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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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Development of Metalworking Industries in Developing Countries

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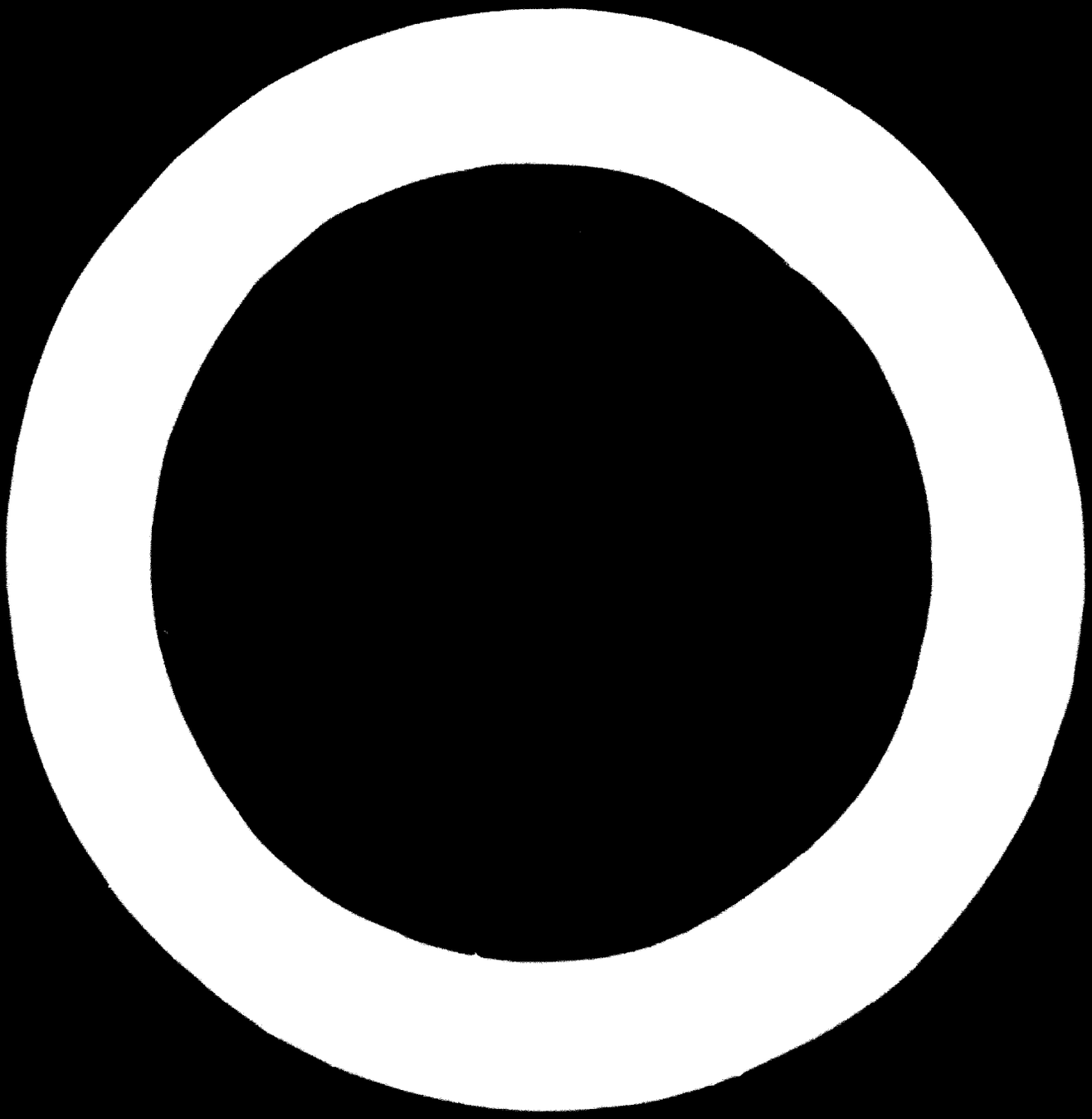

