Engineering laboratories

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Preface

Under the United Nations Development Programme Unesco is responsible for several Special Fund and Technical Assistance projects dealing with the establishment of standards and material testing laboratories. Some of these laboratories are already nearing completion, others are being equipped, and it is expected that Unesco will be associated with further similar projects in developing countries as the need for them arises and countries request assistance from Unesco.

Although each project is designed to meet the specific requirements of the country concerned, there are a number of components and characteristics of these testing laboratories which are repetitive. To support its operational activities in this field and as part of its programme to collect and disseminate information that will assist Member States in applying science and technology to development, Unesco is making studies of the basic characteristics and requirements of prototype testing laboratories, covering the main branches of engineering and many of their sub-divisions.

The studies will include descriptions and specifications of typical engineering testing units, and deal with many different aspects, such as guide lines for planning, layout of buildings, fittings and specialized furnishings, and equipment specifications for the various types of laboratories. They will also deal with the organizational structure of such testing institutes, their administration, and the service relation between them and engineering departments.

The present survey, *Material Testing Laboratories*, is the first to be published in the series entitled 'Engineering laboratories'. It was prepared by Professor L. F. Gillemot, Budapest, at the request of Unesco. It is anticipated that future surveys will deal with hydraulic engineering, thermodynamics, and electricity.

Contents

General considerations

Experience in Central and Eastern European countries of the operation for industry's benefit of national standards and testing laboratories and of the establishment and maintenance of standards and the prosecution of research offers useful examples for study by other countries.

Although each national project should be designed to meet specific requirements which can be drawn up on the basis of adequate preliminary studies, there are many factors in common. Thus it seems reasonable to set up central institutes for the testing of materials and products to cover the following range of duties: (a) material and products testing for companies or individual customers; (b) the drawing-up of quality specifications, quality control, and inspection of deliveries of government purchases; (c) the quality marking of domestic products, according to local conditions, and control; and (d) the presentation of official opinions in legal proceedings.

Scientific research and production engineering development are not included in the duties of the institute. However, so that it may be able to develop and improve its own test methods and measurement techniques, the institute should have equipment for minimum research activity.

A description of some governmental and institutional systems of organization and control of testing establishments that have grown up in Central and Eastern European countries is given in the appendix.

Testing and research institutes in developing economies

The question of what kind of testing institution may be needed must be considered. As a starting point, a central testing laboratory will be needed for materials and products and its scope must be judged according to the economic and industrial advancement of the country concerned. In the second phase of development only a highly developed branch of industry can justify the creation for itself of a central industrial research institute. At this stage the major need will be rather for plant laboratories, and these should be established according to the size and activities of the operating plants.

The setting up of institutions dealing exclusively with basic sciences—in the Eastern European countries these are the academy research institutes—makes sense only when a certain level of economic development has been reached. In earlier phases of development university laboratories offer facilities for fundamental research. They serve three purposes: (a) the education and the practical training of university students; (b) fundamental research work; and (c) the carrying out of more or less extensive test procedures to meet industrial requirements.

However, it does not seem reasonable to rely for too long a time on existing university laboratories, especially for test operations of a repetitive character that tend to overload the university laboratories with routine work.

Guide lines for planning

In the first phase of industrial development it has been found necessary to establish a central laboratory for the testing of products and materials, wherever called for by government or industry. University laboratories can fairly be used for these purposes where industrial production is not yet high enough to justify the organization of a large central test station.

In the light of the experience of the Eastern European economies, the development of central research institutes for industry or basic sciences is justified only in industrially advanced countries, except in very special cases.

In giving the outlines and description of prototype laboratories in the second part of this report, the following considerations have been borne in mind:

1. The institute for metrology of the country is assumed to be independent of the central institute for testing.
2. The general design of the institute must allow for decentralization of its individual laboratories throughout the country as necessary, although they would normally be subject to its central control. In some instances, according to economic circumstances, the entire institute would be in one place.
3. Although, as suggested above, research would not be among the duties of the institute, its location and design should take account of the possibility that at some later phase of development the institute might prove suitable for some research activity not calling for a high capital investment. This consideration applies also to the provision of basic equipment: even were it not fully utilized at first, double investment might be avoided at a later date.
4. Some test methods can be mechanized, but this would be profitable only if the number of investigations called for become sufficiently high. For example, in the examination of ores, metals and alloys, as long as the quantities to be dealt with are not likely to become very large, classical analysis techniques and spectroscopy would suffice; but if the quantities are likely to be larger, automatic spectral analysis might be justified.
5. Where one branch or field of industry in a country is well advanced and has its own laboratories, these might well replace the corresponding department of the central institute. Alternatively, where a country was not active in a specific industry, the corresponding laboratory would not be needed in the institute.
6. Although education and research are only suggested in this report as an incidental part of the institute's duties, planning may reckon with such activities where the training and examination of employees for specialized jobs could be provided for.

Central European experience shows, for example, that skilled welders can conveniently be trained and that they can, if necessary, be re-examined periodically at the institute. These countries often employ industrial research institutes instead of the central materials testing or quality control establishments for the purpose. Western European countries have comparable organizations with the same objective. If a country has no suitable body for the task, it may be useful to consider whether local conditions encourage the idea of entrusting the task to the institute. It would call for only small additions to laboratory facilities.

Buildings

Relating these requirements to desirable plans for buildings it follows that an institute may best be organized in a 'pavilion' layout, where individual buildings for separate but generally related purposes can be furnished with easy intercommunication. Or the laboratories may be located separately if the whole installation is decentralized in a number of cities.

One feasible and simple example for a central laboratory is illustrated in schematic outline in Figure 1. This resembles the layout of the buildings of

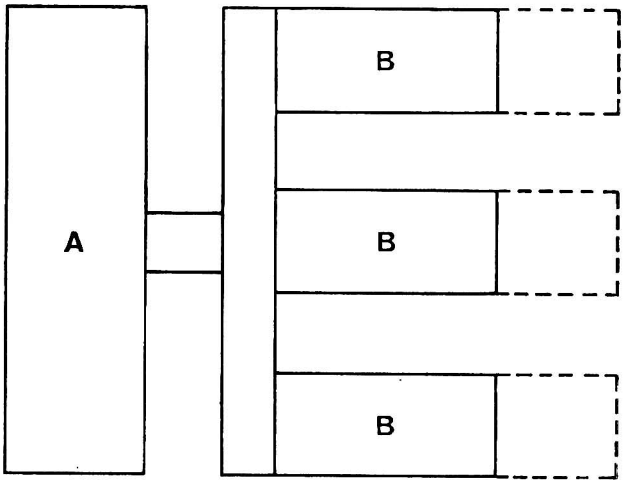

FIG. 1. General layout of a central laboratory.
A, main building, height 3.5 m per floor.
B, hall, height 4.5 m.

the former Kaiser Wilhelm Institut für Eisenforschung which has been copied by a number of laboratories all over Europe. The main building, A, usually accommodates the office premises, library and control laboratories that use light-weight instruments. The testing halls marked B have rather large floor areas and are suitable for heavier measuring equipment—tensile test machines, fatigue test machines and so on.

An advantage of this layout is that extensions are simple, (as indicated by the dashed lines in the figure). Another advantage is the possibility of embedding heavier equipment in the fully supported ground floor structure.

Testing halls for heavy machines and ordinary test equipment should be designed to a maximum height of 4.5 m, unless exceptionally tall equipment is needed. Other laboratories should be not more than 3.5 m in height.

Staffing

No standard international terminology exists for the definition of the several grades of personnel needed by the institute. They may be grouped in the following categories: (a) management and administration—director, accountants, typists, stenographers, documentation staff and librarians, storekeepers; (b) technicians at professional level—university graduates, bachelors and masters with three to five years of study; (c) technicians at sub-professional level—employees without university qualifications, but having completed two to four years of medium-grade engineering studies; and skilled labour; and (d) miscellaneous non-technical help—unskilled labour, janitors, etc.

The numbers of staff under (a) and (d) will be much affected by local conditions. For those under (b) and (c) more informative data can be given (leaving aside such figures as those given on individual laboratory staff requirements in the second part of this report).

In establishments equipped for test series performance purposes the ratio between employees with and without university qualifications as specified under (b) and (c) might be designed generally to fit into the range of 1 : 5 to 1 : 10, according to the type of laboratory and its work. If the laboratory also has research objectives the ratio may be reduced to between 1 : 2.5 and 1 : 5.

For institutes that have a total engineering staff of between 50 and 300, a floor space of some 40-50 m^2 is required for each technical employee engaged. The total floor space thus obtained would cover the overall floor area of the institute, including accommodation for those employees under (a) and (d) who perform no direct engineering activity, as well as all the service areas. The figures given represent average data which vary for different types of laboratories and should therefore be used only to give approximations of what is needed.

Structure of a prototype central testing institute

Apart from the management and administrative staffs, the full prototype institute contains the following departments: 1. Metallurgy; 2. Mechanical engineering; 3. Electrical engineering; 4. Building material and construction industry; 5. Timber, paper and cellulose industry; 6. Textile industry; 7. Leather, rubber, and plastics industry; 8. Food chemistry; 9. Chemistry.

This group of nine departments represents a complete build-up which is required only in exceptional cases. Each department has several laboratories indicated by the symbols A, B, C, etc., which are described in the second part of this report (see also Figure 2).

The second part of this study presents a brief summary of the work of each department. For each laboratory nothing but the most essential basic equipment is listed. The average amount of work each laboratory is capable of is specified as well as the number and composition of the staff. These figures may, however, vary according to local conditions.

