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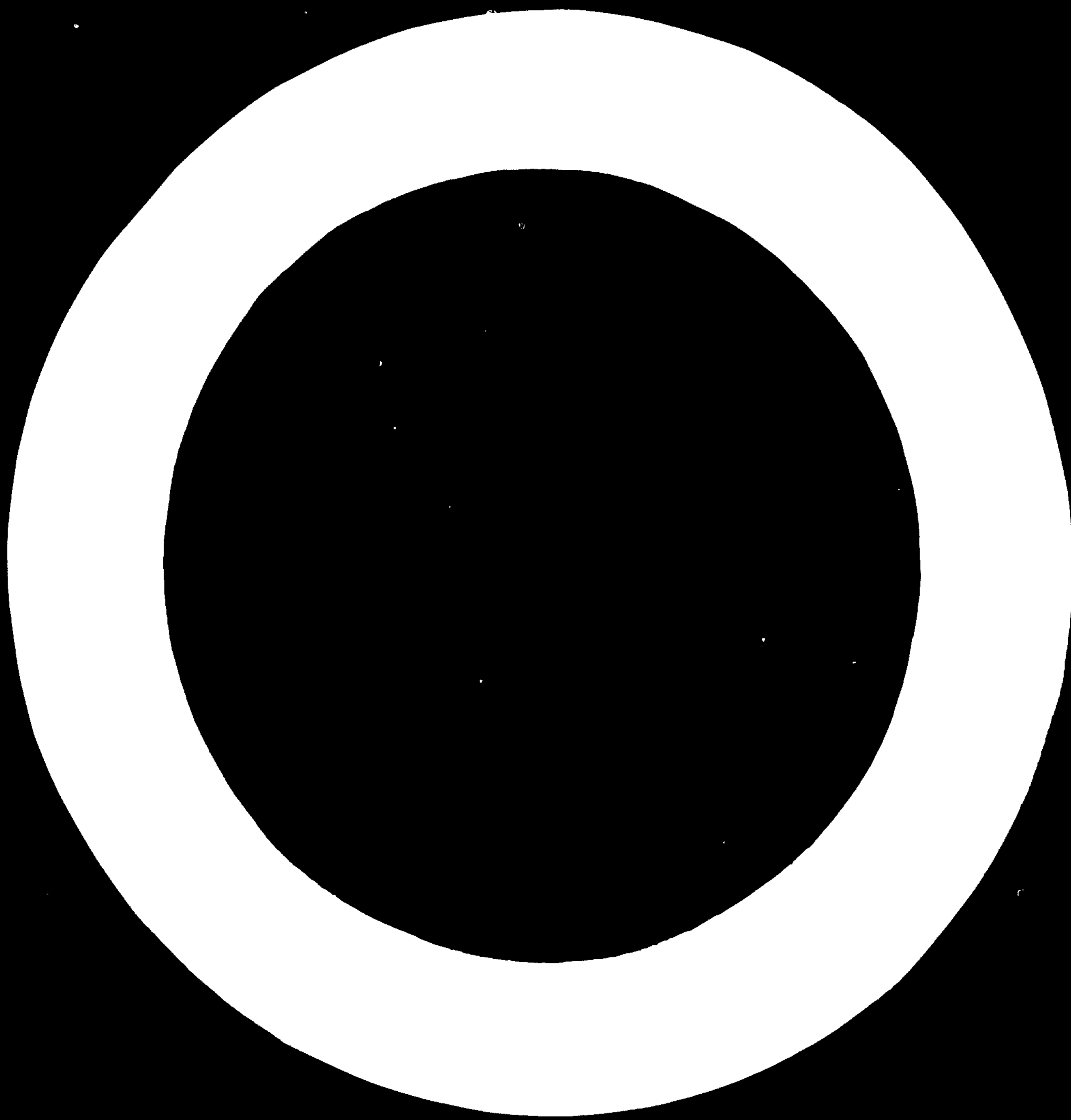

