

Fig. 1 - ORGANISATIONAL LAY-OUT FOR THE METROLOGY ACTIVITIES IN THE CENTRAL LABORATORY

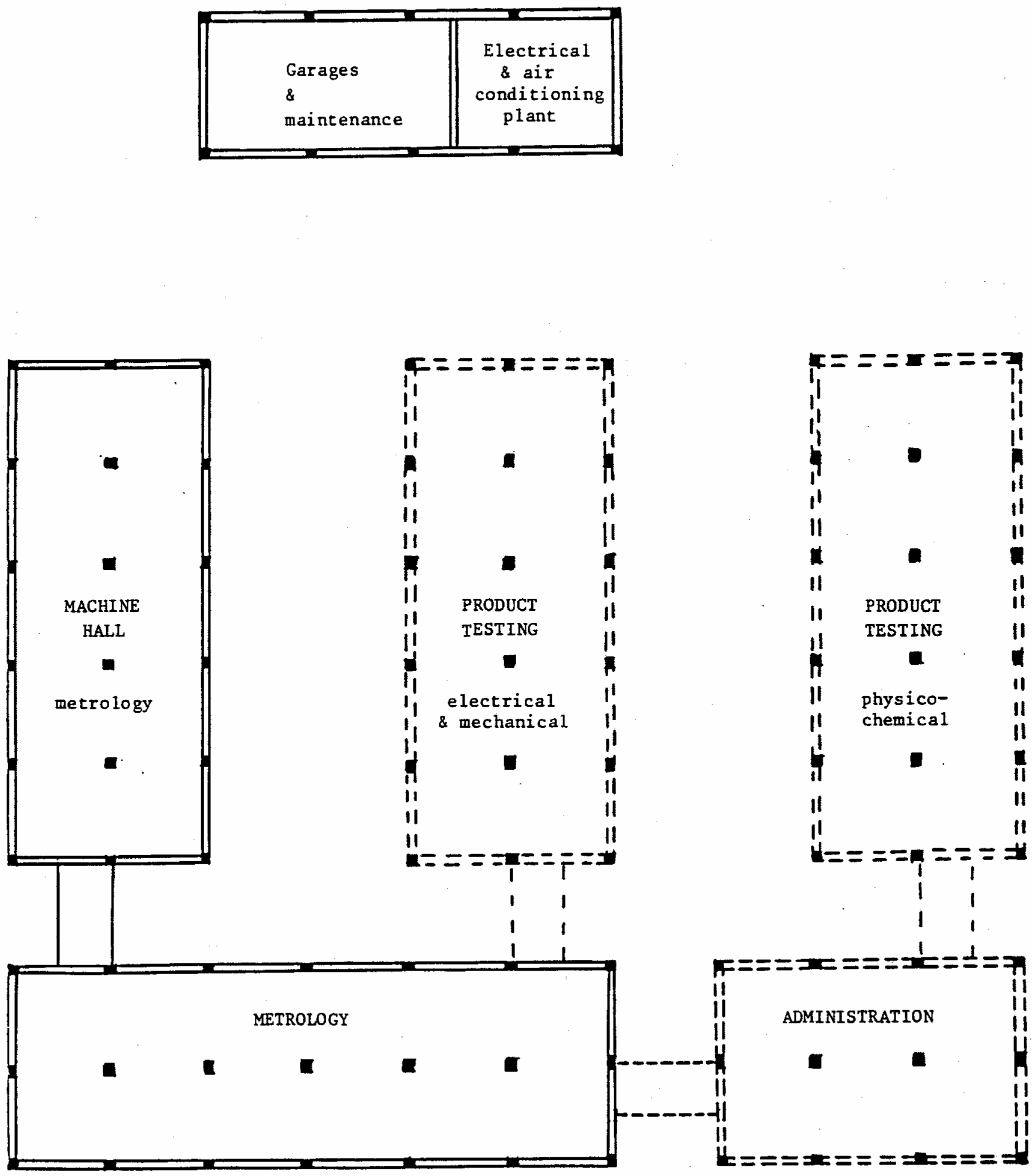

Fig. 2 - PRACTICAL LAY-OUT OF THE METROLOGY BUILDINGS WITH POSSIBLE EXTENSION FOR PRODUCT TESTING

2.2.1. Building site

The site for the buildings should be chosen far from intense traffic roads, heavy industry, high tension lines and powerful radio transmitters. Furthermore the grounds should preferably allow construction of a basement floor fully or at least partly below the ground level.

There are however countries where this may. be difficult because of high ground water level. In such cases it may be possible to create an artificial basement by creating large earth embankments around the building.

2.2.2. Construction, general requirements

Some metrology laboratory buildings have been constructed using very special designs to obtain thermal insulation enclosing quite large laboratory rooms.

We feel however that in view of costs it may be advisable to make use of current dimensional modules and materials but to pay special attention to arrangements of double walls, insulation and special air conditioning for some of the laboratory rooms by proper arrangements inside the limits imposed by the building modules adopted.

Fig. 2 is intended to illustrate an economical and practical form of lay-out of metrology and testing buildings. The size and form of the grounds will decide which lay-out is the best. Most of the laboratories shall be oriented away from direct sunlight (i.e. preferably to the north or north-west side in the northern hemisphere out and to the south or south-west in the southern hemisphere).

The figure also shows how premises for connected extension activities for materials and product testing may be added.

As regards materials the main metrology building usually consists of a reinforced concrete structure with walls preferably made of high quality bricks or, if these are not available, of hollow concrete building blocks. Reinforced concrete walls or wall elements should be avoided for various reasons (vibration, difficulties in fixing equipment on walls, low thermal insulation etc).

Internal wall separations can usually be made of bricks (which allow modifications when required). In several laboratories where very flat and clean wall surfaces are required the walls should receive a suitable finish : plaster and paint in dry atmosphere, and resistant anti-fungus paint in countries with high humidity or in wet laboratories.

The module of the concrete structure should be chosen at about 7 m so that the half-module is convenient for both offices and small laboratories. The length of the building or each wing of the buildings should be limited to 6 or 7 modules maximum, both from the structural point of view and for communication convenience. The resulting elevation of the main building is shown in Fig. 3.