The figures indicating laboratory floor space represent, with some margin, the area required for facilities of primary and secondary importance (i.e. those marked X and XX in the lists of equipment), as well as for the laboratory staff. The brief laboratory descriptions include the possible special requirements but omit standard furniture. Similarly, detailed specification of minor equipment items is omitted.

Each laboratory under departments 1-8 will have to perform certain chemical tests. However, the amount and type of chemical examinations will vary widely between the different categories. A high number of chemical analyses is required in the metallurgy of ores and for alloy testing purposes, but in the latter field the equipment required is the same as that of the chemical laboratory of department 2. Comparatively small-sized chemical laboratories are needed by departments 3 and 4 respectively, whereas the chemical test procedures of departments 5-8 could be performed essentially within a single laboratory. It seems reasonable, therefore, to pool the chemical tasks of departments 1-8 within a common Department of Chemistry having laboratories subdivided in such a manner as to permit installation according to needs.

On these grounds, the Department of Chemistry should have the following laboratories:

1. An ore-testing laboratory to examine rocks, minerals, ores, bauxite, sand and slag types, cement and inorganic products. It will thus be able to carry out all the chemical test duties assigned to departments 1 and 4.
2. A non-ferrous metals laboratory to test aluminium, copper, zinc, lead, magnesium, etc., metals and their alloys. It will be capable of performing the chemical analyses of departments 1, 2 and 3.
3. An iron and steel testing chemical laboratory capable of carrying out the analyses required by departments 1, 2 and 3.
4. A paper, leather, and food-product testing chemical laboratory doing chemical analyses for departments 5-8.

The Department of Chemistry outlined above must be further expanded as regards premises and equipment in order to test the products of any other industry of a marked chemical character. If the institute has not set up all the eight departments, the corresponding laboratories may be omitted from the Department of Chemistry.

Since the daily routine activity of chemical analysis laboratories can hardly be determined in advance, each laboratory is initially provided with only the most indispensable basic equipment and the auxiliary facilities required for automatization.

Although the economic and political systems existing in the countries whose experience has here been drawn upon differ from those of countries in earlier stages of development, this does not affect the conclusions which are based on general considerations.

Departments and laboratories of a central testing institute

Classification of departments

The ten constituent departments which may be required in a fully developed central materials testing institute of the type described in the first part cover the following branches of industry:

1. Metallurgy;
2. Mechanical engineering;
3. Electrical engineering;
4. Building materials;
5. Timber, paper, and cellulose;
6. Textiles;
7. Leather, rubber and plastics;
8. Food and organic chemistry;
9. Inorganic chemistry;
10. Central workshop (as a service department).

The types of testing performed and the laboratories required for each are outlined in the following pages.

Metallurgy

Activities of the Department of Metallurgy include: ore analysis; determination of metal and alloy components by means of chemical and/or physical methods; mechanical testing of steels and other metals; metallographic studies; X-ray structure studies; experimental heat treatment of metals and alloys (not to advance the technology of heat treatment but only to perform heat treatment as required by the specifications).

The department has the following laboratories:

A. Mechanical testing (metals);
B. Metallographic;
C. Heat treatment;
D. Analytical chemistry of ores and slags;
E. Analytical chemistry of non-ferrous metals;
F. Analytical chemistry of iron and steel.

Mechanical engineering

Duties of the department include quality and strength tests of machine components, the detection of internal defects (defectoscopy), control of component dimensions, finish and surface quality, and determination of strength data required for the design of machines. It is recommended to include among the duties of the department the training and periodical examination of skilled welders.

The department has the following laboratories:

A. Mechanical testing (metals);
G. Non-destructive testing (defectoscopy);
H. Training of welders;
J. Measuring laboratory.

Electrical engineering

Experience gained in Central Europe indicates that an electrical engineering department is generally not provided in a central laboratory. The demands of modern electrical industry can only be met by the creation of a separate institute, the facilities of which depend, to a great extent, on local conditions. Thus, studies of power plant or high-voltage transmission equipment require large investments and necessitate a specialized institute. Similarly, the equipment of a laboratory to test the finished products of modern telecommunications depends a great deal on the general character of the industry. The present department is, therefore, intended to perform only fundamental measurements needed to determine the physical characteristics of certain basic types of materials. For this reason, the electrical engineering department described is really an auxiliary body of the other departments engaged in metal testing, and is allocated only one laboratory for the determination of the simplest electric and magnetic properties. The accomplishment of all other tasks should be assigned to special laboratories operated by individual factories.

The department, therefore, consists only of one laboratory:

K. Electric and magnetic measurements.

Building materials

Duties of the department include tests on rock, concrete, cement, etc., as well as on steels and metals used by the construction industry. The department has the following laboratories:

L. Mechanical testing (building materials);
M. Physical testing;
D. Analytical chemistry of slags, cement, concrete, etc.;
B. Metallography;
G. Non-destructive testing (defectoscopy).

Timber, paper, and cellulose

Timber, paper, and cellulose tests are preferably covered by the same department although timber tests could be also included in the activities of the building materials department. Assuming the existence of department 4, only the strength test of small-size wooden samples would be assigned to department 5. This department has two laboratories:

N. Mechanical and physical testing (timber and paper);
O. Organic chemistry.

Textiles

The duties of this department include strength, chemical and physical studies on textile raw materials as well as mechanical, chemical, and physical quality tests of finished products. The department has two laboratories:

P. Mechanical and physical testing (textiles);
O. Organic chemistry.

Leather, rubber and plastics

The duties of this department include mechanical, chemical and physical tests of leather, rubber, and plastic material products. The department has two laboratories:

R. Mechanical and physical testing (leather, etc.);
O. Organic chemistry.

Food and organic chemistry

The duties of this department include food control and the performance of chemical tests required by departments 5, 6 and 7. The department is usually divided into two laboratories although, owing to the similarity of the tasks involved, one single laboratory might suffice. The only reason for dividing the department into two laboratories:

S. Food chemistry,
O. Organic chemistry,

is the possibility of having the duties demanded by departments 5, 6 and 7 accomplished by separate laboratories. The facilities of these two laboratories overlap considerably, and if a fusion is preferred, this can easily be achieved by combining the two equipment lists.

Inorganic chemistry

This department is entrusted with the duties of inorganic analytic chemical testing for departments 1, 2 and 4.

The department has the following three laboratories:

D. Analytical chemistry of ores and slags;
E. Analytical chemistry of non-ferrous metals;
F. Analytical chemistry of iron and steel.

These laboratories need additional premises and staff as follows:

One glass technology workshop (floor space 36 m^2, height 3.5 m), and one or two employees;
One store room for chemicals (60 m^2 floor space).

Laboratory premises D, E and F and their equipment overlap to a considerable extent. Three separate laboratories should be established only if they are definitely necessitated by the extensive activities of departments 1, 2 and 4. The equipment required for ore, iron, steel, and non-ferrous metal tests is almost identical. Nevertheless, the premises referred to above are described here as separate laboratories in order to allow for the separate establishment of each, if necessary. If these three laboratories are united in one group, a certain amount of repetition in premises and facilities could be avoided. Individual laboratories are generally designed for development in two stages, as automated chemical analysis procedures demand relatively expensive investments and therefore deserve introduction only when the number of samples to be tested exceeds a certain limit. Preferably all premises are constructed with a height of 3.5 m and air temperature is maintained at 20° C ± 3° C.

Central workshop

Duties of the central workshop include sample production for all mechanical and physical test procedures with the exception of milling samples for chemical analysis, as the cutting machines required for this purpose are included in the equipment of the chemical laboratories.

Another duty of the central workshop is to provide for the maintenance of the laboratory equipment and instruments as well as to manufacture minor laboratory devices. The central workshop is equipped to perform metal cutting, finishing and precision work. Any welding job which may be required can be carried out in laboratory H.

Premises and staff required are as follows:

Manager's office: floor space 16 m², height 4.5 m (preferably partitioned off in one corner of the workshop);

Stock room: floor space 60 m², height 4.5 m;

Mechanical workshop: floor space 300 m², height 4.5 m;

Precision workshop: floor space 100 m², height 4.5 m;

No particular sanitary engineering stipulations;

Personnel: one shop manager (foreman); twelve skilled workers; four mechanics; two unskilled workers.

Seventeen types of constituent laboratories

In order to bring out clearly the organizational pattern of the structure of a fully fledged central institute for materials testing, the description of the various laboratories has been strictly separated from the description of the departments of the institute. It is important to note, however, that the laboratories described below may each be used by several departments; for instance, the laboratory for mechanical testing may be utilized among others by the department of Metallurgy, the Department of Mechanical Engineering and Department of Building Materials. Seventeen different types of testing laboratories are listed, serving the nine different departments forming the institute as indicated in the organizational chart, Figure 2.

The constituent laboratories which may be required in a fully developed central materials testing institute of the type described in the first part of the report cover the following fields:

A. Mechanical testing of metals;
B. Metallography;
C. Heat treatment;
D. Analytical chemistry of ores and slags;
E. Analytical chemistry of non-ferrous metals;
F. Analytical chemistry of iron and steel;
G. Non-destructive testing (defectoscopy);
H. Training of welders;
J. Measurements in mechanical engineering;
K. Measurements in electricity and magnetism;
L. Mechanical testing of building materials;
M. Physical testing of building materials;
N. Mechanical and physical testing of timber and paper;
O. Organic chemistry;
P. Mechanical and physical testing of textiles;
R. Mechanical and physical testing of leather, rubber and plastics;
S. Food chemistry.