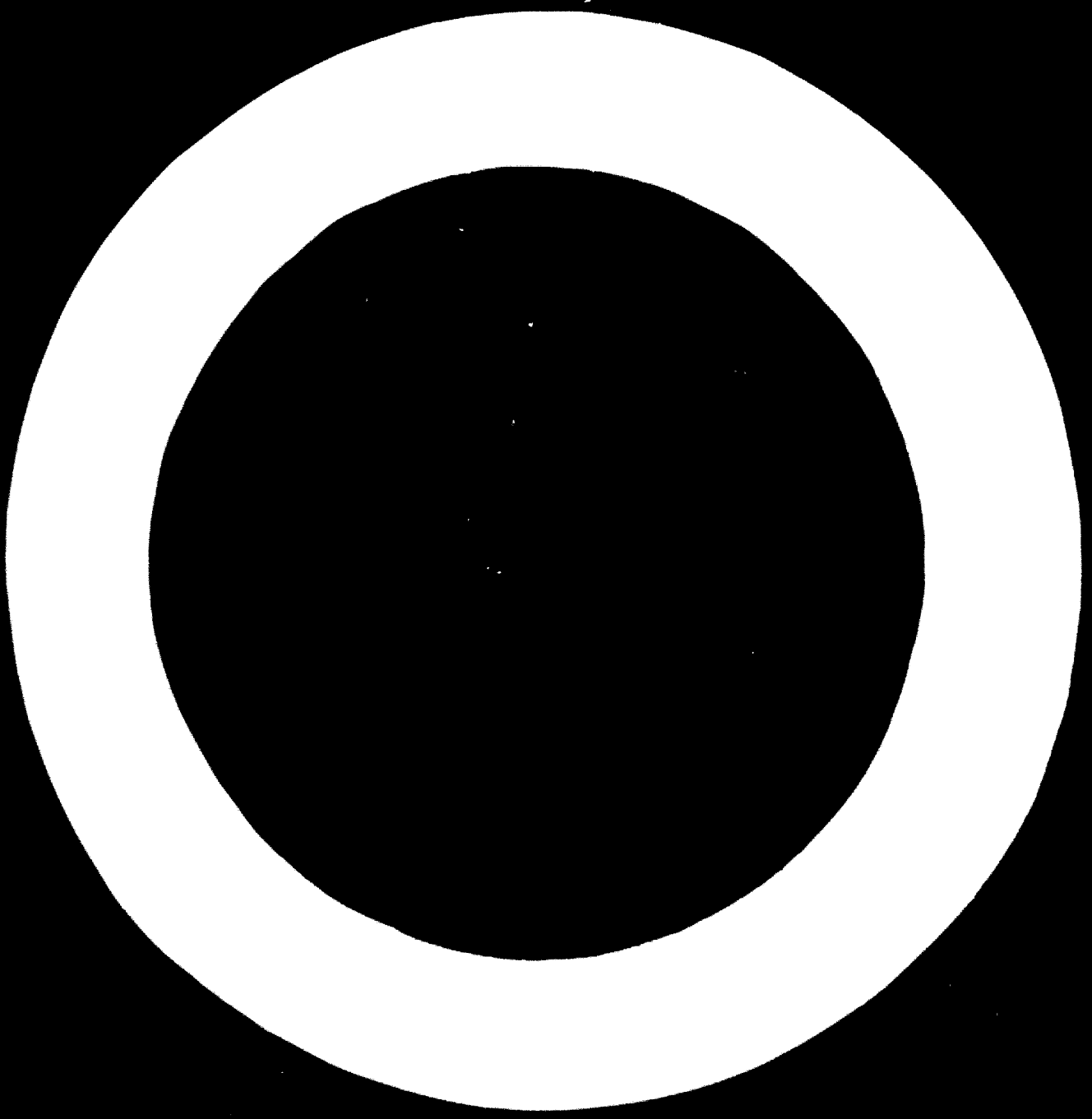

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MAIN TRENDS IN DEVELOPMENT AND ORGANIZATION OF DESIGNING AND RESEARCH WORK IN MACHINE-BUILDING INDUSTRIES OF DEVELOPING COUNTRIES

I. S. Vasiliev, Research Director, Experimental and Research Institute of Metal-cutting Machines, Moscow, Union of Soviet Socialist Republics

INTRODUCTION

Science is assuming an ever-increasing importance and governs, to a large degree, the progress and standards of organization of modern production. The rates of industrial development would be considerably lower, while greater effort and more money would be spent if it were not for the scientifically based organization achieved through research, which is carried out in all modern fields of production and marketing. Of special importance is the proper organization of research in the metal-working industries, where the cost of the means of production is very high. It is necessary to make large expenditures on up-to-date equipment which will be efficient only if the entire production process is duly organized, the tools and fixtures are of good quality, the speeds and feeds are chosen correctly and the servicing workmen are highly skilled. Each of these problems involves a series of other problems whose solution requires highly skilled operators, technicians, engineers etc. The urgent problem currently facing the developing countries is the lack of properly trained craftsmen and engineers.