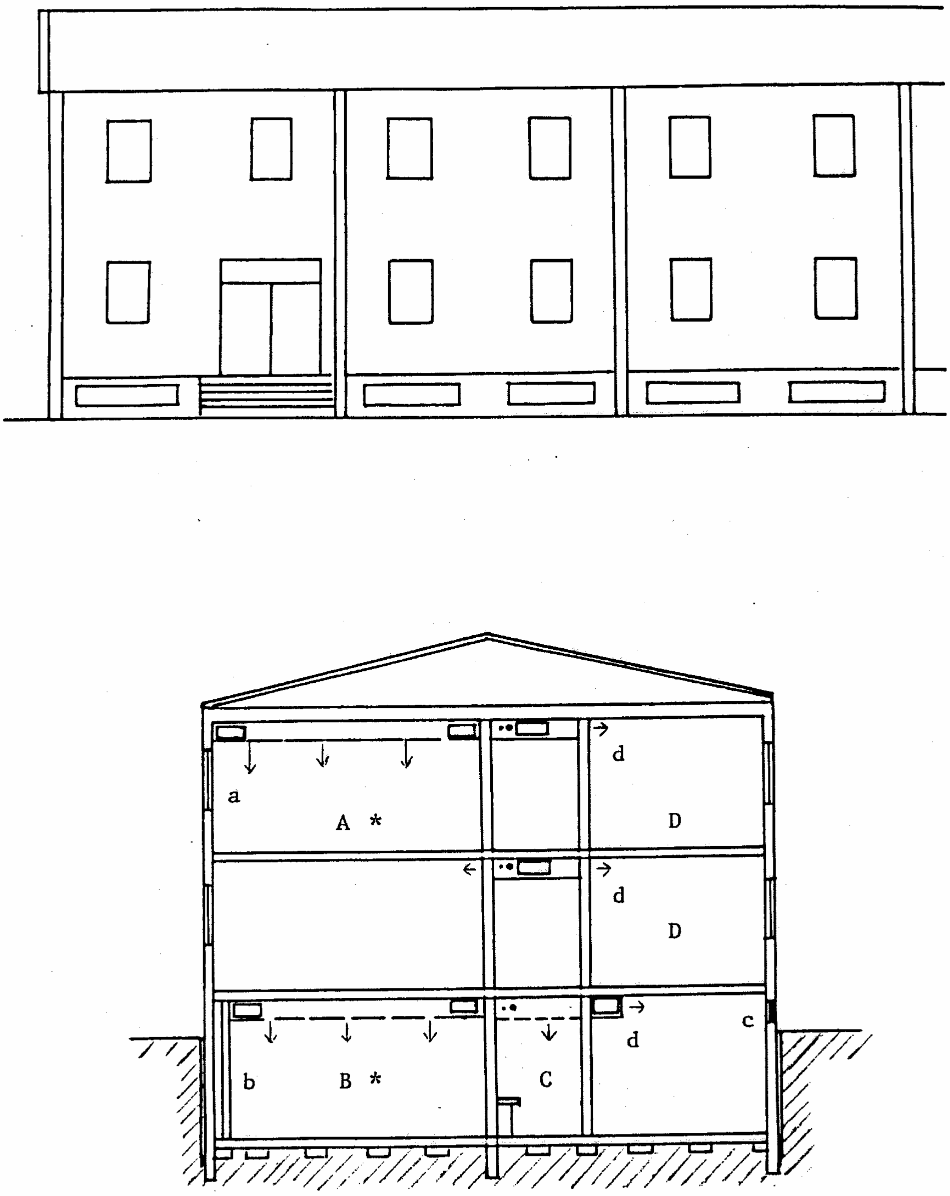

Fig. 3 - TYPICAL ELEVATION OF A LABORATORY BUILDING

A - Electrical metrology
B - Engineering metrology
C - Tape measurements
D - Office module

a - Dust tight double glazed window
b - Double wall for insulation
c - Glass bricks
d - Normal air conditioning

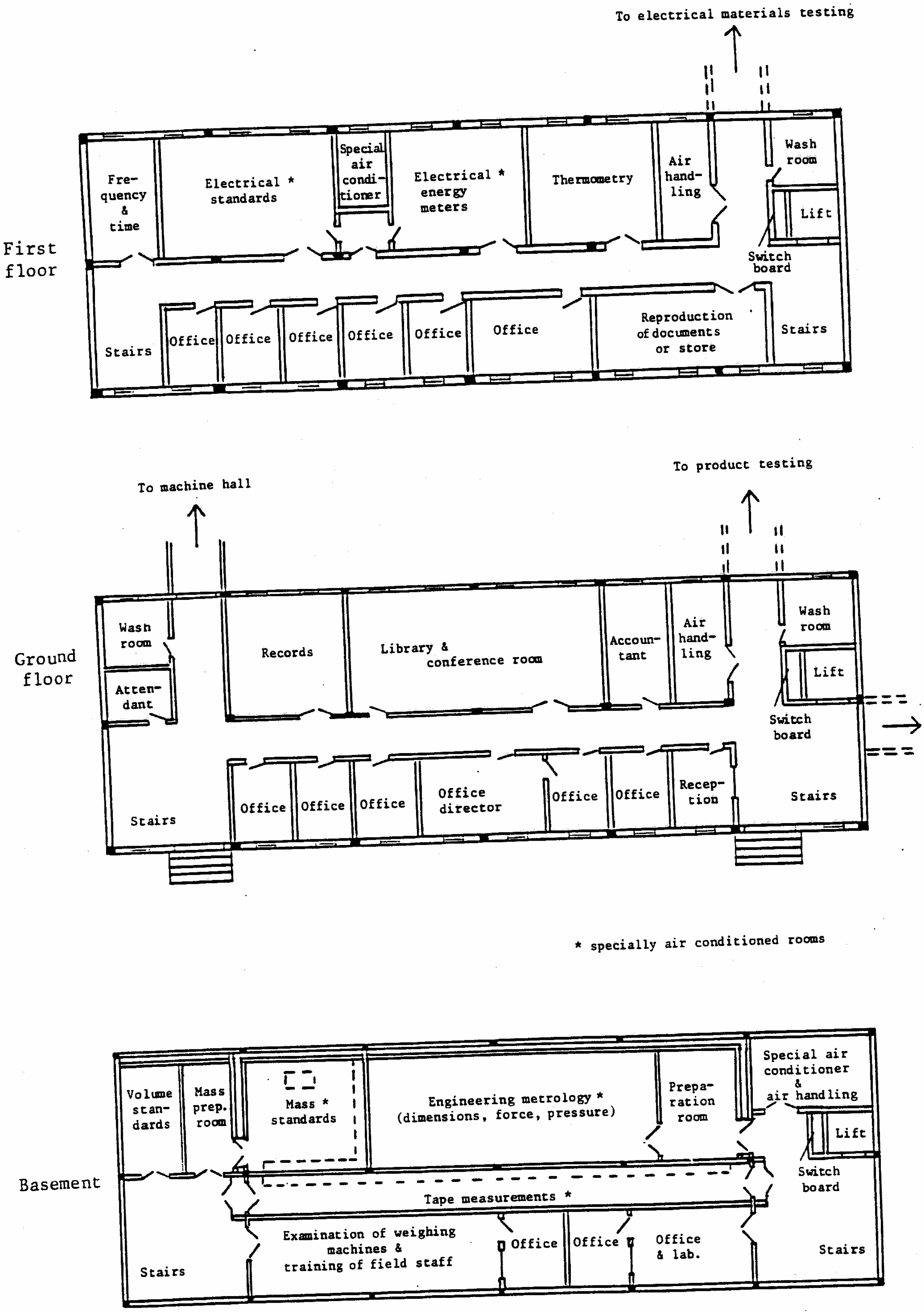

Fig. 4 - EXAMPLE OF LAY-OUT OF MAIN METROLOGY BUILDING

The windows should not be too large (2 windows per full-module with glass panels of about 100 cm wide). The free room height inside the rooms shall generally be at least 320 cm so as to allow false ceilings for air conditioning to be installed in some of the rooms and in all corridors.

The corridors should be sufficiently large (at least 2.3 m wide) so that carts with equipment can easily be moved around. Finally it is very important that stair-cases and doors are sufficiently large so that the measuring equipment and furniture can easily be installed and moved around when required (single doors 80 cm for offices, 100 cm for laboratories, 2 x 80 (or 100) cm for double doors in laboratories)

Floor covering is frequently a problem and subject to compromise. It should be load and wear resistant, hard, not subject to dust retention nor abrasion, not produce static electricity, not be slippy when wet, easy to clean, fire resistant and finally, at least in the laboratories and offices be attractive. Load resistant high quality stone agglomerate or ceramic tiles may do in corridors and passages and in the wet laboratories. However, for most other laboratories a hard plastic tiling must be found which is not subject to build-up of static electricity. So-called vinyl -asbestos tiles have been largely used in the past and were generally found satisfactory except that they were easily breakable if not placed on a fully flat support. However since anything containing asbestos nowadays is reputed to produce cancer—risk some countries may not allow their use. Taking into account the great variety of supplies in most parts of the world it is advised that this matter be carefully investigated with architects and contractors by considering all the above-mentioned requirements. In any case, the preparation of the floors must be perfect and load-resistant and the tiles or other covering must be sufficiently hard, to withstand without indentation or breakage, point loads produced by a mass of at least 100 kg on a surface of only one square centimeter .

For the floors in workshops and the machine hall plastic or ceramic tiles will not be resistant enough and such floors are usually provided either with a concrete finish incorporating colouring and plastic materials or simply painted with a wear-resistant plastic (epoxy) paint.

A lift for heavy and bulky equipment is necessary if products testing activities are to be undertaken in the same building. It may however not be necessary if only metrology activities are being considered (handling of heavy instruments may then take place in the machine hall).

When central air-conditioning for comfort is to be installed it is necessary to provide a special room on each floor for the heat exchanger and ventilation equipment (air handling).

In addition several test rooms will have to be equipped with independent air-conditioning units which can be controlled with high accuracy. A suitable space adjacent to each test room must thus also be provided for these units. See point 2.2.4. for details.