The descriptions of these types of laboratories are presented in two sections. In the first, the required floor areas are estimated, specific working conditions (temperature, humidity, etc.) are stated, and personnel requirements are given for each laboratory. The second section contains a specification of the equipment of each laboratory. Certain items of equipment, or even entire groups of equipment, may overlap, as the same laboratory may serve different departments. The last column of these tables indicates which other laboratory equipment could be replaced by these items.

Symbols X, XX and XXX against instruments and items of equipment should be interpreted as follows:

X —basic equipment item most likely to be purchased;

XX —although basic, not necessarily to be purchased in every case;

XXX—the purchase of such items is only exceptionally

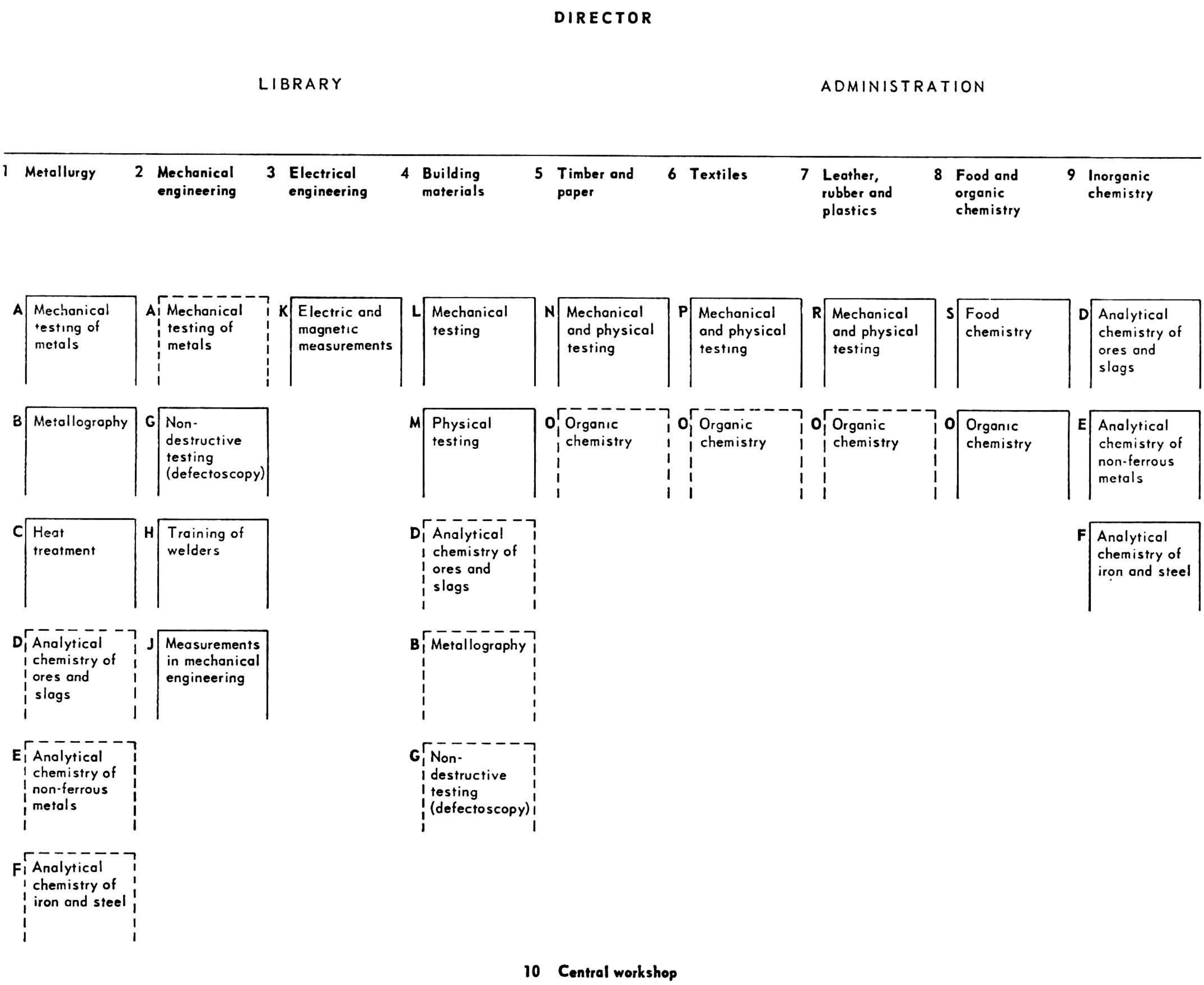

FIG. 2. Organization of the institute (departments).

justified and is to be separately considered, case by case.

Where a particular supplier is mentioned, this should be regarded only as an indication of the type of equipment required; it does not mean that no other company could deliver the instrument referred to or that no other equivalent instrument could be used.

Mechanical testing of metals

This laboratory serves the departments of metallurgy and mechanical engineering.

Manager's office: floor space 16 m², height 3.5 m.

Machine hall: floor space 300 m², height 4.5 m. Fatigue test machines are preferably enclosed within soundproof partitions. The sound-insulated area will house positions 16, 17, 18 and 19.

Creep test room conditioned to 20° C ± 1° C temperature: floor space 30 m², height 3.5 m. Required only for position 20.

Personnel: laboratory manager; assistant, university graduate; four technician assistants; two unskilled workers.

Metallography

This laboratory serves the departments of metallurgy and building materials.

Manager's office: floor space 16 m², height 3.5 m.

Grinding, polishing, and etching room: floor space 25 m², height 3.5 m, equipped with standard hood.

Microscope room: floor space 25 m², height 3.5 m. Black-out facilities recommended.

X-ray structure test room: floor space 30 m², height 3.5 m. Barite insulated walls, black-out facilities.

Dark room: floor space 25 m², height 3.5 m. Labyrinth entrance without door, black tile wall cover up to a height of 2 m, with the walls painted black above.

Personnel: laboratory manager; two technical assistants.

Heat treatment

This laboratory serves the metallurgy department.

Floor space 40 m², height 4.5 m, equipped with air-exhaust installation.

Personnel: manager with an engineering qualification (preferably the person who also manages the metallographic laboratory), and technical assistant.

Analytical chemistry of ores and slags
(also construction materials, about 50 tests per day)

This laboratory serves the departments of metallurgy, building materials, and inorganic chemistry.

Sample preparation and store-room: floor space 25 m², height 3.5 m.

Scale room: floor space 15 m², height 3.5 m.

Wet laboratory: floor space 90 m² (78 + 12 m²), height 3.5 m, four combustion chambers with exhaust installations, air-conditioned to 20° C ± 3° C.

Titre test room: floor space 15 m², height 3.5 m, one combustion chamber, air-conditioned to 20° C ± 3° C.

Photometry and potentiometric titration: floor space 30 m², height 3.5 m, air-conditioned to 20° C ± 3° C.

Electro-analytics: floor space 20 m², height 3.5 m.

Personnel: laboratory manager; nine technical assistants; two unskilled workers.

Laboratory expansion (for testing up to 250 samples daily). The essential feature of the expansion is represented by a quantometer suitable for the determination of twelve components. The expansion project requires:

Chemical preparatory accommodation with a combustion chamber.

Mechanical preparatory accommodation with a floor space of 16 m², and a height of 3.5 m.

Quantometer room: floor space 30 m², height 3.5 m.

Personnel: assistant, university graduate; two technician assistants; one unskilled worker.

Analytical chemistry of non-ferrous metals
(about 50 samples per day)

This laboratory serves the metallurgy and inorganic chemistry departments.

Office of the laboratory manager: floor space 16 m², height 3.5 m.

Sample preparation and store-room: floor space 25 m², height 3.5 m.

Scale room: floor space 15 m², height 3.5 m.

Wet laboratory: floor space 75 m², height 3.5 m, three hoods.

Titre test and polarograph laboratory: floor space 30 m², height 3.5 m, one combustion chamber.

Spectral preparation laboratory: floor space 16 m², height 3.5 m.

Photometry: floor space 30 m², height 3.5 m.

Electro-analytics: floor space 12 m^2, height 3.5 m.
Spectrum evaluation and spectrum photography accommodation: floor space $12 + 12 = 24$ m^2, height 3.5 m. One of the two rooms furnished for dark room purposes.
Spectral analysis room: floor space 25 m^2, height 3.5 m.
Personnel: laboratory manager; assistant, university graduate; ten technician assistants; three unskilled workers.

Laboratory expansion (for testing up to 250 samples per day). Expansion requires only one quantometer room of 30 m^2 floor space as the preparatory accommodations referred to above are suitable also for this purpose.
Surplus personnel: two technical assistants.

Analytical chemistry of iron and steel
(for about 50 sample tests per day)

This laboratory serves the metallurgy and inorganic chemistry departments.
Manager's office: floor space 16 m^2, height 3.5 m.
Sample preparation and store-room: floor space 20 m^2, height 3.5 m.
Scale room: floor space 15 m^2, height 3.5 m.
Wet laboratory: floor space 80 m^2, height 3.5 m, four combustion chambers.
Preparatory accommodation for physical measurements: floor space 30 m^2, height 3.5 m, one combustion chamber.
Photometry, potentiometry: floor space 40 m^2, height 3.5 m.
Electro-analytics: floor space 12 m^2, height 3.5 m.