It is only natural that the organization of designing and research machine-building establishments should be based on the standard achieved by a particular industry in one or another country. Such an organization is planned to provide the developing country with what it needs in this field with the minimum expenditure and with research and designing workers being used in the best way possible. With the development of a machine-building industry, the trained personnel should be qualified in more specialized trades, while the research and designing machine-building centre should gradually be divided into a number of specialized independent research establishments set up for servicing those machine-building branches which have been developed in a particular country.

The most important integrants of this process are: training nationals of the country as research and designing personnel; instructing them in more and more special branches of machine building; and raising the grades of such personnel. This calls for close links between the research establishments and technical colleges of the country, especially at the beginning stages of development of the industries.

At the first stage, much importance should be attached to providing help to industrial enterprises in mastering foreign-made equipment, solving certain technological problems, designing and tools and accessories and attachments, adjusting the machines and their controls etc.

With the industry gaining strength in the country and with the development of machine-building by nationals, new problems will receive priority, for example: working out designs by nationals of the country for certain machines; elaborating technological processes for their manufacturing; providing research work aimed at investigating the performance of the machines, perfecting the technological processes performed by them; seeking ways to raise the efficiency of the machines constructed.

The structure of the research and designing services proceeding from the machine-building prospects may be described as follows:

(a) *Stage I.* A training technical institute whose laboratories and skilled personnel render assistance and give advice to the industrial people on some questions;

(b) *Stage II.* A United research machine-building centre which is independent of the training institute (college). This centre designs machines for the entire machine-building branch, investigates the processes and studies some of the mechanisms at the request of enterprises, renders technical assistance in mastering complicated foreign-made equipment and foreign technological processes and supplies the enterprises with technical and economic information on the latest achievements in the fields concerned. The personnel of the research institute take part in the work done by the engineering colleges;

(c) *Stage III.* A united metalworking centre and individual centres in machine-building branches which produce equipment for processing and mining industries. This centre is specialized in certain types of machines, while its laboratories are engaged both in technology and in the creation and investigation of special types of equipment. They also render assistance to industrial enterprises;

(d) *Stage IV.* Research centres servicing individual machine-building branches and designing and research services established at enterprises. Such centres concentrate on investigating promising technological processes, control systems, machine units and components. The centres also supply information to those who are interested. The designing services of the enterprises are given practical tasks in the creation of new machinery and the supervision thereof.

Each particular country will proceed from its own level of development when selecting its research and designing services. An analysis of experience gained by the countries shows that the above-described methods of organizing research and designing jobs have a practical application under the following levels of development of industries.

The figures shown in Table 1 are, to a large extent, arbitrary and can provide only an approximate idea. Depending upon the conditions found in each particular country, certain departures from the data in the table may be expected. When reading the table, one should bear in mind that the lower quantities prove to be more realistic in the countries with State planning practices, while the higher ones are more characteristic of the countries with more highly developed private initiative. The reason for this is that, in the first case, all the country's specialists gather in one centre and service the enterprises of the given industry. In the other case, many specialists, from 50 to 75 per cent, are scattered among individual enterprises; the research centre proves necessary only for a well-developed industry and is used for tackling the most difficult problems which are beyond the capacity of an individual company and call for the concentration of efforts in related sciences.

It may prove useful if several countries of a common economic region organize united centres for the benefit of all of them, until their industries reach a high level of development.

Table 1

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Number of machine tools (thousands)	Less than 10	10–50	100–200	More than 500
Estimated national annual production of machine tools (millions of dollars)	Less than 5	5–10	15–50	More than 100
Estimated annual production of machine tools *per capita* (dollars)	Less than 0.1	0.1–0.5	1.5–2	More than 3.0

I. LABORATORIES OF TRAINING INSTITUTES

Along with training qualified craftsmen, the polytechnical colleges can be considered primary units capable of rendering technical assistance to the industries. Such assistance may take the following forms:

(a) The enterprises may consult the laboratory on calculations, designing and maintenance of the machines, their controls and drives, manufacturing processes, designing of jigs and fixtures, labour organization, etc.

(b) The laboratories may fulfil some orders of the enterprises related to workability of materials, machining rates, manufacturing processes and tools, jigs and fixtures to be used, machine adjustment, drives and controls, etc.