The central heating and air-conditioning plant should be placed outside the main metrology building in a special house.

Water and sewer pipes should only follow vertical distribution lines throughout the building whereas ducts for air-conditioning and electricity are distributed horizontally for each floor with suitable distribution and control panels near staircases.

The electrical requirements for each laboratory are discussed in point 2.2.5.

For reasons of efficiency and heat dissipation all lighting shall be provided by fluorescent tubes.

2.2.3. Estimates of necessary space

As a rule it is generally easier to estimate the space needed for primary standards activities than to foresee necessary premises for examination of instruments and equipment coming in from industry or public services. The considerations and estimates discussed on this point are taken from experience in a few small or medium- sized developing countries whereby we have generally limited the scope to metrology activities considering that the testing of materials and products will be made in other laboratories or in separate building units as suggested in Fig.2.

In view of the amount of administration frequently necessary it may be preferable to construct from the very beginning a separate administration building interconnecting with the various laboratory units.

However, if the activities of the organisation are intended to be kept strictly limited to metrology, the general administration may probably at least as a start be housed on one floor of the main metrology building as suggested in Fig.A .

The other facilities for metrology illustrated in Fig.4, have been selected on the assumption that, at least as a start, the testing for pattern approval of gas and hydrocarbon fluid meters is made to OIML requirements by official and impartial laboratories abroad which have the necessary equipment and competency.

Note : Regular verification and adjustment of gas, water and electricity meters is generally done by the company or the administration in charge of the distribution.

For domestic gas meters the gas distribution company may typically use as a standard a small bell prover of for example 4 m^3 capacity installed in a well climatized laboratory (temperature stability + 0.3 °C). This bell prover can be calibrated by displacement of water in cooperation with the national metrology service.

In a similar way the water supply company generally has a test bench for domestic water meters using master meters or simply selected meters which are calibrated to a fixed tank of 500 litres or more. The main task of the national metrology service will thus be to verify occasionally this installation, which if it allows sufficient variations of flowrates also can be used for occasional pattern approval testing.

Unless a great number of water meters are manufactured in the country it is thus not necessary to have such a laboratory located at the central metrology compound.

The problem with test installations required for pattern approval of gasoline metering equipment is mainly that comparable results can only be obtained if the meters are tested with the same liquids for which they are intended to be used, or at least with liquids having the same viscosity. Such installations must therefore, in addition to climatized pump installations, master meters and volume standards, include large reservoirs of inflammable liquids.

Based on the above considerations we may estimate the minimum floor space as follows.

Activity	Area	Location
1. Mass and volume		
Mass standards laboratory including verification of fine weights and balances class II	50 m^2	Basement special air conditioning
Examination of weighing machines class III and IIII up to 30 kg	70 m^2	Basement (or ground floor)
Examination of platform machines and various large weighing machines	50 m^2	Machine hall
Calibration of heavy test weight for weighbridges	25 m^2	Machine hall
Unloading area for test truck	50 m^2	Machine hall
Storage space for heavy weights	25 m^2	Machine hall
Workshop	25 m^2	Machine hall
Reference volume standards and calibration of glassware up to 10 L	25 m^2	Machine hall
Calibration and storage of volumetric test flasks used in the field (5 to 1000L)	35 m^2	Machine hall
Offices (minimum 4)	60 m^2	Machine hall
2. Engineering metrology		
Length and angle measuring machines, surface plate, hydraulic force comparator, hardness tests pressure calibrators	70 to 100 m^2	Basement special air conditioning
Preparation and cleaning room	30 m^2	Basement (or ground floor)
Tape measurement (2 × 28m)	56 m^2	Basement, special air conditioning
Office (minimum 2)	30 m^2	Basement (or ground floor)

activity	Area	Location
3. Thermodynamics (Thermometry)		
Calibration of thermometers and optical pyrometers	40 m^2	1 st Floor
Calibration of hydrometers	5 m^2	1 st Floor
Hygrometer testing	5 m^2	1 st Floor
Office (1)	15 m^2	1 st Floor
4. Electricity		
Electrical standards laboratory	70 m^2	1 st Floor special air cond.
Testing of electrical energy meters	50 m^2	1 st Floor special air cond
Frequency (and time)	30 m^2	1 st Floor
Offices (min.3)	45 m^2	1 st Floor

If photometry is to be included in the activities it should preferably be combined with life testing of lamps and will then require additional premises, discussed in more detail on point 3.11.

Additional space will have to be provided for instance in the machine hall for a large climatic test cabinet (4 x 4 m), for vibration testing (4 x 4 m) and for general workshop facilities, especially if mechanical materials testing is to be incorporated in the activities.

As regards offices it must be taken into account that space has to be foreseen for filing cabinets and cupboards for documentation and test records. (It is not appropriate to have such furniture in corridors and passages as frequently seen in many office buildings). The suggested minimum office space is therefore 15 m^2 . In addition, the various laboratories will have office desks for technicians and attendants.

2.2.4. Special air- conditioning requirements for metrology

As already mentioned, regardless of the climate and independently of the heating or coaling provided for comfort, metrology and testing of materials will in several cases require special climatizers to obtain reproducible and comparable test results. The requirements are generally different depending on the type and accuracy of instruments or the products to be tested.

Confining ourselves to metrology the principal aim is to obtain

- a stable temperature and

- a reasonably low air humidity.

There are however generally no stringent requirements as regards dust except that all in-takes of fresh air must be carefully filtered and that all windows must be dust-tight.

As regards the humidity the most troublesome effect in metrology is generally the risk for condensation leading to corrosion of mechanical instruments or lower insulation or even breakdown as regards electronic instrumentation.

The relative humidity (percentage)varies greatly with temperature, thus in a room with constant moisture content (mass of water) it may typically increase by 5 % for a decrease in temperature of only 1 °C. Therefore, to be on the safe side and avoid condensation the relative humidity should not be allowed to be higher than 70 % in the metrology rooms. Furthermore, the air conditioning of these rooms should work continuously and in any case not be subject to daily interruptions which will in most cases lead to condensation both on metrology equipment and in the air conditioning ducts.

As regards temperature the most important is to obtain good stability rather than an exact setting of the ambient temperature. In mechanical metrology the standard temperature is generally 20 °C, however many measuring machines use internal or external standards of steel, therefore if the measured items also are of steel the effect of the ambient temperature is small provided the machine and the measured items are at exactly the same temperature; hence the necessity for stability with time of the ambient temperature. In other cases the temperature can be measured and taken into account provided that the temperature variations are kept low. (In some cases it may also be necessary to keep temperature gradients low within an apparatus but this can generally be taken care of by special insulation and/or location of the apparatus).

The keeping of constant temperature can be achieved in various ways. First it is necessary to insulate properly the rooms concerned from walls which have a different temperature (external walls). This can generally be done by using an additional wall thus providing a hollow space. The use of urethane foam insulation, which is very effective from the point of view of low heat transfer shall be avoided for fire safety reasons.

In most of the laboratories it is also necessary to avoid direct sunlight.

Some metrology laboratories have been constructed using central air-conditioning with individual servo-mechanical damper control in each room. Such installations are very effective and may be justified when several adjacent laboratories have to be temperature controlled and kept at the same mean temperature.

However, when the volumes of the activities related to very high accuracy are limited it is better to provide independent laboratory air with high accuracy temperature control. Special attention has to be paid as regards the position of air inlets and outlets for best efficiency and plans with full details of the rooms have to be supplied to the contractor installing such equipment. The best results may be obtained if both floors and ceilings are constructed . to permit air-circulation between them.

Such an arrangement which requires an independent additional floor is frequently used for computer rooms and may be advantageous for high-accuracy dimensional metrology requiring low temperature gradients and using special anti-vibration supports for the installation of the various measuring machines.

However, as the power dissipation of most of the installed measuring equipment is small, the return air may in most cases be captured by ducts placed near the floor and it may then prove sufficient to arrange for air distribution through outlets in the double ceiling without use of double floors.

This allows greater flexibility for the installation of measuring equipment and is any case recommended for laboratories which are not located in the basement (or the ground floor).