Laboratory expansion (for testing up to 250 samples per day).
Chemical preparations: floor space 16 m^2, height 3.5 m, one combustion chamber.
Mechanical preparations: floor space 16 m^2, height 3.5 m.
Quantometer room: floor space 30 m^2, height 3.5 m.
Surplus personnel: assistant, university graduate; two technician assistants.

Non-destructive testing (defectoscopy)

This laboratory serves the departments of mechanical engineering and building materials.
Manager's office: floor space 16 m^2, height 3.5 m.
X-ray and isotope laboratory: floor space 104 m^2, height 4.5 m. Barite insulated walls for protection against secondary radiation. Flush 2 m^3 concrete basin of standard wall thickness for isotope storage.
Dark room: for radiograph development purposes. Floor space 25 m^2, height 3.5 m. Labyrinth entrance without door, black tile wall cover up to a height of 2 m, with walls painted black above. If the metallurgy department has a dark room, a separate room is not essential here, but the equipment of the former should be completed by the addition of development bath tanks of adequate dimensions to permit radiograph development.
Measuring room: for instruments not operating with radiation, floor space 20 m^2, height 3.5 m.
Personnel: laboratory manager (engineering qualification); two technical assistants; one unskilled worker.

Training of welders

This welding shop is in the mechanical engineering department.
Floor space 60 m^2, height 4.5 m. Airexhaust system and dark-coloured partitions of 3 m minimum height between welding sites: dark curtains may be used instead of partitions.
Personnel: shop manager (university graduate) responsible for training and examinations; four professional skilled welders; one unskilled worker.

Measurements in mechanical engineering

This laboratory serves the mechanical engineering department.
Manager's office: floor space 16 m^2, height 3.5 m.
Measuring room: floor space 50 m^2, height 3.5 m, temperature controlled to $20°$ C $\pm$ $2°$ C, vibration-proof foundation.
Personnel: laboratory manager; three technical assistants.

Electric and magnetic measurements

This laboratory is intended to perform only the simplest fundamental measurements of electric and magnetic properties, for reasons given in the description of the electrical engineering department. It is the only laboratory of this department.
Measuring room: floor space 40 m^2, height 3.5 m.
Instrument store-room: floor space 16 m^2, height3.5 m.

Manager's office: floor space 16 m^2, height 3.5 m.
Personnel: laboratory manager (bachelor's or master's degree); four assistants.

Mechanical testing of building materials

Facilities for this laboratory include equipment for testing hardware used in the building industry. A number of items are identical with those of laboratory A in the metallurgy department. These items are noted in the last column of the equipment schedules and can be omitted if the institute is to have a metallurgy department as well. The laboratory premises are:
Manager's office: floor space 16 m^2, height 3.5 m.
Preparatory accommodation for rock crushing: floor space 60 m^2, height 4.5 m, air-exhaust installation.
General preparatory accommodation: floor space 60 m^2, height 3.5 m.
Furnace room: floor space 50 m^2, height 4.5 m.
Mechanical test laboratory: floor space 260 m^2, height 4.5 m.
Personnel: laboratory manager; assistant, university graduate; six technician assistants; two unskilled workers.

Physical testing of building materials

Separate manager's office not required.
Floor space 180 m^2 including a 16 m^2 sound-proof compartment for acoustic measurements. Height 3.5-4.5 m.
Personnel: laboratory manager; three technical assistants; one unskilled worker.

Mechanical and physical testing of timber and paper

Manager's office: floor space 16 m^2, height 3.5 m.
Laboratory: floor space 100 m^2, possibly divided into two, height 3.5 m or 4.5 m.
Personnel: laboratory manager; four technical assistants; one unskilled worker.

Organic chemistry

It is preferable to equip this laboratory to serve also the three departments of timber, paper, and cellulose; textiles; and leather, rubber and plastics.
Manager's office; floor space 16 m^2, height 3.5 m.
Scale room: floor space 15 m^2, height 3.5 m (if practicable, shared with food-chemistry laboratory S.
Sample preparation and store-room: floor space 20 m^2, height 3.5 m.
Three laboratories of 28 m^2 floor space each, or one of 75 m^2, with three combustion chambers; temperature controlled to 20° C $\pm$ 3° C.
Personnel: laboratory manager; six technical assistants; two unskilled workers.

Mechanical and physical testing of textiles

Manager's office: floor space 16 m^2, height 3.5 m.
Test laboratory: floor space 140 m^2 possibly divided into a number of sections, relative humidity 65 per cent, air-conditioned to 20° C.
Personnel: laboratory manager; six technical assistants; one unskilled worker.

Mechanical and physical testing of leather, rubber and plastics

Manager's office: floor space 16 m^2, height 3.5 m.
Test laboratory: floor space 120 m^2, height 3.5 m.
Personnel: laboratory manager; four technical assistants; one unskilled worker.

Food chemistry

Manager's office: floor space 16 m^2, height 3.5 m.
Sample preparation and store-room: floor space 25 m^2, height 3.5 m.
Scale room: floor space 15 m^2, height 3.5 m.
Wet laboratory: floor space 50 m^2, height 3.5 m. Three standard combustion chambers with the necessary ventilation system. Temperature controlled to 20° C $\pm$ 3° C.
Polarographic and photometric laboratory: floor space 30 m^2, height 3.5 m possibly divided into two, with two standard compartments and temperature controlled to 20° C $\pm$ 3° C.
Vitamin and enzyme laboratory: floor space 20 m^2, height 3.5 m. Temperature controlled to 20° C $\pm$ 3° C.
Laboratory for measurement of the radioactive content of foodstuffs: floor space 20 m^2, height 3.5 m. Air-exhaust installation.
Personnel: laboratory manager; six technical assistants; two unskilled workers.

Equipment of laboratories (including central workshop)

Position no.	Set or piece	Specification	Order of importance	Notes
A. Mechanical testing of metals				
1	1	Universal tensile testing machine for tensile, compression and bending, maximum load 50 tons	X	L, no. 20
2	1	Universal tensile testing machine, maximum load 10 tons	XX	
3	1	Universal tensile testing machine, maximum load 5 tons, with electronic loading cells, e.g. Instron	X	L, no. 21
4	6	Mechanical tensometer, e.g. Huggenberger	X	
5	1	Electroinductive strain recorder, e.g. Hottinger	X	
6	1	(a) Strain gauge apparatus with oscilloscope and graphic recording (b) Checking equipment	X	L, no. 26
7	1	(a) Automatic selector to no. 6 (b) Level-recorder to no. 6	XX	L, no. 27
8	1	Impact bend-testing machine, Charpy or Izod 10 mkp	X	
9	1	As no. 8, but for impact bending and tensile testing with electronic stress and strain recorder	XX	
10	1	Test-piece dividing machine for round and flat bars	X	
11	1	Universal hardness tester for Brinell and Vickers testing	X	L, no. 12
12	1	Hardness tester for automatic determination of Rockwell hardness	X	
13	1	Hardness standard instrument for checking the hardness testers	XX	
14	1	Ring-force contact arm for checking the tensile machines, with optical reading. For tension up to 100 tons for compression up to 300 tons	XX	L, no. 29
15	1	Micro-tensile testing machine for test pieces 1-4 mm diameter, e.g. Chevenard	XX	
16	1	Torsion testing machine, 10 tm	XX	
17	4	Rotating-beam testing machine, up to 15 mm diameter test pieces	X	
18	2	Tensile and compression testing machine with pulsator, maximum load 10 tons	XX	If this, A, no. 2 superfluous
19	1	Tensile and compression testing machine, maximum load 100 tons	XXX	
20	8	Long-time creep testing machine, with automatic temperature control up to 900° C, maximum load 3,000 kp	XX	
21	1	Universal deep-drawing tester. Range of drawing-force 100-2,000 and 100-8,000 kp	X	
22	1	Tensile testing machine, horizontal type, for testing chains, ropes, etc., maximum load 250 tons	XXX	
23	1	Wire forward and backward bending tester, according to the related standards	X	
24	1	Dynamic indentation tester, Shore	XX	
25	2	Relaxation machine, maximum load 5,000 kp	XX	L, no. 23
26	2	Precision extensometer, measuring length 100 mm, accuracy 0.005 mm	XX	L, no. 28
B. Metallography				
1	1	Metal microscope, magnification up to 2,000×	X	
2	1	Heating and vacuum chamber to no. 1	XXX	

Position no.	Set or piece	Specification	Order of importance	Notes
3	1	Polishing machine, with two disks	X	
4	1	Grinding (sliding) machine with four disks	X	
5	1	Automatic grinding and polishing machine with two disks	X	
6	1	Electrolytical polishing machine	XX	
7	1	Microhardness tester, for no. 1	XXX	
8	1	X-ray equipment for Debye-Scherrer and back-reflex methods	XX	
9	1	Electron microscope magnification 100,000×	XXX	
10	1	Dilatometer, e.g. Chevenard or Bollenrath	XX	
11	2	Laboratory furnace up to 1,000° C, 100-200 cm³ capacity	X	
12	1	Dark room outfit, for microphotographs	X	

C. Heat treatment

1	1	Heat-treating furnace, salt-bath type, maximum temperature 1,350° C, capacity 2,000 cm³	X	With automatic temperature control (nos. 1–5)
2	1	Preheating furnace, metal or salt bath type, to no. 1, maximum temperature 900° C, capacity 2,000 cm³	X	
3	1	Universal heat-treating furnace, for quenching, surface hardening, etc., maximum temperature 1,200° C, capacity 5,000 cm³	X	
4	1	Salt-bath type furnace up to 700° C for heat treating of non-ferrous metals, accuracy of temperature ± 5° C, capacity 3,000 cm³	X	
5	1	Furnace up to 200° C for precipitation hardening of non-ferrous alloys, accuracy ± 2° C	X	
6	5	Cooling vessel for quenching media about 10,000 cm³ capacity	X	
7	5 sets	Thermo-elements with galvanometers	X	
8	2	Optical pyrometer	X	