(c) The laboratory may make up reference tables or other reference materials on various questions;

(d) Suggestions on standards and standard specifications may be prepared;

(e) The laboratory may work out, make and adjust instruments;

(f) Workmen at the enterprise may be instructed in maintenance rules and the handling of complicated machines and instruments.

Table 2 shows a representative structure of an institute with such laboratories. The names of the departments of the processing and mining industries are arbitrary. Actually, such chairs will vary from country to country.

Table 2

REPRESENTATIVE STRUCTURE OF A POLYTECHNIC INSTITUTE

Mining industries department	*Processing industries department*	*Metalworking technology department*	*Machine components department*	*Drives and controls department*	*Technical measurement department*
Oil, gas and oil equipment laboratory	Textile technology and equipment laboratory	Metal-cutting laboratory	Machine components and mechanical drives laboratory	Electrical engineering laboratory	Metrology laboratory
Machine work and equipment laboratory	Food technology and equipment laboratory	Stamping laboratory	Hoisting and mechanical handling equipment laboratory	Hydraulics laboratory	Mechanical, electrical and electronic measurement laboratory
		Heat-treatment laboratory			

depending upon the particular industries for which specialists are being trained.

The metalworking processes department and its laboratories would be responsible for solving practical tasks faced by the developing country.

It would be advantageous if the machine-components department had either two laboratories, as shown in table 2, or one laboratory if experts were lacking at the moment and those available could not devote themselves to more specialized subjects. A laboratory for mechanical handling equipment could serve as a primary unit which would subsequently train specialists in construction machines, loading machines for seaports and roads, road-construction machines, mechanical handling etc.

The name "Drives and controls department" is rather arbitrary. This department would attract electrical engineers, engineers on electrical motors and controls, and specialists on hydraulic pumps and hydraulic drives for machines. Since such drives are to be found in a great variety of machines and all of them have very much in common, it would be expedient if, at first, the laboratories were closely connected so that practical tasks could be solved comprehensively and reasonably economically.

One cannot very well imagine the production of modern machines without first solving a number of measurement problems and those of inspection of individual components and assemblies. It follows, therefore, that due attention should be paid to developing the means of linear and angular measurements; this is usually done by the metrology service. Of no less importance is the measurement of other values: force, pressure, liquid consumption, amperage and voltage, power, speeds, acceleration etc. The latter tasks would be the domain of the other laboratory, which should provide uniform measurement practice throughout the country and should supervise the condition of measuring means used at the enterprises. The laboratory would also render necessary technical assistance should an enterprise encounter a complicated type of measurement calling for some special devices (measuring noise, vibration etc.) or it were in need of a scientific approach to obtain correct results (measuring wear and tear, thermal strains etc.).

Brief as the foregoing list is, it shows the wide scope of the problems which could be handled by the laboratories for the benefit of enterprises.

Each laboratory may employ from five to fifty people.

II. United Research Machine-building Institute

A united research institute can deal with a wide variety of problems. In addition to the jobs done by the college laboratories, such an establishment can carry out the investigations described below.

A profound study can be made of the technology of the processing and mining industries developed in the given country. The objectives of such an investigation would be to adapt the experience gained by the rest of the world to local conditions, to search for new economic and efficient processes, to utilize by-products, to improve technological equipment and study the best conditions for its maintenance and repair, and to develop new articles and processes.

The institute may undertake the development of metal-working processes as a part of comprehensive problems while concentrating particularly on heat treatment, as related to properties of materials, blanking operations, forging and casting. More attention will be given to machining the parts by cutting, especially to finishing processes. Large-batch manufacturing on production lines, assembling and adjusting machines etc.

The institute may become the first establishment in the country to work out its own designs of machines for the most important industries, farming and transport machinery. With this aim in view, its organization should include a designing office. This will, in turn, be subdivided into offices according to the types of machines whose production is planned in the country (e.g. textile machines, food-processing machines etc.). Such an organization will allow the designers to use their abilities to the best advantage. It will also facilitate the training of young specialists by permitting them to share in the creation of efficient units and mechanisms of machines, and in the working out of designs with good manufacturing qualities; by teaching them the rules for assembling and adjusting the machines, and the methods for achieving planned capacities; and by their observation of the instruction of production people in correct working methods and the reasonable management of production. Gathering the designers, at the first stage, within one centre will allow correct provision of the enterprises with standards and standard specifications for parts, components and basic parameters of machines, which are indispensable prerequisites for organizing centralized manufacturing of the parts common to most machines. This will conserve the means for both making new machines and maintaining the existing ones through an essential decrease in the prime cost of machine components by reducing, in the first place, the number of fixtures required and, secondly, through the better methods which are possible under the conditions of centralized manufacturing.