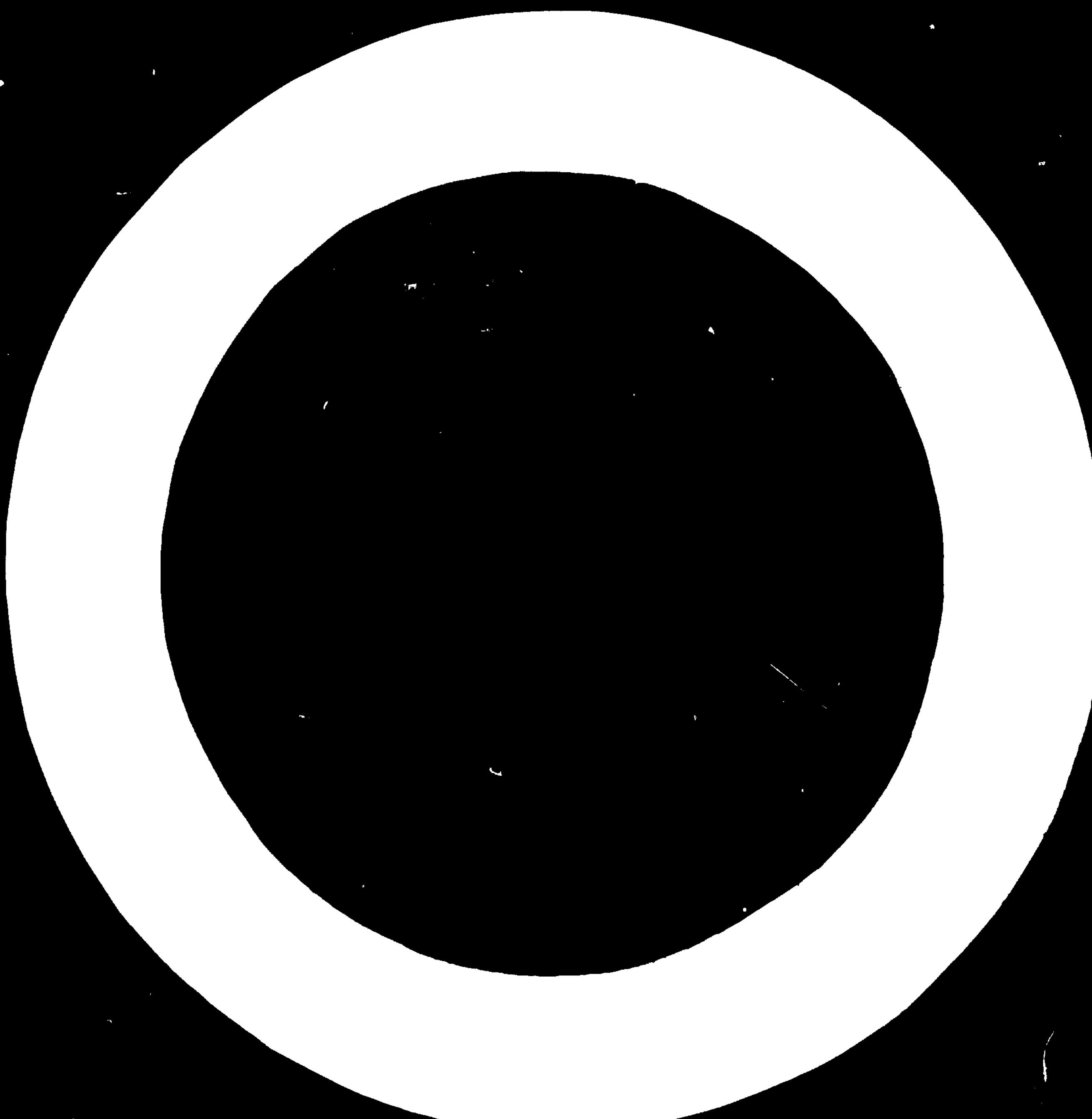

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CRITERIA AND BACKGROUND INFORMATION FOR PROGRAMMING THE MACHINE-TOOL INDUSTRY

Secretariat of the United Nations Economic Commission for Latin America

Industrially developing nations which are starting the expansion of their traditional industries must evaluate the extent to which capital goods and, within this vast branch, machine tools, should be manufactured in the country.