D. Analytical chemistry of ores and slags

For 50 tests per day

1	2	Hammer-mill, for 200 g samples	X	E, F, no. 1
2	1	Ball mill, for 200 g samples	X	E, F, no. 2
3	2	Analytic sieve set, with shaking apparatus	X	
4	3	Analytical balance, up to 100 or 200 g	X	E, F, no. 4
5	1	Balance, up to 1,000 g	X	
6	1	Work bench (wet laboratory), with 8 working positions	X	Similar to E, F, no. 5
7	4	Standard combustion chamber (wet laboratory), with ventilation system	X	Similar to E, F, no. 6
8	2	Heating furnace, for 10 crucibles up to 1,000° C	X	E, F, no. 7
9	2	Heating furnace, for 10 crucibles up to 1,300° C	X	E, F, no. 8
10	1	Sulphur burning apparatus (System Marsh)	X	E, F, no. 9
11	1	Fluor distillation apparatus	X	
12	1	Automatic titration equipment, with 4 working places	X	E, F, no. 11
13	1	Spectrophotometer, in ultra-violet and visible spectra (186 mμ-3.6 μ), recording type	X	E, F, no. 13
14	1	Flame photometer, with oxy-acetylene burner, recording type	X	E, F, no. 14
15	2	Potentiometric titration equipment	X	

Position no.	Set or piece	Specification	Order of importance	Notes
16	4	Electroanalyseı, with turning anode	X	E, F, no. 15
17	1	Water-distillation apparatus or ion exchanger for distilled water	X	E, no. 20, F, no. 22
18	2	Drying chamber	X	E, F, no. 10
Expansion for 230 tests per day				
19	1	Work bench, with two working positions	XX	E, no. 21 F, no. 23
20	1	Combustion chamber, with exhaust	XX	E, no. 22 F, no. 24
21	1	Carbon cutter	XX	E, no. 23 F, no. 25
22	1	Turning lathe for carbon	XX	
23	1	Automatic spectrophotometer, with recording apparatus (Quantometer)	XX	E, no. 25 F, no. 27

E. Analytical chemistry of non-ferrous metals

For 50 tests per day				
1	1	Hammer mill	X	D, no. 1
2	1	Ball mill	X	D, no. 2
3	1	Turning, boring and cutting off machine for preparation of metal samples	X	
4	3	Analytical balance, up to 100 or 200 g	X	D, no. 4
5	1	Work bench (wet laboratory), with 6 working positions	X	Similar to D, no. 6
6	3	Standard combustion chamber (wet laboratory), with ventilation system	X	Similar to D, no. 7
7	2	Heating furnace, for 10 crucibles, up to 1,000° C	X	D, no. 8
8	2	Heating furnace, for 10 crucibles, up to 1,300° C	X	D, no. 9
9	1	Sulphur determination apparatus (System Marsh)	X	D, no. 10
10	5	Drying chamber	X	D, no. 18
11	1	Automatic titration equipment	X	D, no. 12
12	1	Polarograph P.O.4	X	
13	1	Spectrophotometer, recording type in range 186 mμ-3.6 μ	X	D, no. 13
14	1	Flame photometer, recording type	X	D, no. 14
15	2	Electroanalyser, with turning anode	X	D, no. 16
16	1	Metal enriching equipment with Hg-cathode	X	
17	1	Recording microphotometer	X	
18	1	Dark room outfit	X	
19	1	Spectrophotometer, with arc exciter	X	
20	1	Water-distillation apparatus	X	D, no. 17
Expansion for 250 tests per day				
21	1	Work bench, with 2 working positions	XX	D, no. 19
22	1	Standard combustion chamber, with exhaust	XX	D, no. 20
23	1	Carbon cutter	XX	D, no. 21
24	1	Turning, boring, and cutting off machine	XX	F, no. 3

Position no.	Set or piece	Specification	Order of importance	Notes
25	1	Automatic spectrophotometer, with recording apparatus (Quantometer)	XX	D, no. 23

F. Analytical chemistry of iron and steel

For 50 tests per day				
1	1	Hammer mill	X	D, no. 1
2	1	Ball mill	X	D, no. 2
3	1	Turning, boring, and cutting off machine, for preparation of metal samples	X	
4	3	Analytical balance, up to 100 or 200 g	X	D, no. 4
5	1	Work bench (wet laboratory), with 6 working positions	X	Similar to D, no. 6
6	3	Standard combustion chamber, (wet laboratory), with ventilation system	X	Similar to D, no. 7
7	2	Heating furnace, for 10 crucibles, up to 1,000° C	X	D, no. 8
8	2	Heating furnace, for 10 crucibles, up to 1,300° C	X	D, no. 9
9	1	Sulphur determination apparatus (System Marsh)	X	D, no. 10
10	5	Drying chamber	X	D, no. 18
11	1	Automatic titration equipment, with 4 working places	X	D, no. 12
12	1	Polarograph P.O.4	X	
13	1	Spectrophotometer, recording type in range 186 mμ-3.6 μ	X	D, no. 13
14	1	Flame photometer, recording type	X	D, no. 14
15	2	Electroanalyser, with turning anode	X	D, no. 16
16	1	Metal enriching equipment with Hg-cathode	X	
17	1	Recording microphotometer	X	
18	1	Dark room outfit	X	
19	1	Spectrophotometer, with arc exciter	X	
20	1	Ströhlein apparatus, for C determination	X	
21	2	Rapid photometer, in range 360-1,000 mμ	X	
22	1	Water-distillation apparatus	X	D, no. 17
Expansion for 250 tests per day				
23	1	Work bench, with 2 working positions	XX	D, no. 19
24	1	Standard combustion chamber, with exhaust	XX	D, no. 20
25	1	Carbon cutter	XX	D, no. 21
26	1	Turning, boring, and cutting off machine	XX	E, no. 3
27	1	Automatic spectrophotometer, with recording apparatus (Quantometer)	XX	D, no. 23

G. Non-destructive testing (defectoscopy)

1	1	Portable X-ray apparatus, maximum voltage 180 kV	X	
2	1	Portable X-ray apparatus, maximum voltage 120 kV	XX	Necessary only for thin (1-2 mm) plates
3	1	Portable isotope container for Co^{60} isotopes, with 1 Ci intensity	X	
4	1	Portable isotope container for Ir^{192} isotopes, with 20 Ci intensity	X	

Position no.	Set or piece	Specification	Order of importance	Notes
5	1 set	Dark room outfit for X-ray photographs	X	
6	1	Portable ultrasonic testing equipment	X	
7	1	Magnetic crack-testing apparatus	X	
8	1	As no. 7, portable system	XX	
9	1	Magnetic sorting bridge	X	

H. Training of welders

1	6	Arc welding apparatus (dynamo), maximum 350 A	X	
2	4	Apparatus for oxy-acetylene welding	X	
3	2	Apparatus for oxy-acetylene cutting	X	
4	10	Welding-desk, for nos. 1, 2, and 3	X	
5	1	Submerged arc-welding apparatus, maximum 1,000 A	X	
6	2	Shielded inert-gas welding apparatus, maximum 500 A	X	
7	1	Slag-welding apparatus, maximum 2,000 A	XXX	
8	1	Drying chamber, minimum 60 × 60 × 30 cm, temperature up to 150° C, for drying of low-hydrogen type electrodes	X	

J. Measurements in mechanical engineering

1	1	Measuring stand	X	
2	1	Universal length-measuring machine, e.g. Zeiss, gauge length 500 mm	X	
3	1	As no. 2, gauge length 1,000 mm	XX	
4	1	Universal measuring microscope, e.g. Zeiss	X	
5	1	Profile projector, e.g. Zeiss or Hauser	X	
6	3	Simple callipers, 170 mm, 500 mm, 1,000 mm	X	
7	2	Micrometer series, gauge length 0-500 mm, accuracy 0.01 mm	X	
8	2	Micrometer series, accuracy 0.01 mm	X	
9	1	Thread-measuring micrometer, with wire series	X	
10	1	Equipment for determination of eccentricity up to 500 mm (Run-out measuring equipment)	X	
11	1 set	Gauge block series, in range 0.001 mm, 0.01 mm, 0.1 mm and 1 mm up to 100 mm	X	
12	1 set	Gauge block series, up to 1,500 mm	X	
13	1	Gauge block clamping device, for checking of the hole-measuring instruments	X	
14	1	Micrometer, for measuring of holes	X	
15	1	Ultraoptimeter, for length measurement	XX	
16	1	Surface-roughness tester, with recording apparatus	X	
17	1	Universal gear testing machine, e.g. Zeiss or Klingelnberg	X	
18	1	Centre-distance measuring equipment	X	
19	1	Portable precision sound-level meter	XX	M, no. 15
20	1	Frequency analyser, for the range 20-20,000 c/s	XX	M, no. 16
21	3	Precision thermometer, accuracy 0.1° C	X	
22	1	Binocular microscope, magnification up to 50×	X	
23	2	Dynamometer: (a) up to 50 g; (b) up to 1,000 g	X	