Technical tasks concerning the further improvement of components and units should be entrusted to special sections under the guidance of one department. One of the laboratories should be concerned with mechanical parts or elements for drives, e.g., fixtures, fittings, geared and belt drives, bearings, reduction units, speed and feed change gear-boxes etc. It will render skilled assistance in this field to enterprises and to sections of the institute, while designing, calculating, testing and adjusting all these devices. The other laboratory should be engaged in similar work, but its field will be electrical motors, which will include not only motors, but also controls, electrical apparatuses, rules for mounting and maintaining electrical equipment and energy systems. This body will be a basis for further development of most branches of the electrical motor manufacturing industry and of power engineering, and will later provide a basis for creating an independent organization having more specialized tasks in this particular field.

The field of the third laboratory will be hydraulics, hydraulic engineering and hydraulic drives, which currently comprise a well-developed branch and are applic-

able in a wide range of industrial and farming machinery. Development of machine building is largely dependent upon hydraulic drives, whose moderate-sized and comparatively light-weight power units provide considerable working efforts. Because of their flexibility and high reliability, hydraulic controls are preferred to electrical ones under difficult working conditions.

Modern methods for the design of machines are based on a profound theoretical knowledge and employment of computers. Since these problems are specific, while the regularities of computation practice are common to many machines, it will be quite reasonable to gather computing specialists and means at one centre with the capacity to service all the sections of the institute and thus to fulfill the orders of the enterprises. Such a centre should employ specialists in metal fatigue and strength, dynamic-load calculations, vibrations, stability and automatic adjustments, calculations of optimal processes, mathematical statistics and probability theory subjects which find application in many modern industries.

The measurement service should be duly organized from the very outset. The measuring laboratory will be responsible for introducing uniform basic physical measuring units throughout the country and, especially for ensuring that the enterprises use uniform measures and that their measuring equipment operates properly. To this end, the laboratory should be equipped with accurate measuring means which have been declared fit for work after being compared with the appropriate standards.

Other important tasks which will be faced by the laboratory will include working out the correct methods for taking measurements, giving certificates for various items in industries and helping the enterprises to take measurements calling for special instruments and highly skilled operators.

Table 3 shows an approximate organizational structure of the centre, giving a general idea of how such a centre can be organized. Local conditions will, no doubt, call for some alterations in the structure. At first, when the centre employs a staff of 100 persons or fewer, the laboratory can function with four departments. With the extension of the centre, its structure will be subject to further differentiation.

The activity of the research centre will be fruitful if it is given a pilot enterprise which can build the products according to the institute's blue prints and make necessary stands and instruments. In this way, the centre will be able to introduce all possible improvements into the design of a new machine and the models intended for the industries will be thoroughly tested before being suggested for operation at enterprises. This will contribute to smooth co-operation between the research centre and the enterprises. The staff of the pilot enterprise should correspond to that of the research centre, and the enterprise should be equipped with facilities allowing production of the main machines while reasonably utilizing the help of the industrial enterprises.

With the growth of the country's industry, the centre will gradually extend. At some stage, when the staff of the centre is about 1,000, it should be divided into a number of specialized research organizations, while independent centres will be established for servicing the producing and mining industries. One of the first independent centres to be isolated from the others will be the metalworking research institute.

III. Metalworking research institute

Table 4 shows an approximate structure of such a centre. At this centre, the specialization will go further and investigation into certain types of metalworking processes will be undertaken.

The technological department will employ specialists in metal cutting, who will study cutting rates and workability as related to various metals and the elaborate manufacturing processes to be applied in the production of

Table 3

Representative structure of a united machine-building institute

Technological department of industries	*Metal-working technology department*	*Designing office*	*Units, drives and controls department*
Textile manufacturing process laboratory	Machine-cutting process laboratory	Textile machines: designing office	General machine-building units and components laboratory
Food-manufacturing process laboratory	Forging and casting process laboratory	Food machines: designing office	Electrical equipment and instruments laboratory
Electric-motor manufacturing process laboratory	Metals, heat-treatment and welding laboratory	Hoisting and road-construction machines: designing office	Hydraulics and hydraulic-drives laboratory Engineering calculations and machine-testing laboratory
Hoist and road-construction manufacturing laboratory	Plastics, oils, paints and electroplatings laboratory	Metal-cutting machines, forging and casting equipment laboratory	Metrology and measuring means laboratory
		Standards and scientific information office	