It is particularly important that the air-conditioning units are provided with precision controls of temperature (and humidity) through sensors which can be suitably positioned in the laboratory room. Many individual air conditioners are in fact only provided with internal controls and mainly intended to keep the temperature within a few degrees while usually allowing for important heat dissipation and fresh air intake.

It is therefore necessary to provide for the contractors, in addition to descriptions, drawings and outside weather conditions, the following typical data :

Laboratory	Staff	Heat Dissipation	Temperature	Admissible temperature variation
Engineering metrology (length)	2	2 kW	20°C (or 23°C) (*)	± 0.5 °C
Tape measurements	1	1 kW	20°C (or 23°C) (*)	± 1 °C
Mass standards	2	1 kW	"	± 0.5 °C
Electrical standards	3	3 kW	23 °C	± 0,5 °C
Electrical energy meters	2	5 kW	23°C	± 1 °C

Relative humidity for all rooms not to exceed 70 % under most unfavourable weather conditions.

In practice the temperature variations will usually be double the above indicated target data. Experience seems to show however that the prescribed design data have to be lower so as to avoid the provision of too rough temperature control !! The indication of the number of staff in the rooms will allow the contractor to calculate the amount of fresh air intake.

As regards the <u>mass standards laboratory</u> the requirements are not stringent as regards the value of the ambient temperature itself which can usually have any value between 18 and 27 °C. However, it must be ensured that the temperature is kept stable within at least ± 0.5 °C for periods of several hours to provide enough stability during a series of weight comparisons. (High-accuracy electronic balances may in this respect require temperature stabilization for longer periods than classical mechanical balances). Furthermore air-draft and pressure variations must be avoided.

(*) In many countries 20 °C will be too low for human comfort and difficult to maintain without risk of high relative humidity. If 23 °C is chosen as a compromise, all reference standards used must be certified for this temperature.

As a result of these considerations and in view of the low internal energy dissipation in a mass standards laboratory, the best solution seems to be to provide it with external air circulation in-between double walls and use only a small (closable) air intake/outlet for human comfort.

From the design point of view it may thus be possible to make use of the same air conditioning unit for both the primary mass room and the engineering metrology laboratory with the temperature sensors installed in the latter. The same also holds for the two electrical laboratories in which case the sensors shall be installed in the electrical standards room.

Temperature (and humidity) recorders should be provided in all the specially climatized rooms. In addition, a barometric pressure recorder may be useful in the primary mass standards room.

In most of the other metrology laboratories (temperature, volume, examination of weighing machines, frequency etc.) it will generally be sufficient to maintain the temperature stable within a few degrees, which usually can be provided by the central air-conditioning taking into account that some instruments used (for instance in thermometry) will have their individual thermostating and that in most other cases it will be necessary to measure the temperature (of liquids or of instruments). However, if very great temperature variations between night and day are expected it may be better to maintain the central air-conditioning in operation without interruption.

It should be noted in this connection that some types of continuously running electronic equipment such as frequency standards are designed to operate at a maximum temperature of 30 °C which must not be exceeded at any time.

Such problems do of course not arise in countries where there is no need for central air-conditioning in which case the ambient temperature may be kept reasonably stable in the last mentioned laboratories simply by the thermal inertia of the building or by occasional use of suitably thermostated heating facilities.

2.2.5. Electrical supply requirements

It is important that the electrical supply lines to the various laboratories should be rated largely above the current normally taken by the equipment; in other words that the installed power for laboratory equipment is large compared to the mean power supplied by the central distribution transformer. This is of particular importance as regards certain testing activities where great flexibility is required since it allows modifications of the equipment without the need to provide special lines except inside the laboratory room concerned. For metrology it permits to diminish the effect of voltage drops on the internal lines which are sometimes troublesome if they are not constant.

Most of the laboratories should be supplied with three-phase plus neutral lines even when only monophase is needed. This allows several circuits to be installed for the sockets in each room and some circuits may be kept in reserve. The illumination of the rooms and corridors as well as all air-conditioning shall of course be made on separate circuits.

On every floor level there shall, near the staircase, be a separate distribution fuse board (control panel) with signal lamps showing which laboratory rooms are energized. However it may not be appropriate to provide a too easy on/off switch for the lines on this distribution panel. Such switching should normally require the opening of a panel door.

Several types of laboratory activities require in fact continuous operation, others may require that power is switched off for fire safety reasons at periods when the laboratory room is not attended.

The switching of the power to each laboratory should therefore take place individually for each room through a switch panel conveniently placed at the entrance to the room. It will thus be necessary to provide special low-power signal lines from each laboratory to the control panel near the staircase where a watchman can see which laboratories are energized and check whether this is motivated by an appropriate sign on the laboratory door.

Each laboratory must be provided with a separate safety earth line which must be so connected that it under no circumstances can serve as neutral to a monophase line. Furthermore it is necessary for the chemical and wet laboratories that automatic circuit breakers for earth leakage current are installed.

The correct grounding of the earth line should be tested by specialists at the acceptance inspection of the electrical installation of the buildings.

The switchboard placed in each laboratory room shall be provided, in addition to a main switch (push-button contactor or similar) with a certain number of, preferably automatic, monophase circuit breakers connected to the various lines in the room; for example, one for each of three walls and two or more spare circuits for special equipment. These circuit breakers can preferably be of modular design to allow combinations of 16,25 or 32 A. If the monophase supply is 220 (or 240 V) it seems reasonable to choose most automatic circuit breakers (or fuses) for 16 A and the internal wiring accordingly. Instruments and test equipment will anyway have to be protected by their own internal fuses. Special lines will have to be installed individually for equipment requiring more current or three-phase connection.

In general the monophase sockets should withstand 16 A and be of the safety-pin non-reversible type, so that the plug of the test equipment always must connect the neutral in the same way. For the same reason the position of the neutral of all sockets shall be verified at acceptance testing of the installation. Sockets in wet laboratories, machine halls and workshops shall be of the splash protected type.

If the main switch in the laboratory is an automatic breaker of the push-button type it should be ensured that it is wired so that it is automatically energized in case of short power failures.

The estimated necessary amperage is indicated in Chapter 3 for each laboratory, based on the assumption that the supply voltage is 220 V monophase and 380 V three-phase. If other systems are used the estimates must be converted accordingly.

3. DESCRIPTIONS of the METROLOGY LABORATORIES

In this chapter we are treating in more detail the requirements of each laboratory illustrated by typical lay-outs in Fig. 4.

3.1. Mass standards laboratory

Activities :
- Calibration of secondary standard weights to national reference standards
- Verification of precision weights (OXML class F_1, F_2 and M_1)
- Testing (for pattern approval) of analytical and jeweller's balances (OIML class II)

Equipment :
- Sets of primary and secondary weights (to be kept in lockers)
- One set of four analytical balances for primary comparisons of weights, 20 g to 2 kg
- One 20 kg equal-arm balance (or electronic mass comparator)
- Set of three electronic top-loading balances up to 30 kg connected to printer for rapid verification of weights

Installations :
- Room with no windows and thermally insulated to maintain the temperature within ± 0.5 °C for several hours, if necessary by stabilized air circulation between double walls Small, closable, fresh-air ventilation near entrance door
- Electrical switchboard 220 V with two 16 A monophase circuits connected to sockets placed above the benches as indicated below
- Two stone benches, one for the primary balances (20 g to 2 kg) and the other for occasional testing of precision balances and for rapid verification of weights using the electronic balances. Each bench should have a top of polished marble or similar covering material placed at a height of 75 cm. The width shall be 65 cm. The top can be supported by pillars made of brick, dimensions 24 x 55 cm which are covered by concrete finish and painted. The total length of the benches shall cover two sides of the room or be at least 5 m. Electrical monophase + earth sockets, dual type, should be located every 2 m at 90 cm from floor all along these benches.
- One support for the 20 kg balance according to construction requirements or generally consisting of a polished stone or marble plate 140 x 75 cm placed at a height of 75 cm and supported by two brick pillars 24x65 cm covered with concrete finish and painted
- Three steel lockers 50 x 100 cm, height 200 cm with reinforced shelving to support heavy weight boxes (shelf load 200 kg)
- Two tables on wheels for sets of weights
- Office desk (laboratory table type)

3.2. Laboratory for examination of weighing instruments

Activity : - Examination (for pattern approval) of weighing instruments class III and IIII up to a capacity of 30 kg

- Training of metrology inspectors (temporary activity).