This problem has not been posed with a view to attaining total national autonomy as regards the elaboration of capital goods, but rather to determine, quantify and qualify the type of domestic effort to be realized in front of global demand, a relationship which should be considered under a certain discipline.

One method of tackling the subject might consist of finding out whether there exists a useful historical correlation between national manufacture of machine tools and the size of the machine inventory used by the mechanical industries.

This should be followed by broad consideration of the predominant characteristics of the products, showing which are the means available to this industry for obtaining specific technical and economic results.

Both methods comprise aspects of diverse natures, not always easy to separate and ponder, as a more detailed analysis would require. In practice, different solutions may be applied to the same problem.

Because machine tools constitute the most significant investment within the mechanical industries (from 50 to 65 per cent of total fixed investment), they have now become the most popular work instrument, as were manual tools in earlier times. It seems therefore convenient to take into account their elaboration in expanding areas, paying attention also to the strategic role they have been acquiring within today's technical and economic evolution.

Thus, first in these notes, an analysis is made of some dynamic factors determining the importance of national manufacture of machine tools and of the magnitude of the inventories operating on the mechanical industries; this indirectly shows an aspect of domestic participation on apparent consumption. The successive sections deal with the industry in charge of the construction of these machines, summing up its peculiar technical problems equivalent to the various stages of development. The last section is about the usually admitted dependency between the machine-tool manufacturer and the rest of the mechanical industry, that dependency increasing in quality, volume and technique as progress is made on the construction of more complex units.

It should be pointed out that the conclusions of this essay must be interpreted as global, because though a great number of the variables in the construction of machine tools have been taken into account, there are still many more. However, once the results of the following preliminary estimates are deemed satisfactory, they can serve as a basis for carrying out the detailed study of one or more specific factors for products of a given design.

THE DOMESTIC MACHINE-TOOL INDUSTRY

Classification of machine tools

Because of the great number of divergent interpretations with regard to the types of machines included as such, machine tools are here defined as metalworking machines in cold and in hot, and the metal-cutting as well as metal-forming machines, leaving aside those for working wood, plastics and non-metallic materials. Within the category of metalworking machines, those indicated in table 1 have been selected because, though not representing the total means available to the mechanical industry for the manufacture of its products, they constitute a significant majority.

In practice, for the user as well as for the constructor, the denomination of lathes, milling and drilling machines, etc., is too generic, as each category has numerous variables widely differing in outline, controls, productivity, size and other factors. In order to establish an order of magnitude concerning the number of variables applicable to each machine, two criteria have been adopted:

(*a*) Assume for each type of machine, lathes for example, certain variables sufficiently differentiated to individualize the operational as much as the structural and constructive characteristics;

(*b*) Relate each of those variables to four basic conditions of utilization: micro-mechanics, light and current mechanics and medium, semi-heavy, and super-heavy mechanics, which do not exist necessarily in all the variables.

On the basis of these criteria, it has been possible to quantify, for each machine, the most important types and models which together constitute the large family of machine tools in the constructors' vast world supply. Table 1 shows the results obtained: 1,037 main variants, 776 of which (75 per cent) correspond to the category of metal cutting machines, and 261 (25 per cent) to metal-forming machines.