Position no.	Set or piece	Specification	Order of importance	Notes

K. Electric and magnetic measurements

Position no.	Set or piece	Specification	Order of importance	Notes
1	1	Wheatstone bridge, with galvanometer	X	
2	1	Thompson bridge, with galvanometer	X	
3	1	Ultrathermostat, for the determination of temperature coefficient of electrical resistance	XX	
4	1	Portable equipment for electrical resistance measurement, e.g. Sigma test Type 2063, Inst. Dr. Förster, 0-0.5 MΩ; 5-60 MΩ; 20-30 MΩ	X	
5	1	Universal equipment for testing of magnetic properties: (a) Hysteresis losses; (b) Magnetic induction; (c) Coercitive force; e.g. Ferrograph Type 1032, Inst. Dr. Förster	X	
6	1	Eppstein apparatus for determination of hysteresis losses	X	
7	2	Apparatus for determination of coercitive force: (a) 0.1-100 oersted; (b) for magnetic hard materials 0-500 oersted	X	
8	1	Equipment for magnetic inductance measurement, 10,000-20,000 oersted	X	
9	1	Inductance and capacitance meter inductance 0-300 mH in six subranges, capacitance 0-30,000 μμF in three subranges	X	
10	1	Vacuum-tube voltmeter, d.c. voltages 1-1,000 V in six subranges, a.c. voltages 1-300 V in six subranges	X	
11	1	Vacuum-tube voltmeter, high sensitivity amplifier type, 3-1,000 mV in six ranges	X	
12	1	Megohmmeter, range 1-10^8 MΩ	X	
13	1	Impedance-meter, 1 Ω to 1.1 MΩ, 25 cps to 1 Mc frequency range	X	
14	2	Spot-galvanometer, for measuring millivolts and microamps	X	
15	4	Simple volt and ampere meter, not exactly specified, for common measurements	X	
16	2	Precision wattmeter, (a) single-phase model, (b) three-phase model	X	
17	1 set	Variable standard resistors	X	
18	1 set	Standard capacitors	X	

L. Mechanical testing of building materials

Position no.	Set or piece	Specification	Order of importance	Notes
1	1	Stone saw with disk	X	
2	1	Stone frame saw	X	
3	4	Concrete cube and concrete joist moulds, 10 × 10 × 10, 20 × 20 × 20, 30 × 30 × 30, 70 × 15 × 10 cm of edge length	X	
4	1 set	Tamping appliances or tamping machine	X	
5	1	Moulding equipment for bars (160 × 40 × 40 cm)	X	
6	2 sets	Test sieve set, (a) for concrete aggregates, (b) for sand, gravel and crushed materials	X	
7	1	Drying chamber, net volume *c.* 1 m³	X	
8	1	Freezing chamber to 28° C, net volume *c.* 1 m³	X	
9	1	Steam-heated furnace	X	
10	1	Universal tension and bending strength tester, maximum load 1,000 kp	X	

Position no.	Set or piece	Specification	Order of importance	Notes
11	1	Universal hardness tester for ball pressure and ball indentation test, maximum load 52.5 kp	X	
12	1	Universal hardness tester for metals	X	A, no. 11
13	1	Mortar mixer	X	
14	1	Bulk-weight measuring instrument with litre vessel and top vibrator	X	
15	4	Shrinkage measuring instrument	X	
16	1 set	Impact hardness tester (according to Smith)	X	
17	1	Compression press, 60 tons	X	
18	1	Compression and bending press, maximum load 300 tons	X	
19	1	Compression and bending press, maximum load 500 tons; transverse beam for width between supports from 500 to 4,000 mm; head clearance between the compression plates adjustable from 0 to 3,500 mm	XX	
20	1	Universal tensile testing machine, maximum load 50 tons	X	A, no. 1
21	1	Universal tensile testing machine, maximum load 5 tons		A, no. 3
22	1	Testing cylinder equipment for static testing of structural parts, about 6 m length; 4 cylinders, 20 tons maximum load each	XX	
23	2	Relaxation machine, maximum load 5,000 kp	XX	A, no. 25
24	1	Abrasion testing machine	X	
25	2	Balance, (a) for 1,000 g; (b) for 2,000 g	X	
26	1	(a) Strain gauge apparatus with oscilloscope and graphic recording, 25 strain sensitivity, (b) Checking equipment	X	A, no. 6
27	1	(a) Automatic selector to no. 26; (b) Level recorder to no. 26, e.g. Bruel and Kjaer	XX	A, no. 7
28	2	Precision extensometer	X	A, no. 26
29	1	Ring-force contact arm for checking the testing machines	XX	A, no. 14

M. Physical testing of building materials

1	1	High-pressure autoclave for testing the constancy of volume, maximum pressure 25 atm, *c.* 160 mm diameter × 380 cm^3 volume	X	
2	2	Air-content tester: (a) for concrete, 8 litre volume, (b) for mortar, 1 litre volume	X	
3	1	Water-proof tester	X	
4	1	Flow-table, e.g. according to DIN 1164	X	
5	1	Slump table, e.g. according to DIN 1048		
6	1	Needle or setting-time apparatus for cement		
7	1	Plastometer for testing the plasticity of clay and loam	X	
8	1	Specific heat tester		
9	3	Climate apparatus, temperature 0-100° C, humidity contents of air 10-100%	X	
10	1 set	Thermo-elements with galvanometer	X	
11	1 set	Temperature measurement apparatus with thermistors	X	
12	1	Apparatus for testing the heat conductivity	X	
13	1	Differential dilatometer, temperature range 0-900° C		
14	1	Standing wave apparatus for measurements of absorption coefficients and specific acoustic impedance	XX	
15	1	Precision sound-level meter (portable)	XX	J, no. 19
16	1	Frequency analyser for the range 20-20,000 c/s	XX	J, no. 20
17	1	Random noise generator	XX	

Position no.	Set or piece	Specification	Order of importance	Notes

N. Mechanical and physical testing of timber and paper

Position no.	Set or piece	Specification	Order of importance	Notes
1	1	Strength tester for load 5-50 kp	X	P, no. 1
2	1	Strength tester for load 100-5,000 kp	X	A, no. 3
3	1	Printability tester	XXX	
4	1	Paper-sizing degree tester	X	
5	1	Paper-smoothness tester, testing surface 10 cm^2	XX	
6	1	Folding tester, for determining the folding endurance of paper	X	
7	1	Fatigue bend-testing machine, for testing strips of paper, leather, plastics and metal foils	X	
8	1	Freeness degree tester, for the determination of the rate of de-watering of paper pulps, wood pulps and lignin	X	
9	1	Paper-sheet former and dryer, for sieve fractionation, the determination of the behaviour to dehydration and the manufacture of the paper sheet in one working process	X	
10	1	Stuff grinding and dispersing machine, volume about 10 litres, propeller speeds 1,000-3,000 r.p.m.	X	
11	1	Densometer, test area about 10 cm^2, partial vacuum variable between 0-100 mm W.G.	X	
12	1	Bursting strength tester for paper, pressure gauge 0-10 kp/cm^2	X	
13	2	Thickness gauge: (a) 0-10 mm; (b) 0-2 mm	X	
14	1	Drying chamber 0-100° C	X	
15	2	Balance, 0-100 g (analytical), 0-1,000 g (0.1 g sensitivity)		
16	2	Mechanical extensometer, accuracy 0.1-0.01 mm, for measuring the deformation of wood	X	
17	1	Microtome	X	
18	1	Microscope, 1,000 × magnification for wood and paper	X	
19	1	Climate apparatus, temperature 0-100° C, humidity content of air 10-100%	X	
20	1	Equipment for ultra-violet radiation for paper and wood	X	If possible, combined with no. 19

O. Organic chemistry

Position no.	Set or piece	Specification	Order of importance	Notes
1	2	Balance (analytical), 200 g (or 100 g)	X	
2	1	Balance, up to 1,000 g	X	
3	1	Work bench (wet laboratory), with 4 working positions	X	
4	3	Standard combustion (wet laboratory) chamber with ventilation system		
5	1	Heating furnace for crucibles (10) up to 1,000° C	X	
6	1	Heating furnace, for 10 crucibles up to 1,300° C	X	
7	2	Equipment for N_2 determination	X	
8	2	Burning apparatus, for organic materials	X	
9	2	Sulphur and arsenic determination apparatus (System Marsh)	X	
10	5	Drying chamber	X	
11	1	Polarograph, Type P.O.4		
12	1	Rapid photometer, in the range 360-1,000 mμ		

Position no.	Set or piece	Specification	Order of importance	Notes
13	1	As no. 4, with three working position (for polarographic room)		
14	1	Fluorometer, for determination of F content		
15	1	Electrolytic analysis equipment, for Cu, Zn, etc.		
16	2	Distillation apparatus		
17		Different laboratory glass wares, not specified here		
18	1	Water-distillation apparatus, or ion exchanger for distilled water		

P. Mechanical and physical testing of textiles

1	1	Strength tester for load 5-50 kp	X	N, no. 1
2	1	Strength tester for load 250-1,000 kp	X	
3	1	Strength tester for superfine single fibres, maximum load 100 g; magnification for optical reading of elongation 40-50 ×	X	
4	1	Thickness gauge	X	
5	1	Evenness tester	X	
6	1	Roving measuring equipment	X	
7	1	Twist counter, for threads and twines	X	
8	1	Abrasion tester	XX	
9	1	Balance for 100 g	X	
10	1	Balance for 500 g	X	
11	3	Torsion balance, for 10 mg; 50 mg; 1,000 mg	X	
12	1	Climate apparatus	X	N, no. 19
13	2	Drying chamber	X	N, no. 14
14	1	Microscope, magnification 1,000 ×	X	N, no. 18
15	1	Microtome	XX	N, no. 17
16	1	Balance for determination of weight/m^2 cloth	X	
17	1	Semi-automatic length tester for wood and cotton	X	
18	1	Apparatus for testing the elasticity of cloth	X	
19	1	Endurance tester	XX	
20	1	Equipment for ultra-violet radiation for textile materials	XX	N, no. 20