Equipment : - Sets of test weights

- Loading and unloading machine for wear tests

Installations: - Room preferably with small windows (or glass bricks) having their lowest part at about 2 m above floor level.

- Adjacent office room with large fixed window 2 x 1.2m (at 1 m above floor) in the wall separation, overlooking the laboratory
- Electrical power on switchboard : 220/380 V 25 A three phase with six monophase circuits fused for 16 A each
- Monophase earthed 16 A dual sockets distributed along the long walls at 2 m intervals and about 1 m above floor level
- The furnishing consists mainly of a large number of tables (16 or more) which can be arranged along the walls or otherwise
- Three steel lockers, heavy duty type 100 x 50 cm, can be installed along the short wall at the entrance.

3.3. Laboratory for small volume standards

Activity : Calibration of secondary standard volume measures and glassware up to 10 L

Equipment : - Set of standard automatic standard burettes

- Top loading (mechanical or electronic) balances up to 30 kgfor occasional gravimetric calibration of volume standards and glassware

Installations : - Distilled or demineralized water supply

- Electrical switchboard 220 V 25 A with automatic switch for earth leakage current. Safety type splash protected monophase sockets 16 A located at 1 m above floor at 2 m intervals along external walls
- Two cupboards
- Six laboratory tables

3.4. Engineering (dimensional) metrology laboratory

Activities : All or some of the following :

- Calibration of end gauges (block gauges)
- Calibration of line standards (up to 1 or 3 m)
- Dimensional measurements and verification of streightness using surface plate
- Angle measurements
- Accurate inspection work including screw threads, surface finish etc
- Calibration of pressure gauges and barometers using deadweight piston testers and standard mano-barometer
- Comparison of dynamometers using hydraulic comparators
- Hardness measurements

Equipment : Main items only :

- Universal measuring machine (1or 3 m) allowing comparison of long end gauges and calibration of line standards as well as measurement of external and internal diameters, etc., installed on concrete supports made on the spot according to drawing supplied by the instrument manufacturer
- Profile projector (optical contour magnifier)
- Surface plate of stone 1500 x 1000 mm on supports supplied by manufacturer
- Barometer test chamber and standard mano-barometer
- Standard piston pressure gauges
- Brinell and Vickers hardness testers
- Load cell and dynamometer hydraulic comparators (to 700 kN)

Installations : - Fully independently air-conditioned room with very good temperature stability (design targets : ± 0.5 °C, humidity always less than 70 %), no windows. Uniform air distribution through double ceiling

- Electrical power on switchboard located in preparation room : 220 V/380 V three phase 25 A, with three monophase circuits installed 16 A each
- Some instruments are installed directly on floor using supports designed by instrument manufacturers, suitable furnishing for the others :
- Two heavy workshop type benches
- Six (or more) laboratory tables
- Six steel lockers 50 x 100 cm with strong reinforced shelving
- Two tables on wheels
- One office desk

Preparation room : This room serves as air lock and does not need special air-conditioning. It will be used for storage (several cupboards), cleaning and greasing of gauge blocks and various other items

A sink of stainless steel with hot and cold water taps should be installed in this room.

3.5. Laboratory for tape measurements

Activity : Comparison and verification of length measuring tapes and other length measures (rulers)

Equipment : - Set of standard 20 or 25 m tapes of stainless steel and stretching devices - Comparator for commercial length measures up to 5 m

Installation : - Thermally climatized corridor, usually allowing free passage except during measurements (or passage only in case of emergency), temperature uniformity along bench ± 1 °C

- Electrical 16 A sockets, every 4 m above bench connected to switch board in preparation room
- Bench, length 26 m along one wall preferably covered with polished stone or marble top 50 cm wide, placed at a height of 90 cm supported by brick pillars at maximum 1.5 m intervals
- At each end : free space (about 1 m) for wheels supporting tensioning weights for the tapes.

3.6. Electrical standards laboratory

Activities : - Maintenance of the national standards for voltage, resistance and capacitance
- Calibration of electrical and electronic instruments for DC and low frequency AC

Equipment : - Thermostated units for Weston cells, oil bath for resistors, resistance bridges, AC/DC transfer apparatus, voltage and current calibration sources for DC and AC, capacitance bridge etc.

Installation : - Fully air-conditioned room with double ceiling, no windows or small double windows with thick curtains. Room temperature 23°C + 0.5°C. Entrance normally through air-lock. Insulated double door to corridor for occasional intake of equipment
- Electrical power on switchboard in air-lock room :
220 V 25 A three phase distributed over three circuits fused for 16 A
Dual monophase + earth sockets every 1 m at 90 cm above floor along all walls except corridor wall
- Laboratory tables along all walls except corridor walls, and in two free-standing rows (total estimated number 22)
- Six steel lockers 100 x 50 cm along corridor wall.

3.7. Electrical energy meter test laboratory

Activities : - Calibration of wattmeters and secondary standard energy meters
- Verification (on sampling basis) of energy meters
- Calibration of instrument transformers

Equipment : - Electronic power and energy standard
- Test set for energy meters
- Test rack for mounting energy meters
- Instrument transformer calibrator
- Storage racks for test items

Installation : Same as for electrical standards laboratory, except switchboard power increased to 40 A three phase and number of laboratory tables reduced to 8 and steel lockers to 2.

3.8. Frequency and time standards laboratory

Activities : - Calibration of frequency standards

- Dissemination of standard frequency (and time) by suitable means (VHF radio link to users or by transportable electronic clocks)

Equipment : - Frequency standards (atomic clocks)
- Electronic counters
- Radio receiving (VLF) and, if required, small VHF transmitter

Installation :-Normally air-conditioned room (temperature not to exceed 30 °C)
-Electrical switchboard for 220 V 25 A, three monophase circuits fused for 1^6 A monophase + earth dual sockets along the walls at 90 cm above floor and every 1 m
-One steel locker
- Five laboratory tables

3.9. Thermometry laboratory

Activities : - Calibration of electrical and liquid-in glass thermometers
- Verification of disappearing filament optical pyrometers
- Verification of hydrometers
- Calibration of hygrometers

Equipment : - Standard resistance thermometers and thermocouples
- Calibration baths and furnaces. Calibrated pyrometer lamps
- Resistance bridges and digital voltmeters, lamp power supply
- Thermostated bath for comparison of hydrometers
- Hygrostat or climatic cabinet for calibration of hygrometers by comparison to dew point hygrometer

Installations : - Normally air-conditioned room with small double windows and thick curtains. Temperature between 20 and max. 25 °C during working hours
- One stainless steel sink with hot and cold water supply
- Electrical power on switchboard 220 V/380 V 40 A three-phase, four connected monophase circuits fused for 16 A
- Four steel lockers 100 x 50 cm along corridor wall
- Laboratory tables along other walls and free standing in the middle, estimated number : 14

3.10. Machine hall

Activities : - Calibration and adjustment of heavy test weights (20 to 1000kg)
- Calibration of volume test flasks (5 to 200 L) by comparison to standards
- Examination of platform and other balances (range 50 to 2000 kg)
- Climatic testing of weighing and other equipment
- Vibration and other mechanical testing of small equipment
- Mechanical workshop

Equipment : - Balances or electronic mass comparators for 20 and 1000 kg
- Sets of standard test weights (50 x 20 kg and 500 or 1000 kg reference standards)
- Volume standards 5 to 200 L for fixed use, 1000 L standard on mobile cart
- Climatic test cabinets (one of walk-in type, 16 m^3 or more)
- Vibration and shock table

- Workshop equipment: drill, lathe and milling machine

Installations : - Free height inside machine hall 5.5 m or more. Small windows starting at 3m above floor
- Heating and air-conditioning to maintain the temperature between 18 °C minimum and 27 °C maximum
- Floor to stand distributed load of 10 tonne/m^2 at least for half of the machine hall where the testing of heavy weights takes place.(The total expected load is maximum 100 tonnes). Point loads at the weight testing area may reach 3 tonne on a surface of 0.1 m^2.
The floor may be provided with concrete finish incorporating plastic and colouring materials or, if not available, painted with .resistant epoxy paint
- Temperature regulated cabin for 20 kg electronic mass comparator (if required)