The information in table 1 cannot be free from subjective interpretations and, also, from incomplete data regarding some of the variables, in which case figures

Table I

NUMBER OF TYPES AND MODELS OF MACHINE TOOLS IN THE WORLD MARKET

Denomination of the machines	*Number of types and models*
Metal-cutting machines	
Lathes	106
Milling machines	63
Drilling machines	46
Shapers and planers	32
Threading machines	27
Saws	19
Gear-cutting machines	94
Boring machines	84
Grinding machines	131
Tool-grinding machines	43
Broaching machines	30
Lapping and honing machines	33
Special machines composed by work units	46
Other machines of difficult classification	22
	776
Metalworking machines	
Mechanical presses	75
Hydraulic presses	54
Forging machines	23
Metal-forming machines in cold	24
Machines for sheet	85
	261
Total machine tools	1,037

should be taken rather by default. But even with all the limitations, the data appear acceptable for the purpose.

Another important factor which might have been added in combination with the above figures, to obtain a greater number of variables, is quality. However, at this stage of the analysis, it has been deemed advisable to omit it as inclusion would not alter substantially the determination of an indicator that points out the percentage of national manufacture of the variables in front of their statistical universe, a a function of the numerical value of the machine-tools inventory.

Participation of national manufacture in relation to installed inventory of machine tools

Within the order of ideas mentioned, an endeavour will be made to determine national constructors' possible reactional behaviour, measured in the variety of types and models as a function of the numerical value of the inventory. Conceptually, two different aspects exist simultaneously within an inventory: the serial factor (purchasing power, high population, both, etc.), and the variety and complexity of the mechanical and electromechanical products manufactured. In the measure that these factors are considered to be growing, the one as well as the other will urge for the utilization of more improved technological productive means which in practice will be translated into a progressive increase in the variety of types and models of machines in use. This evolutionary process takes place under different combinations of the elements taken into account, with direct impact upon national industry. This implies admitting *a priori* that to equal numerical values of inventories, different actions may correspond on the part of the constructors. Nevertheless, it does not seem arbitrary to assume that national manufacture of machine tools participates within minimum and maximum limits, susceptible of definition for the various situations.

To this end, it has been possible to reconstruct the number of types and models of machines elaborated in some countries, thus establishing percentual relationships with the previously fixed statistical universe. Interest in such an analysis is now circumscribed b knowing the behaviour of supply for countries with inventories of less than 500,000 units.

Almost all the available information derives from studies being systematically carried out in the region by the Economic Commission for Latin America (ECLA) on the mechanical industries in general and especially on machine tools. Figure I shows a summary of the data, as well as an interpretation of its trend adjusted to Gompertz' curve (curve I). It may be observed that in Latin America, when inventories are of less than 10,000 units, no cons ruction activities of machine tools have occurred, a fact which is apparent. But when inventories comprise from 10,000 to 20,000, the first local initiatives are already starting, naturally polarized on the manufacture of simple machines of still deficient quality.

To attain the elaboration of forty to sixty variables of low-cost and low unit-weight machines does not altogether constitute a very significant step towards mastering this difficult technique, and its achievement is generally possible without the support of an important technological infrastructure on the rest of the industry. This first stage of supply of elementary machines, practically abandoned in countries with a high industrialization index, is in great part the result of the strong incidence of small industry and the many artisans who have proliferated in this area due to rather peculiar conditions. At any rate, it is perhaps convenient to accept, as a characteristic sign of underdeveloped countries, the fact of an operational co-existence within the same inventory, of machines with a limited technical capacity and few years use, together with others of medium and elevated category, the first ones in high proportions.

Starting from a given situation of supply, for example forty to sixty variables, or inventories of 80,000 to 100,000 units, this becomes progressively complex as the increase in the variety of types and models implies almost systematically higher standards of quality within an international pattern. In order to reach those qualitative demands, technically well-structured factories and efficient auxiliary industries are required.