R. Mechanical and physical testing of leather, rubber and plastics

1	1	Ring-punching machine, in order to make rubber test rings	X	
2	1	Strength tester for maximum load 50 kp	X	N, no. 1
3	1	Strength tester for 500 kp	X	if N, no. 2, or A, no. 3 is an electronic loading cell type, it is applicable instead of this
4	1	Plastometer (Mooney), shear disk type	X	
5	1	Hardness tester, initial load 50 g, main load 1,000 g; die: ball	X	
6	1	Indentation hardness tester, for the determination of Shore A hardness of rubber and rubber-like plastics; die: cone	X	
7	1	Pendulum impact tester, maximum impact energy 400 kgcm	X	
8	1	Pendulum impact tester, maximum impact energy 20 kgcm	X	
9	1	Vicat needle apparatus	X	

Position no.	Set or piece	Specification	Order of importance	Notes
10	1	Equipment for the determination of glow resistance of plastic insulating materials	XX	
11	1	Martens dimensional stability tester under heat (for plastics)	X	
12	1	Shock elasticity tester	X	
13	2	Fatigue bend testing machine	X	
14	1	Abrasion tester, for rubber and rubber-like materials	XX	
15	1	Adhesiveness tester		
16	1	Plasticity tester, according to DIN 53514, for cylindrical test specimens, 10 mm diameter		

S. Food chemistry

1	1	Equipment for welding of plastics	X	
2	1	Cutting equipment, not specified	X	
3	1	Vacuum safe-locking equipment	X	
4	2	Balance (analytical), 200 g (or 100 g)		
5	1	Balance, up to 1,000 g	X	
6	1	Work bench (wet laboratory), with 4 working positions	X	
7	3	Standard combustion (wet laboratory) chamber with ventilation system		
8	1	Heating furnace, for crucibles (10) up to 1,000° C	X	
9	1	Heating furnace, for 10 crucibles up to 1,300° C	X	
10	2	Equipment for N_2 determination	X	
11	2	Burning apparatus, for organic materials	X	
12	2	Sulphur and arsenic determination apparatus (System Marsh)	X	
13	5	Drying chamber	X	
14	1	Polarograph, type P.O.4		
15	2	Rapid photometer, in the range 360-1,000 mμ		
16	1	Ultra-violet spectroscope, for absorption spectra		
17	1	As no. 7 (polarographic and photometric room)		
18	1	As no. 6 (polarographic with 3 working positions)		
19	1	As no. 6 (vitamin and enzyme room) with 2 working positions		
20	1	Fluorometer, for determination of F content		
21	1	Electrolytic analysis equipment, for Cu, Zn, etc.		
22	1	Scaler, for determination of radiation matter content		
23	2	Distillation apparatus		
24		Different laboratory glass wares, not specified here		
25	1	Water-distillation apparatus, or ion exchanger for distilled water		

Note. The total number of working positions is greater than the number of employees but the possibility of enlargement was taken into account.

Central workshop

1	3	Lathe, height of centres 200 mm, length between centres 500 mm		
2	4	Lathe, height of centres 100 mm, length between centres 300 mm		
3	1	Lathe, height of centres 200 mm, length between centres 1,000 mm		
4	2	Universal drilling machine, medium size		

Position no.	Set or piece	Specification	Order of importance	Notes
5	1	Horizontal shaping machine, medium size		
6	1	Vertical shaping machine, medium size		
7	1	Grinding machine, for test pieces up to 50 mm diameter		
8	1	Tool grinding machine		
9	10 sets	Callipers, up to 200 mm		
10	10 sets	Micrometer, accuracy 0.01 mm		
11	2 sets	Micrometer, accuracy 0.001 mm		
12	1	Drilling machine		
13	1	Simple shaying machine		
14	12 sets	Hand tools, not specified here		
15	2 sets	Soldering bit		

Note. It is assumed that the welding equipment is installed in laboratory H, precision measurement of test pieces or machine parts will be made in laboratory J, and electrical measurements will be made in laboratory K.

Summary and conclusions

Organization and equipment

1. As illustrated in Figure 2, the institute as a whole is equipped to test ores, iron and other metals, machine components, welded structures, building materials, timber, paper, and textile materialls, eather, rubber and plastics materials and food items, including their mechanical, physical, and chemical examination.

For chemical investigations, the metallurgy department, mechanical engineering department, and building materials department require approximately the same analytical facilities. Similarly, identical analytical equipment is required by the timber and paper department, textile industry department, and the leather, rubber and plastics department, and this equipment is essentially identical to that of the food and organic chemistry department as well.

Consequently, the institute may be developed as a single institution containing all nine departments, or it may be divided into two independent institutions. In the latter case, it seems reasonable to group the following departments in one of the two independent institutions: metallurgy, mechanical engineering, electrical engineering, building materials, and inorganic chemistry, Laboratories A, B, C, G, H, J, K, L, and M will also be included in this institute.

The equipment of the analytical laboratory should be chosen in accordance with the number of tests to be carried out. If the total number of samples to be analysed does not exceed 50 per day, laboratory-type D will suffice. If, however, the total approaches 250 per day, laboratory D should be constructed with the extension as projected. Either laboratory E or F is necessary if the number of samples is between 250 and 500, and both are required if the total is between 500 and 750. As indicated by the equipment specification of the chemical laboratories, the instrumentation of laboratories D, E and F is very similar; the difference between these laboratories lies in the number of instruments and stations provided rather than in the types. Evidently, where the number of iron and steel samples is predominant, it is reasonable to build laboratory F instead of D, whereas with a preponderance of non-ferrous metal samples the laboratory project E should be preferred. Only where the number of samples to be tested amounts to 750 per day, or more, should all three types be established together.

The other independent institute may include the following departments: timber and paper, textile industry, leather, rubber and plastics, and food and organic chemistry.

The chemical analysis requirements of these four departments are fundamentally identical; they may therefore be conveniently combined to form a single institute.

Accordingly, the two following variations may be suggested, each of which represents an economic solution: (a) a single institute comprising all nine departments, or (b) two separate institutions (any part of which may be omitted to conform to local conditions).

2. Wherever it is feasible, identical instrument types are specified for the different laboratories. A twofold purpose is served by the provision of interchangeable equipment. First, only one department need be fully equipped until the increased activity of the institute justifies expansion (e.g. equipment item A, 1 is identical to L, 20, etc.). Projected overlaps exist, primarily, among departments 1, 2, 4, and 5, 6, 7, respectively, making the classification under paragraph 1 most economical.

The other reason for preferably installing identical instrument types wherever possible is that the individual departments will be able to assist each other in case of break-down; and in addition, repair and maintenance will be easier.

3. Individual departments may be established inde-

pendently. It is possible, for example, to establish a metallurgy department entirely on its own, but its facilities will not be so well utilized as with either of the two variations suggested in paragraph 1.

According to experience gained in Central and Eastern Europe, the optimum number of staff for such central testing institutes is between 100 and 200. The co-ordinated control of organizations exceeding this size would be difficult, and the ratio of administrative personnel to technical staff might prove disadvantageous. Experience shows that the number of personnel who are only indirectly engaged in laboratory work (management, accounting, correspondence, guards, material handling, etc.) amount to 18-30 per cent of the total number of actively engaged laboratory staff (university graduates, technical assistants, skilled and unskilled workers).

4. The floor space requirements specified in the individual laboratory descriptions represent the net laboratory area. To this must be added the floor space required for management, administration and library premises, depending on the dimensions of the institute. The area thus obtained must be further increased by an allowance of 30-40 per cent for corridors, staircases, lavatories, wardrobes, storage of files, etc., depending on design conditions and local circumstances.

5. The central workshop specified in the second part of this report is designed on the assumption that all nine departments are to be established. If the project is to consist of two separate institutes as indicated in paragraph 1, the personnel of the central workshop is distributed, approximately, in the following proportions: 75 per cent for the institute consisting of departments 1-4, and 25 per cent for the institute consisting of departments 5-8.

6. Storage spaces are projected only for the chemical laboratory and for the central workshop. The dimensions of the eventual central storage of the institute depend on the legal stipulation of how long the samples must be kept after they have been tested. In line with the previous assumption that the institute would test samples submitted by customers, the only material to be stored will be the material for consumption by the chemical section and by the central workshop. This is why storage space is projected for these two facilities only.

7. Of the various types of equipment needed by the individual laboratories, only the most important items have been specified, that is, the most expensive equipment and also certain minor instruments which are indispensable.

In calculating investment costs, the specified and itemized instrument prices for the individual laboratories may be reckoned to cover about 75-80 per cent of the total investment for instrumentation. This means that the total expenditure required for instrument equipment will exceed the amount indicated by the specifications by a factor of 1.33 to 1.25.

General plan of a central testing institute consisting of nine departments

On the assumption that all nine departments are to be established in the central testing institute, and that the number of ore, metal and building material samples will not exceed a total of 250 per day, it is sufficient to make provision for the inorganic chemistry department laboratory plus extension D. Assuming, furthermore, that the number of food industry samples and the number of paper, leather, rubber and plastics material samples to be tested each day will not exceed fifty for each group on the average, the full-size inorganic laboratories S and O will have to be set up as well.