- The outside entrance for a truck at one end shall consist of a folding door (dust tight), width 5.5 m, height 5 m
- A travelling hoist, capacity 4 tonne, should preferably be installed for unloading heavy weights and equipment. (If the room height does not allow such a hoist, unloading may be done by a fork-lift of capacity 2 tonne stored in the machine hall)
- Electrical power on switchboard 220/380 V three phase 100 A Monophase + earth 16 A splash protected sockets distributed at 3.5 m intervals along the main long walls. Individual electrical wiring to machines and to climatic cabinets as required
- Water distribution ; taps near every pillar along one of the walls. Sewer water evacuation on floor near pillars. Two stainless steel sinks also to be installed along this wall
- Compressed air distribution along both main walls, compressor preferably installed outside
- Six heavy workbenches
- Four heavy steel lockers

3.11. Photometry

Since photometry does in many cases not form part of legal metrology activities it has not been included in the examples of simplified technical lay-outs in Fig. 4. However if the legal metrology activities are combined with testing of electrical products it is usually appropriate to provide for a photometry laboratory which can make measurements for instance of the luminous flux of incandescent and fluorescent lamps as a part of quality control activities. The photometry laboratory may occasionally also calibrate illuminancemeters.

Equipment : - Sets of calibrated incandescent lamps for luminous flux and luminous intensity

- Integrating sphere, diameter 2.5 m to accommodate both incandescent and fluorescent lamps
- Bench for calibrating illuminance meters with adjustable standard lamp support and black velvet curtains
- Linear digital photometer and colorimeter
- Digital AC/DC voltmeter
- Electronic DC power supplies for 110 and 220 V DC, 5 A
- Stabilized 1 kW AC supply for flourescent lamps

Installations : The minimum internal height of the photometry laboratory should be 3.2 m, preferably more, to accommodate the integrating sphere. The dimensions of the room should be minimum 7 x 7 m or 50 m^2 . Main entrance to laboratory; two double doors with air lock Temperature stability to be maintained at about ± 3 °C with a dissipation of about 2 kW. No windows.

- Six laboratory tables
- Six steel lockers whereof two with supports for storage of standard lamps in their normal working position
- Four tables on wheels
- Electrical switchboard for 220/380 V, 25 A with two monophase 16 A socket circuits installed.

The <u>life testing of lamps</u> shall take place in an adjacent room (minimum 70 m^2) with good natural ventilation (dissipation of up to 15 kW).

4. PRODUCT AND EQUIPMENT TESTING ACTIVITIES

4.1. Introduction

As the scope of this brochure is mainly confined to metrology activities we will only briefly treat some typical product and equipment testing activities which developing countries may be confronted with; in particular those which in one way or another need calibration by the central metrology organisation and for convenience have laboratories located on the same grounds or even form part of a same organisational compound (see Fig. 2).

Such typical activities are first those which directly involve human safety and are subject to legal prescriptions, such as electrical equipment and supplies, certain building materials and pressure vessels. These items are usually regulated by reference to national or international standards as regards the detailed technical requirements and related testing.

Other product testing activities may concern a great number of items for which compulsory or voluntary quality control schemes are to be established for reasons of consumer's protection, certification to standards, product licensing for local manufacture, export promotion, etc. These latter activities including a large amount of chemical testing are dealt with in other publications (*).

4.2. General considerations for the planning of product testing

Experience shows that it is advisable to repeat what was already mentioned in the first chapter :

PROCUREMENT OF ANY PRODUCT TESTING EQUIPMENT AND PLANNING OF LABORATORIES MUST BE PRECEDED BY ADOPTION OF PARTICULAR STANDARD TEST METHODS

It is in fact too frequently found that a piece of test equipment purchased hastily or when founding was suddenly available, does not have exactly the facilities prescribed by the test standard adopted. It should also be verified for any new procurements that the test gear or instrument on all points fulfils the requirements contained in the standard. This may need some additional correspondence with the supplier.

In this connection it should be emphasized that some test equipment may be attractive from the point of view of measuring principle used, accuracy, presentation and commodity in use, etc. or in brief characteristics which would generally satisfy the metrologist. However, as regards product testing the main aim is frequently to obtain reproducibility with respect to results obtained in other laboratories. The tests must therefore be done under identical conditions and practically regardless whether the measurements or tests express true material data or not. The rule for product testing is : same temperature, same humidity, same test speed, same test force or test pressure, same test sequence, same number of cycles etc. etc.

(*) A manual with the title "The Establishment of a Testing Laboratory" is being prepared by ISO-DEVCO.

Comparisons by interpolation or extrapolation of data obtained under slightly different conditions are difficult. Furthermore certain characteristics in particular concerning various polymers, textiles etc, are greatly depending on humidity and conditioning or previous history of the specimen. Humidity absorption of many products greatly depends on temperature.

4.3. Test climates for product testing

The testing of mechanical and electrical products can generally be done in a less critical laboratory environment, i.e. between 15 and 30 °C with a relative humidity not exceeding 70 %.

However a great number of textiles and polymers require special environments which may be even more difficult to maintain than those required for metrology. In fact the reference environments specified by many standards for example for textiles and in some countries also for polymers is : 20 ± 2 °C and 65 ± 2 % RH. For paper testing the international practice is now and in some countries also for leather, plastics and rubber 23 ± 1 °C and 50 ± 2 % RH. It is in any case advised to consult the most recent international test standard for each product.

These are, however, reference climates which apply for instance in relation to material characteristics of export (or import) products. As regards products which are locally used such as paints it is necessary to choose test climates or exposures which reflect realistic local conditions such as for instance mean weather data during the warmest or most humid month of the year. Such test climates must also be maintained with great accuracy in the laboratories in order to obtain reproducible results.

In brief, all laboratories concerned with testing of textiles, paper and polymers of various kinds must be provided with independent air-conditioning units which can be set to the test requirements laid down by the international or national standards.

It must be mentioned, however, that humidity regulation with a variation of the RH value of maximum ± 2 % can never be attained in a test room where staff is present and only with great difficulty in some small climatic test cabinets. The humidity regulation in well designed laboratories provided with air locks is generally at best about ± 5 %. It may however be suitable to instruct suppliers of equipment that the specified RH-value must at all times be maintained within these latter limits, considered as extremes. The humidity sensors used are generally subject to drift and the air-conditioning equipment will have to be adjusted regularly and according to season. High quality temperature and humidity recorders will always have to be available and regularly checked on the spot, using standard thermometers and Assman or other psychrometers. Failure to do so may lead to shifts of values in test results on sensitive materials.

Rooms where advanced physico-chemical analytical instruments are to be installed frequently need to be temperature controlled to specifications to be supplied by the manufacturer.

The floor surface needed for a special room to house the installation of an independent air-conditioner for a laboratory with a volume of 150 m^3 is at least 2 x 3 m taking into account the necessary ducts, control panels, etc. (not including air-washing ventilation such as required for paint drying tests).

Air-conditioning units for direct installation in the laboratory room itself usually take less space but should be avoided for reasons of noise, vibration and maintenance. Special rooms for such equipment must therefore be provided. It may then be convenient to combine them with the air lock (minimum 2 x 2 m) constituting the usual entrance to the laboratory. Space may be saved if for instance two independently air-conditioned laboratories are located so that a common space is provided for the two air-conditioners and one air lock allowing entrance to the laboratories on either side. Air-conditioners of the size considered will usually have liquid-cooled condensers and one or several cooling towers will have to be installed on the roof or outside the building.

The requirements for air-conditioning of the various laboratory units will have to be taken into account right at the start of the planning stage when preparing the first drawings of the testing laboratory building.

4.4. Testing of mechanical products, textiles, rubber, etc.

Small scale testing of the strength of metals can take place in the premises planned for metrology. For this purpose it is only necessary to provide for a hardness tester and a tensile testing machine of 100 kN capacity which can be installed in the machine hall already provided for metrology.