Table 4

REPRESENTATIVE STRUCTURE OF A METALWORKING RESEARCH INSTITUTE

Metalworking technology department	*Designing office*	*Units, drives and controls department*	*General metalworking department*
Metal-cutting laboratory	Metal-cutting machines: designing office	Standardized units laboratory (couplings, bearings, reductors, guides)	Laboratory for business conditions and engineering and economic studies
Forging laboratory	Forging presses: designing office	Electrical motors and controls laboratory	Standards, patents and information office
Metals, heat-treatment and welding laboratory	Tools and dies: designing office	Hydraulic drive, apparatus, lubrication and filters laboratory	Machine calculation and testing laboratory
Casting-technology laboratory	Casting, heat-treatment and welding equipment: designing office	Jigs, fixtures, accessories and attachments laboratory	Metrology and measuring means laboratory
			Plastics, paints, electroplating and chemical laboratory

machine parts—casings, bodies, gear-wheels, bushings, sleeves, levers, brackets etc.—as well as of special parts ordered by enterprises. This body will also have specialists in the forging and casting processes. The laboratory should undertake further development of metals and heat treatment, as the scope of its investigations grows.

At that stage, the designing office will have designers who are concentrating on metal-cutting machines, while others will specialize in forging equipment. A special group should be set up to deal with cutting tools and dies: this group will not only design and improve the all-purpose tools, but will also handle the special-purpose tools ordered by the factories. Still another group will deal with heat-treatment and casting equipment.

The department of units, drives and controls will, for the most part, retain its structure, but it also will become more specialized. Thus, the electrical-engineering laboratory will no longer deal with power-plants: instead, it will concentrate on developing motors for metal-cutting machines and their controls. This will encourage the automation of many processes and the independent tackling of more complicated problems. The laboratory for hydraulic drives will devote itself solely to developing and improving the hydraulic drives used in metal-cutting machines. The drives will be constantly improved, the operation of the systems will be made more stable and more attention will be paid to lubrication and oil-cleaning, and to other questions.

It will then be necessary to organize a laboratory for jigs, fixtures and accessories, which will work out the designs for the centralized manufacturing of all-purpose jigs and fixtures, and which will fulfil orders of certain enterprises for special jigs and fixtures and similar articles.

The department of general metalworking problems will be occupied with solving the problems common to the entire metalworking branch. This department will collect information on machine tool building practices throughout the world, and on specifications of machines, price lists, costs and performance, as well as other economic and technical data required for the proper orientation of those who develop the equipment for the metalworking industry in a particular country while basing it on economic and technical considerations.

The standards laboratory will study the experience gained in industrialized countries, analyse the features pertaining to the country concerned and use the data obtained from these studies to prepare the standards and permissible norms valid for the particular country. This laboratory also will supply the industrial enterprises with generalized and selected information materials on the most important achievements of each particular enterprise.

The laboratory for calculating and testing should render assistance to the enterprises in making the most complicated calculations requiring special knowledge in the theory of elasticity and strength of materials, vibration theory, stability theory and automatic adjustment, or in the event that the calculations require the use of computers. The same laboratory should help the enterprises to test and to examine thoroughly new machines, its role being mainly in working out the necessary methods and in supplying the enterprises with the instruments needed for the purpose.

The measurement laboratory will fulfil both the assignments of the institute and the orders of the factories, helping them to solve their measurement problems.

The quality of the metalworking equipment is largely dependent upon the proper selection of varnishes, paints and grades of electroplating, and on the methods used for coating the machine surfaces therewith. This is especially true for tropical countries. The same requirements apply to the selection of plastics, protection slushing and films to prevent the parts from corrosion and to ensure their good appearance. All these problems are a source of work for a special laboratory.

Thus, the structure of the research centre reflects the main problems to be solved. The staff of an institute can

vary from 150 to 600. It is very important that the pilot enterprise should be attached to such an institute, the staff of the latter being approximately equal to that of the institute. The pilot enterprise will have to construct the machines designed at the institute.

IV. Research Institute of Metal-Cutting Machines

With the further development of industry, and especially of the metalworking branch, in a particular country, with a rather developed machine tool industry having about ten factories, it may prove reasonable, especially with an aim of employing the best designers available, to establish a special institute of metal-cutting machines.