Along curve I, a position that might be called of high national effort is clearly discernible exactly between points A and B. Should this position be related to the Latin American panorama, it would broadly represent the transition from under development to a satisfactory development of the mechanical industries, comprising under the concept of development the serial aspect as well as the diversification of mechanical products. It now seems advisable to admit that especially between points A and B different ways may exist in connexion with the position of supply and that the previous and subsequent situations to these points would present further stability. Such ways would explain, as already said, that not always equal technological potentials correspond to equal magnitudes of inventories, with obvious repercussions upon supply; and also, that the observable differences would derive from those existing between a developed country and another in the process of development. This is clearly confirmed by comparing Argentina's and Brazil's position (less than 200,000 units installed) with

dynamism in front of a given inventory. The complementation and refinement of data to be obtained in the near future will confirm whether the limits established in Figure I through curves 1 and 2 are real and applicable to a great number of cases for countries in the process of development. Attention then will be drawn to the distortions resulting when the structure of machine tools national manufacture is bulky due to exportation of some

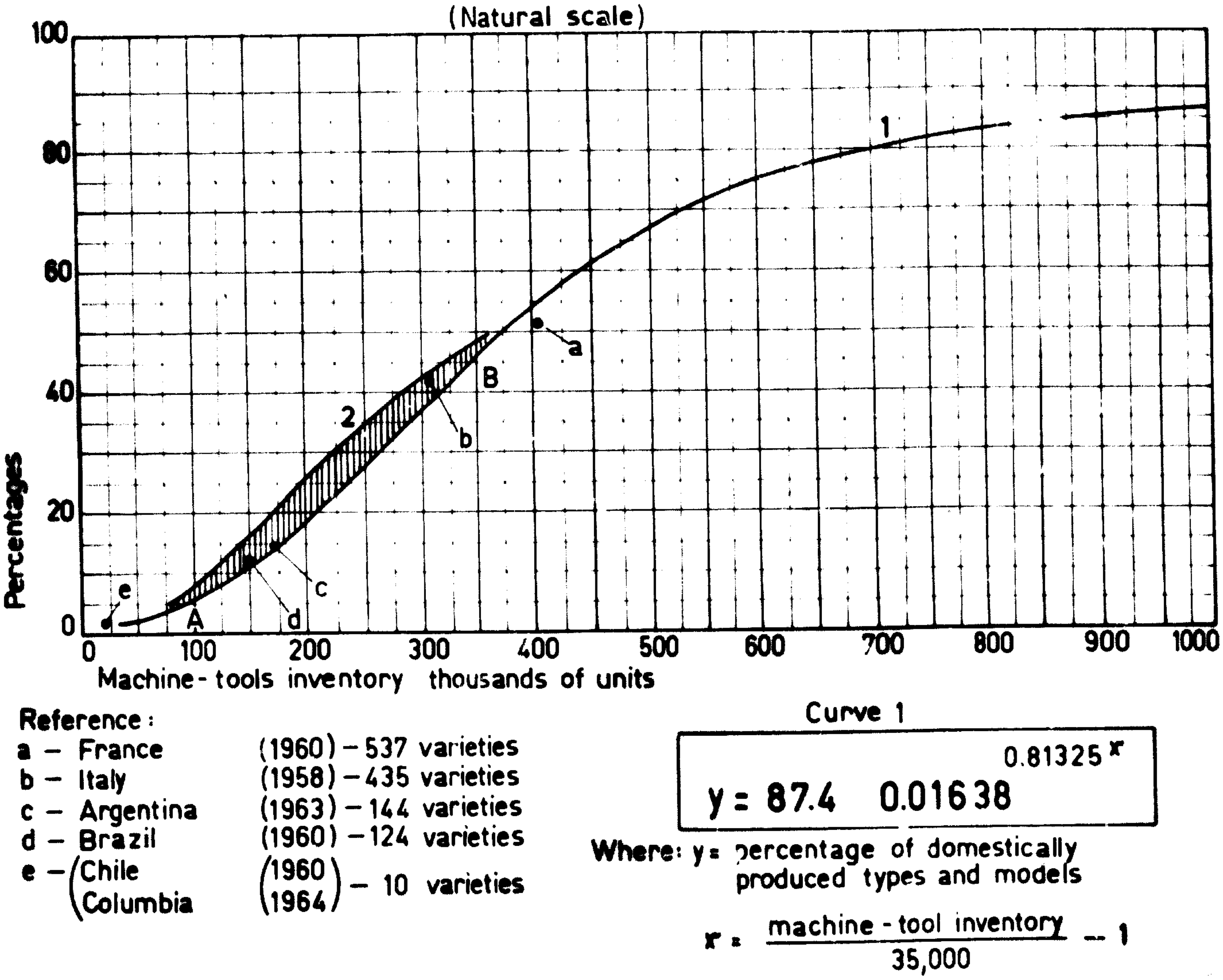


Figure I

RELATIONSHIP BETWEEN THE INVENTORY OF THE METAL-TRANSFORMING INDUSTRIES AND THE PERCENTAGE OF DOMESTICALLY PRODUCED TYPES AND MODELS

that of Italy and France when they had a similar number of machines which served such important sectors as aeronautic construction, that of ships of more than 10,000 tons, and the manufacture of other diversified and complex capital goods not being developed in the two Latin American countries. The machine-tool supply accompanied this process, with a consequent further diversification of types and models than those elaborated by Argentina and Brazil.

This and other examples would be better represented by curve 2 laid out empirically to illustrate those cases in which the behaviour of supply maintains its maximum of its products, a fact which was not taken into account in this preliminary outline.

Starting from situations of more than 500,000 installed units, it is easy to understand that, though the technical problems the constructors must face continue to grow, the magnitude of the market and the infrastructure that should exist in the rest of the industry constitute factors sufficiently attractive that supply adjusts itself to the requirements of internal consumption in an increasing and varying manner.