Summarized data for the complete institute, including all the nine specialized departments, are listed in Table 1.

This table contains the cumulative data on all necessary laboratories and also indicates the department which each laboratory is to serve. The figures in brackets in the second column indicate other departments whose activities the laboratory will be able to assist.

This review confirms that, if necessary, the institute may be divided to form two independent institutions (see paragraph 1 above).

The institute comprising nine departments will require the following administrative personnel and additional floor space:

Personnel	Floor area (m^2)
1 manager	36
1 secretary	16
10 administrative employees (accounting, purchasing, correspondence)	80
2 library employees	260
10 miscellaneous (guards, charwomen, etc.)	
—	——
24	392

The administrative offices should preferably be located in premises with a height of 3.5 m.

Accordingly, the total floor area of the institute is:

Clear height 3.5 m: 1,393 + 392	1 785 m^2
Clear height 4.5 m:	1 530 m^2
	3 315 m^2
Service area, according to paragraph 4, calculated on an average of 35 per cent	1 120 m^2
Total floor area of the institute	4 435 m^2

The total number of the engineering staff engaged in the laboratories (university graduates, technical assistants, skilled workers) is: 19 + 82 = 101; Floor space per technical employee: 4,435 ÷ 101 = 44 m^2, which is in good agreement with the empirical data given under the first part, 'General considerations'.

TABLE 1. Laboratories of complete institute of nine departments (according to Figure 2)

Laboratory		Department served	Floor space (m^2)		Personnel		
			Height 3.5 m	Height 4.5 m	University graduates	Technical Assistants & skilled workers	Unskilled workers
A	Mechanical testing (metals)	1, 2	46	300	2	4	2
B	Metallography	1, 4	121	—	1	2	—
C	Heat-treatment	1	—	40	1	1	—
D	Analytical chemistry,	9					
	50 samples per day		195	—	1	9	2
	Expansion of D for						
	250 samples per day	9 (1, 4)	46	—	1	2	1
E }	Only if samples	9	—	—	—	—	—
F }	exceed 250 per day	9	—	—	—	—	—
G	Defectoscopy	2, 4	61	104	1	2	1
H	Training of welders	2	—	60	1	4	1
J	Engineering measurements	2	66	—	1	3	—
K	Electrical measurements	3	72	—	1	4	—
L	Mechanical testing (building)	4	76	370	2	6	2
M	Physical testing (building)	4	—	180	1	3	1
N	Timber testing	5	116	—	1	4	1
O	Organic chemistry	8 (5, 6, 7)	126	—	1	6	2
P	Textile testing	6	156	—	1	6	1
R	Leather testing	7	136	—	1	4	1
S	Food chemistry	8	176	—	1	6	2
	Central workshop	10 (all other departments)	—	476	1	16	2
	TOTAL		1 393	1 530	19	82	19

The total number of technical assistants, skilled and unskilled workers assigned to laboratory work amounts to 82 + 19 = 101. The ratio of this figure to the total number of university graduates (19) gives 101 : 19 = 5.3 which closely approximates the 1 : 5 lower limit specified in the first part. Both indices, the floor space per technical employee, and the ratio of the number of university graduates to that of other laboratory personnel, reveal that the total number of technical assistants and unskilled workers may be increased by, say, 10-20 per cent, without requiring any change in the floor area provided.

The cumulative data of the institute composed of nine departments are as follows:

Total floor area		4 435 m²
Building volume:		
Clear height 3.5 m	6 250 m³	
≃ 35 per cent (for service area)	2 220 m³	
		8 470 m³
Clear height 4.5 m	6 850 m³	
+ 35 per cent (for service area)	2 400 m³	
		9 250 m³
Total building volume		17 720 m³

Personnel	
Management, library, administration, and non-laboratory auxiliary staff	24
University graduate laboratory staff	19
Technical assistants	82
Unskilled workers	19
Total number of employees	144

The ratio of those indirectly engaged in laboratory work to those assigned to direct laboratory activities amounts to 24 : 120 = 20 per cent, representing a reasonable figure.

Dividing the testing institutes into two institutions as described in paragraph 1 will result in somewhat less favourable performance indices. The total construction costs of the divided institute would be only about 5-10 per cent greater than that for the combined and unified institute. On the other hand, if single departments are established as independent and separate units, this would considerably increase the total costs of construction and instrumentation alike.

Appendix

Governmental and institutional organization of testing establishments

Industrial research and testing institutes in the Central and Eastern European countries, as developed since the war, can be divided into four categories:

1. Institutes primarily intended to deal with the basic sciences, including (a) institutes under the supervision of an academy of sciences; and (b) university laboratories working either under an academy or some appropriate ministry.
2. Industrial research institutes concerned with the development of a branch of industry and working either under the supervisory authority of a ministry or of an authority representing the central laboratories of major trusts or undertakings.
3. Plant laboratories undertaking only routine test work or the development of the product and production technology in individual plants.
4. Central test laboratories which do not undertake research or development but are employed on product and material control. They deal with measurements and tests officially required but take on also commissions for fees.

All four types are financed by government through the ministries or trusts to which they are responsible, but the expenditure on plant laboratories is taken care of by the operating companies.

The end of the Second World War marked a stage in the development of the laboratory network of the Eastern European countries. Before the war there were generally only two types of laboratory. Most belonged to individual factories and worked on research and development and testing. Hardly any State-supported central laboratories existed save those working in fields of little or no direct industrial interest—meteorological or geological institutes, for example.

However, nearly all those countries had central testing laboratories supported to a certain extent by the government but with the rest of their costs covered by charges for services to private industry. Their duties included the inspection of industrial products made to government order, and they also worked for factories which, not having their own laboratory facilities, paid for this service according to fixed tariffs.

Scientific research activities were conducted mainly in university and plant laboratories. University laboratories made inspections also if commissioned.

Industrial or professional research institutes—the general description covers a wide variety of establishments—have been developed at a very rapid rate in the Eastern European countries since the war. They all have in common that they undertake the scientific research work called for by individual branches of industry. Thus their specializations vary considerably from country to country, according to the degree of industrial advancement or other local considerations.

There is, for example, in the German Democratic Republic a separate Central Institute of Welding—Zentralinstitut für Schweisstechnik. In other countries, e.g. Czechoslovakia, with its Vyskumny Ustav Svarky, welding research is carried out in institutes that cover other specialities as well. Generally, these industrial research institutes deal with the development targets of the appropriate branches of industry and their costs are met by the government and by allocations from the industries concerned. They may, however, take on also other work for companies and meet requests to develop technological processes or individual products.

In the U.S.S.R. the history of industrial research institutes is generally longer. They have been developed gradually since the early 1930s. In type, and in the scope of activity they engage in, these establishments—representing central research institutes of the several industries—carry out the same kinds of work as do the comparable institutes in the other socialist countries. In addition, they set up their network of academy research institutes for the development of basic sciences. Essentially the same objective is served by the university laboratories established in the first place for educational purposes. Factory laboratories are there to carry out the test and development work for the plants with which they are immediately associated, but the duties and significance of the State-sponsored test laboratories have been modified to a considerable extent. The whole range of research institutions can thus be classified under the four headings set out at the beginning of this appendix.

While all the Central European countries have their central testing stations, there is a good deal of variety in their organization. In Hungary, for instance, all testing laboratories are accommodated in a single building. In the German Democratic Republic, on the other hand, there is a much more complex organization spread over the whole country, the Deutsches Amt für Material und Warenprüfung. This body is divided into nine departments dealing with metallurgy, mechanical and electrical engineering, technical chemistry, architecture, the textile, leather, timber and food industries. In these nine departments there are sixty-two laboratories or testing stations, forty-three of them are under the authority of the institute and nineteen belong to other institutions, though professional supervision for them comes under the central body. The laboratories are located in twenty-two cities.

In Hungary, where pre-war industry was largely concentrated around Budapest, the Hungarian Commercial Quality Control Institute, in its single building and dependent on other organizations only in a few professional fields, has departments dealing with: (a) machines, metals, precision mechanics and the vehicle industry; (b) the rubber, plastics, leather and shoe industries; (c) the textile, paper and furniture industries; (d) agriculture; and also a physiochemical laboratory; and economy and management. There are further sub-divisions of laboratories inside this framework.

Duties of central test stations

The duties assigned to the central testing stations vary a great deal from country to country. An institute of the widest range would have the tasks described below.

Prototype tests. No product may be marketed until prototypes have been tested by the institute and judged suitable for consumer use. This applies alike to domestic and foreign manufactures. Identical control examinations are required for commodities whose materials or production technology have been modified since the introduction of the original prototype.

The institute performs random sampling of products already on the market and reports changes in quality to the government authority concerned.

At the order or request of the ministries concerned, the institute carries out laboratory tests of certain products or materials and, if required, presents official comments on the results.

On request, the institute renders professional advisory services to companies on the quality specification of products.

The institute assists in deciding disputes concerning the quality of products. In cases of dispute between domestic commercial organizations, the official opinion of the institute is decisive as to quality.

Commodities forming the subject of complaint by private purchasers will be tested by the institute if the complaint can be settled only by laboratory tests. The professional opinion of the institute must be accepted as binding by all parties concerned.

The institute maintains the register of marks and is responsible for the continuous quality control of trademarked products.

Finally, the institute co-operates and uses its expert facilities in setting up standards where standardization of products for the market is to be carried out.

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