Table 5 shows a representative structure of such a metal-cutting institute. One alternative way is to set up a few other research centres; thus, in addition to the institute of metal-cutting machines, a centre of forging and metal-cutting machines can be established, whose activities will cover more than one production sphere.

The main feature of the structure shown in table 5 is deeper specialization of engineers, technicians and researchers.

At this stage, a laboratory engaged in the entire complex of technological problems involved in the production of machine tools, along with laboratories of metals and heat-treatment, and of measurement will deal with the problems peculiar to machine tools. Thus, more importance will be attached to the problems intimately associated with machine tools, i.e. to stabilizing the sizes and shapes of parts and to raising their wear resistance, while less attention will be given to such problems as strength of materials.

The designing office will comprise a few laboratories specializing in certain groups of metal-cutting equipment. It is essential that one compartment should unite the specialists engaged in improving some types of machining jobs (turning on a lathe, boring, milling, etc.) and the specialists designing the equipment intended for performing such operations. There is no doubt that there must be close everyday links based on creative activities of the specialists of the two groups if the institute is to aim at achieving appreciable advances in various types of machining.

Jigs, fixtures and tools provide sufficient reason for setting up a separate laboratory since similar jigs and fixtures and tools can be applicable to various types of machines and are based on some common subjects, such as the material from which the tools are made, heat treatment, the geometry of the tools' lips as a factor of the material to be worked, tool grinding etc.

The laboratory of machine units and components will be concerned with its own problems, as in the previous case.

The staff of the department of general machine tools building problems will concentrate on approximately the same questions studied in the similar department of the metalworking centre, but the problems referring to metal-cutting machines will be given priority.

In this case, a pilot plant will also be necessary, so that the machine tools designed at the institute may be constructed under the direct supervision of the institute.

The staff of the institute should be at least 200 people.

V. Relations between Research Institute and Industrial Enterprises

Organizing research centres is the first step to be taken on the path of development of engineering services in industry. With the development of production and the quantitative growth of engineers and technicians, care should be taken that not only are research centres organized but also that the enterprises' services are established and that this comprise designing and technological offices directly at the plants. These services should gradually take over the management and provision of routine production. Such services will, of

Table 5

Representative structure of a research institute of metal-cutting machines

Technology department	*Designing office*	*Units, drives and controls department*	*General machine tool building department*
Machine tool building technology laboratory	Lathe machines and technology laboratory	Laboratory of standardized units (spindle bearings, guides, couplings, reductors)	Laboratory for investigation of business conditions and engineering and economic data
Machine tool metals and heat-treatment laboratory	Boring machines and technology laboratory	Laboratory of electrical motors and controls for machine tools	Machine calculation and testing laboratory
Metrology and measuring means laboratory	Milling and planing technology and machines laboratory	Hydraulic drives and lubrication laboratory	Standards, patents and technical information office
	Abrasion technology and machines laboratory	Cutting tools, jigs and fixtures, accessories and attachments laboratory	
	Gear-cutting technology and machines laboratory		

course, receive help from the research centres when dealing with the construction of new promising machines, solving most complicated designing and technological problems, investigating in machines, adjusting intricate controls etc.

It will be found that various activities of the research centre will prove helpful for enterprises. To what degree the enterprises will be interested in the institute's activities and in what way they will pay for the jobs done by it will depend upon each particular type of activity. The latter can be classified as follows:

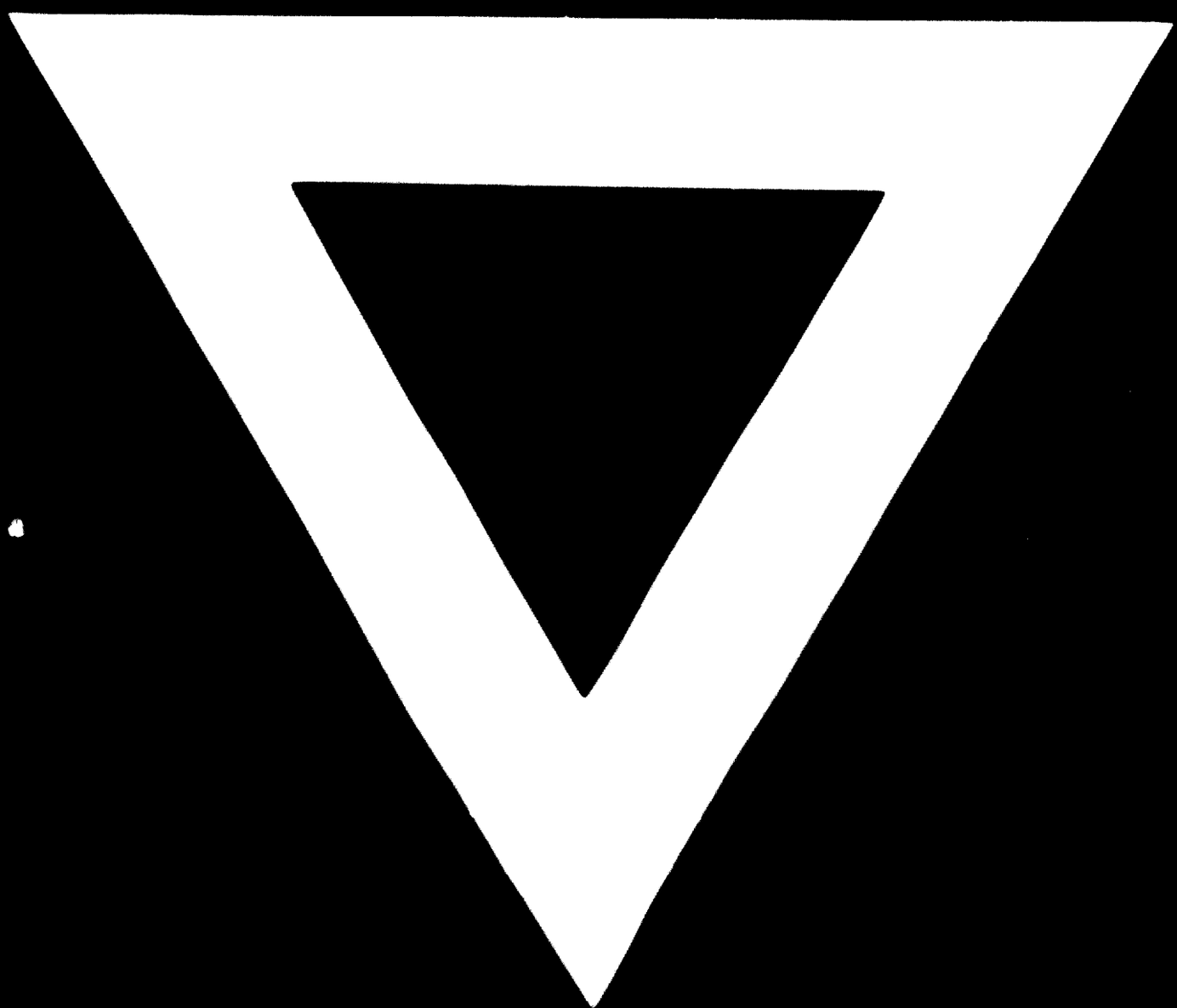
(*a*) General information on business conditions of the world machine-building industry, achievements in machine building, standards and norms assumed for the basic parameters and general calculation methods, working out of general-purpose units and components, working out of cutting rates etc. All these problems are of interest to the machine-building branch as a whole and, as such, must be financed either by the Government or by certain State establishments supervising the given branch, or else by collected fees if the enterprises are affiliated to some association and the research centre is a part of it;

(*b*) Investigation into development of a certain group of machine tools which are produced by a few enterprises of the country, designing of units for this group, new technological processes, new tools or jigs and fixtures etc. These problems concern only certain enterprises and, as such, must be financed by their joint efforts;

(*c*) Finally, some jobs may be confined to the products and machining methods found at one enterprise only. These jobs should be financed by the enterprise concerned.

In this connexion, an important question may be posed: is the information collected necessary only for the one who has ordered it or is it of interest to other enterprises which did not finance the collection of the information in question? In the latter case, the information may, in the author's opinion, be supplied to non-paying enterprises only if consent is granted by the payers.

The author of this paper does not claim to have given exhaustive and definite answers for such a complicated problem as economic and efficient organization of engineering services in industry. However, the organizational structures, approximate duties of personnel and lists of tasks which can be found in the present paper are made on the basis of experience gained by some countries through the successful application of the principles discussed above. Proceeding from this, one may maintain that the suggested structure of the research centres can ensure proper and reasonable methods of solving the problems discussed. The methods suggested in this paper are flexible enough to be adapted to the specific features of industrial development pertaining to any developing country.



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