Despite the fact that the preceding notes do not intend to lead towards the formulation of exact decisions on the problem under analysis, they are explanatory enough in regard to the philosophy to be followed by those countries whose development depends upon significant apparent consumption of machine tools. There could not be important and prolonged expansion of the mechanical industry without a gradually increasing contribution from local industries constructing machine tools. The framing of an even partial attitude of participation in the domestic manufacture of the capital goods in question is of vital importance not only for improving the balance of payment of this item, but also for familiarization with every characteristic problem in the elaboration of machines. Manufacturers must be responsible and offer users the possibility of direct contact.

When dealing with machine-tool manufacture, different stages of supply development will be considered in an indirect manner, that is, showing which qualitative and varying production potentials may be attributed to a specific number of enterprises typified by diverse structures, from the humblest to the well-equipped, generally knowing that such initiatives get consolidated in the measure that the inventory improves in its numerical and technological aspects.

Characteristic problems of machine-tool manufacture

Introduction to the subject

To facilitate research into some general laws, it seems advisable to apply a restrictive criterion to the universe of types and models of machines, selecting those with more homogeneous and similar fabrication problems. The machines used in micro-mechanics, heavy and super-heavy mechanics are thus excluded, incorporating instead the ones used in current, medium and semi-heavy mechanics, which are more popular.

The unit weight of the machines is limited to approximately ten tons; the highly specialized types, such as the jig boring machines, machined units and others, are not taken into account. The same happens with the machines using numerical control programmers, etc. Despite these restrictions, the rest comprise the majority of existing variables in the world market and cover to a great extent the fabrication interests of countries with relatively small demand, concentrated on the most current types of machine tools.

The final objective of this outline is the analysis of global machine-tool manufacturing, trying to frame the technical, practical and economic fields of action of the construction enterprises. At the same time, it is intended to indicate how the "economy of scale" concept, so closely connected to the applicative effects of the machines once they have been installed in the workshops, has a different meaning when referred to the elaboration of those machines.