The testing of finished products on a more frequent sampling basis such as reinforcement steel and other products, will require more preparatory space and heavier testing machines. An additional machine hall with increased workshop facilities may be needed in this case.

The testing of samples of gas cylinders or other pressure vessels by an hydraulic pump using water requires a separate small annex (25 m^2) in or outside the machine hall and constructed so that there is no danger to operating personnel in case of material failure.

Other testing of products such as gas cookers, etc. may also require more space, provided with natural heat evacuation, and sufficient room height (4 m or more).

Building materials are, because of sampling and transport problems, usually tested on their site of manufacture or use. However, if it is found necessary to provide the central testing laboratories for such facilities it will be necessary to provide for a special machine hall or part of the machine hall.

Because of the need for specialized staff, the planning for a specific building materials testing laboratory should be considered within a framework comprising not only sampling control of some building materials but also research, and development for industries and authorities responsible for implementing building standards.

The testing of textiles requires at least one specially air-conditioned room (25 to 30 m^2).

Mechanical tests on plastics and rubber may require another specially air-conditioned room of similar size. Depending on the standard test climate chosen it may also be possible to include the testing of paper and leather in one or the other of these laboratories. In both cases these specially conditioned rooms shall be connected to preparation rooms (40 to 50 m^2) provided with normal air—conditioning.

The testing of paints requires also a specially conditioned room in particular for the drying of samples whereby the vapours must be properly evacuated or washed-out in the air-conditioning system specially installed for this purpose.

These three laboratories for textiles, polymers and paints may occupy the ground floor of one wing or a separate "chemistry building" with three chemical laboratories for inorganic, organic and biological analysis located on 'the top floor near the roof so as to provide easy evacuation for the fume hoods by ventilators placed on the roof of the building.

The physical analysis instruments usually employed for product testing can be installed in two rooms of office size and grouped so as to include infrared and ultraviolet spectrophotometers in one room and gas chromatograph and atomic absorption spectrophotometer in the other.

The temperature stability in these rooms should however be better than + 2 °C which thus may require special air-conditioning.

4. 5. Testing of electrical materials

The typical electrical products which may have to be tested on sampling basis are cables, wires and cords, lamp holders, switches, connectors and plugs, car batteries, dry cells etc.

All these items are subject to IEC publications which give details about requirements, test methods, test rigs and other equipment necessary. Much of this equipment will however have to be made to order by specialized workshops. Special attention has to be paid to the wear testing apparatus required for plugs, sockets and switches and it is advisable to consult other national testing bodies as to suitable sources of supply for such machinery.

No special air-conditioning is generally needed for the electrical tests. The room used for testing of storage batteries should however be provided with special forced ventilation.

As regards necessary space it may be convenient to reserve the first (or second) floor of one wing of the buildings for the electrical testing activities. This wing with a total floor space of 500 m^2^ should be placed so that there is easy communication with the electrical metrology laboratories.

The testing of lamps can also be accommodated in this wing, see point 3.11.

4.6. Conclusions concerning the planning for product testing

The planning of laboratories for product testing must be done on a basis of charts or lists taking into account the following points (*)

a. type of products to be tested and product standard

b. number and size of samples of each type to be tested per month or year

c. test method (standard to be used).

In order to avoid over-planning and unnecessary expenditures it must also be considered how much of the testing should be done directly at the premises of the manufacturer under supervision by the testing authority. There are in fact a great number of products for which testing may be easier and more frequently carried out using the test equipment of the manufacturer provided that this has been duly verified and accepted as regards the metrological and operational characteristics.(**)

For the case that product testing will extensively take place at the site of the manufacturer it is necessary to provide the inspection service with transportable working standards and reference materials and the necessary transport means. This will generally lead to considerable operational costs but the follow-up of a certification system may on the whole be more effective and not simply limited to the examination of initially submitted patterns of the product concerned.

(*) In doing such planning the author has found it very useful to draw up for each kind of product a chart such as shown in Fig. 5 which indicates the relation between product requirement standards and test method standards. Such charts display directly the most frequent test method for which equipment, test premises or testing arrangements will have to be provided.

(**) A typical example is burst testing of plastic pipes which requires special fittings for each size (diameter) produced. In this case the manometer used in the manufacturer's test installation should be verified at regular intervals.

TESTING OF PLASTIC PIPE, FITTINGS AND TUBING

Product		Standard *	Dimensions	Sustained pressure	Burst pressure	Flattening	Extrusion quality	Deflection load	Chemical resistance	Water resistance	Impact	Deflection temperature	Impact resistance	Tensile strength	Joint tightness	Threads	Acid conditionning	Dimensional stability	Carbon black	Density	Environmental cracking test
		Test method *	D2122	D1598	D1599		D2152	D2412	D543		D2444	D648	D256	D638					D1505	D1505	
PVC	Pipe	D2241	x	x	x	x	x														
	fittings	D2464, D2466	x		x											x					
	drain & vent pipe	D2665	x		x	x	x	x	x	x	x				x	x					
	tubing	D2740	x	x	x	x	x														
ABS	Pipe	D2282	x	x	x		x														
	fittings	D2465, D2468, D2469	x		x											x					
	drain & vent pipe	D2661	x		x	x		x	x	x	x	x	x	x	x	x					
	composite pipe	D2680	x					x									x				
	sewer pipe	D2750, D2751	x					x	x	x	x				x			x			
PE	Pipe	D2239	x	x	x														x	x	x
	fittings	D2609, D2683	x		x																
	tubing	D2737	x	x	x														x	x	x
PB	Pipe	D2662	x	x	x														x		
	tubing	D2666	x	x	x														x		

* Numbers indicated in this example refer to ASTM Vol.26, 1969 edition. It is advised to use recent ISO Standards

Fig. 5 - EXAMPLE of PRODUCT TEST PLANNING CHART

5. LABORATORY FURNITURE

The large amount of furniture required for the laboratories usually implies special manufacture by local suppliers. There are in most countries no great difficulties for such manufacture except possibly as regards the table tops for some of the chemical laboratories where strong acids or solvents are being used. Preparations with such liquids must always take place inside fume hoods which can be ordered as kits from well-known international laboratory suppliers.

Such problems do not arise as long as only metrology and physical testing activities are considered and below we are giving some indications as to how such furniture can be constructed.

The mass and length metrology activities will require special stone benches supported by brick pillars. The specifications for these items were already given in points 3.1 and 3.5. For the length measuring machine it is necessary to consult the manufacturer in order to obtain the drawings of the required concrete supports.

In most other cases a type of standard laboratory furniture may be adopted. Some of this furniture will no doubt remain at fixed locations but some of it should be easily movable according to needs and the arrival of equipment, the exact installation of which cannot always be foreseen in advance. Except for the chemical laboratories, most benches should be provided for sitting work. In order to avoid the need for high laboratory chairs which require a foot rest ring, the height of these benches should be 75 or 76 cm. Some tables should however be manufactured with a height of 90 cm for standing work. The design may then be such that the legs of these high tables can be cut to bring them to standard sitting height, when necessary.

The benches shall for reasons of flexibility, be composed of individual very sturdy tables which are installed side by side without any other form of assembly. Experience with such tables having a welded steel structure has been extremely good, see Fig. 6. It is important, however that such table units are not too big and that they fit dimensionally into the modules of the rooms. The length of the table top should preferably be double its width though this is not an absolute condition and depends on the inside dimensions of the rooms and the spacing of the windows. Taking into account the dimensions of many instruments experience has shown that the width (or depth) should not be smaller than 650 mm and not larger than 750 mm. The corresponding length should thus be 1 300 mm minimum and 1 500 mm maximum. Particular attention has to be paid to the quality of the table tops which should be made of high-quality, mat laminate-covered core board or particle-board, covered on both sides so as to obtain dimensional stability. The edges must not be fragile and should not be made of laminate. Metal edges should also not be used as many tables will carry electrical cables. Hard 2 mm thick polyethylene strips or 8 to 10 mm hard wood may be used as edging material. Drawer unit inserts should be available for a large part of these tables but low-locker type of inserts are of little use since they are inconvenient for access to instruments.

For storage of mechanical or electrical instruments one should choose steel double-door lockers (without glass) of similar type as those used in offices but slightly deeper. The shelves as well as their fixtures should be reinforced. The preferred dimensions of such lockers are 50 cm deep, 100 cm wide and 185 to 190 cm high.

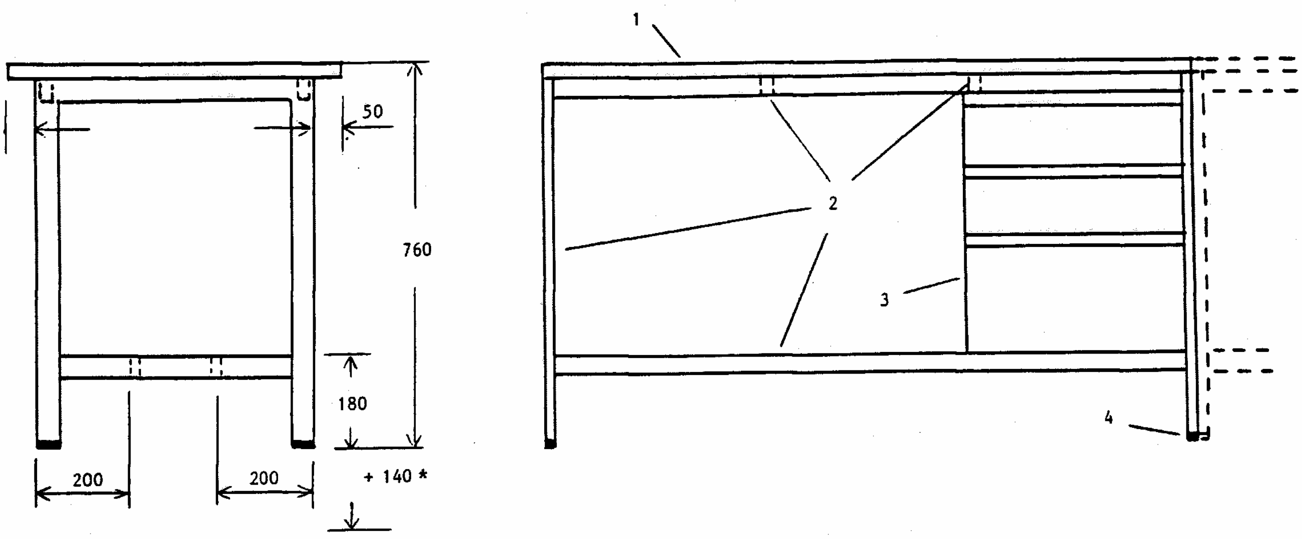

Fig. 6 - LABORATORY TABLE

1 - Table top (for instance 1350 x 675 mm) made preferably from 20 mm thick coreboard (or 25 mm chipboard) covered on both sides with mat melamine laminate (formica) of light grey-green colour without texture. Edges covered with resistant insulating material or hard wood (teack) without any protrusions as the tables are to be put side by side.

2 - Welded structure made from 20 x 40 mm rectangular steel tubing painted black or with aluminium paint (for easy repainting).

3 - Drawer insert made from steel sheet (on some tables only) to be fixed from the bottom by four screws. Spray-painted in light grey-green colour. Width of drawers 450 mm, height of drawer modules 2 x 125 and 1 x 250 mm.

4 - Feet made from hard rubber.

* Additional height for some tables used for standing work, total height 900 mm

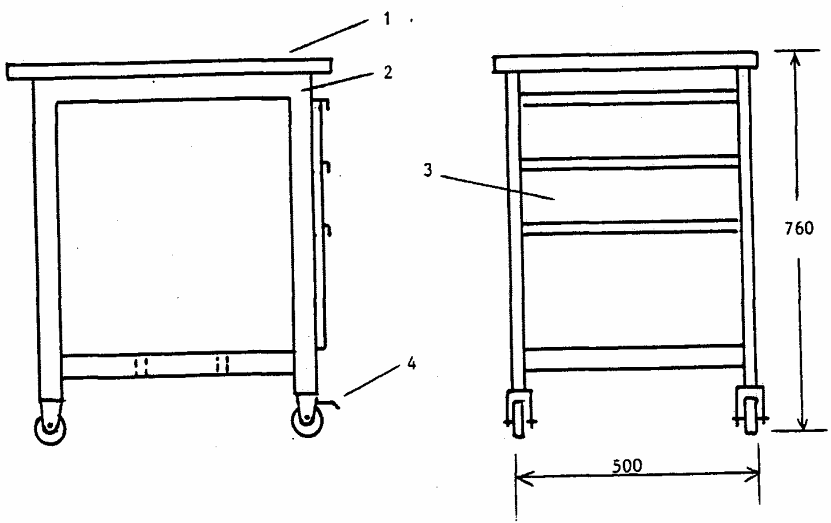

Fig. 7 - TABLE on WHEELS

1 - Table top specifications as for laboratory table in Fig. 6 but length shortened to about 550 mm as to cover outside distance between casters.

2 - Welded structure made from rectangular steel tubing 20 x 40 mm. Total height shall include casters.

3 - Drawer insert as in Fig. 6 (on some tables only).

4 - Rubbercoated casters, diameter minimum 50 mm maximum 60 mm with fixing brackets rotating around their axis of fixation. Two of the casters shall be equipped with foot pedal blocking devices.

The rack-type of storage is also convenient especially for mechanical and electrical equipment and for in-or out-going test items. A suitable model which can easily be locally manufactured is shown in Fig. 8.

Tables on wheels (trolleys) are also very useful in particular in the electrical and thermal laboratories but also for transporting boxes of weights or test items. A model matching the laboratory bench is shown in Fig. 7.

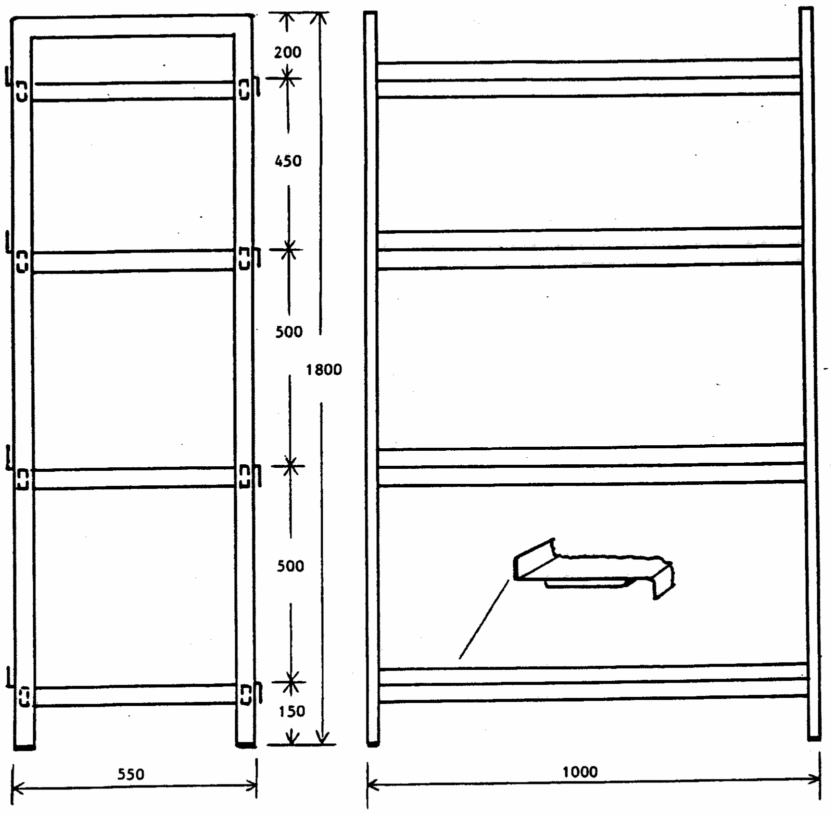

Fig. 8 - RACK WITH OPEN SHELVING

Storage rack consisting of two welded ladder structures made from 20 x 40 mm rectangular steel tubing connected longitudinally by tubes of the same section on which are fixed four shelves made from 1 mm steel sheet reinforced in the middle. The shelves have 40 mm borders bent upwards at the rear and downwards in front. All spray-painted in light grey-green colour.

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