Unlike other sectors of the mechanical industries where the same product may be elaborated for a long time, machine-tool manufacture, with the exception of some simple types, is constantly evolving in details as well as in general composition, because of the need for more productivity at the same price, weight or power. This situation is reflected in the fabrication series of identical products, reducing them in a sensible manner. Because composition of machine-tool inventories is related to the quality, the variety, and the series of products, when development of the mechanical industry starts, the demand for machines corresponds to elementary types for maintenance and fabrication of simple articles. As in this stage of development demand is scarcely diversified in types and models, favourable conditions are present for construction in series, above a hundred, for example, which represents a high scale in machine-tool manufacture on the order of one ton weight. However, while the number of machine tools integrating an inventory increases and new products are launched into the market, a substantial change takes place in the requirements of users who first try to obtain the type of machine best suited from the standpoint of operation technology (more variety) and then, according to the serial size, the most productive machine.

It is difficult to reconcile the interests of a very diversified demand with those of machine-tool construction in important series. Here it must be recalled that, during a period shortly before the Second World War, different production scales of mechanical manufactures were generally attained through the installation of larger or smaller numbers of equal machines. The technology trend prevailing at present, far from eliminating the multiplicity of types and models of machines, tries to find the most adequate solution to the problems. As an extreme, it might be said that for some articles maximum productivity is only achieved by means of special and complex machines, elaborated to order. In other words, the maximum production scale for the users would correspond to the minimum scale for the constructors. This indicates a certain relationship of inverse proportionality between the user's series and that of the machine-tool manufacturer.

In order to condense the peculiar operative conditions upon which the sector must rely, the producers' main problems have been typified through five sizes of machine-tool construction enterprises, assigning to them beforehand the equipment together with direct and indirect labour corresponding to predetermined manufacturing structures to produce a wide variety of types and models of machines. The possibility and convenience of elaborating given types related to each size of enterprise is then examined, considering the greatest possible number of variables in order to synthesize the most characteristic technical and economic problems of the sector.

The first two sizes of enterprise represent embryonic technical situations of an artisan type which are specially useful in countries with low industrialization indices. The last two sizes denote more advanced structures of specialized factories already able to produce complex machines for more demanding and developed markets. The other type of enterprise constitutes a sort of transition from artisan production to production of great industrial significance.

The values assumed as well as the conclusions are always indicative of intermediate situations. The basic data related to the first three sizes of enterprise have been obtained from studies of the machine-tool industries of Argentina and Brazil. Information for the other enterprise derives from some Western European firms.

The method took account, simultaneously, of a vast *ensemble* of products and factories of diverse technical operative characteristics and represents an approach the ultimate objective of which is to favour the formation a ' selection of basic ideas with regard to the new initiatives frequently emerging from this sector in countries with mechanical industries in the process of development.

Variables

Machine, type, model, accessory

The term "machine" designates a lathe, a milling machine or an eccentric press. The type determines one of the probable variables in the construction of a machine; in milling machines, for example, there are the universal, horizontal, vertical, simplex, duplex, for splines and copying types. In its turn, the model indicates mainly the size of each type and is directly related to work capacity, installed power and other characteristics.

The type and model are usually accompanied by a series of accessories diversified in form, complexity and weight so as to offer greater utilization capacity. Production machine equipment is studied and adapted especially for specific applications such as feeders of pieces. When the producers design, manufacture and supply equipment, they are compelled to involve themselves with the production problems of the user in a much more intense way than the constructor of universal machines. At any rate, the inclusion of standard and special accessories to the normal line of production implies supplementary series of fabrication which overlap the basic problems, thus augmenting the variable factors that affect the producers.

Complexity index

One of the obstacles met in this study is that of classifying and comparing even approximately the difficulties of construction of the great number of machines, types and models in existence. To assert, for instance, that the elaboration of a parallel lathe is easier than that of a turret lathe of the same power, is not always true.

In order that the machines may be comparable by fabrication, it is necessary to introduce an index number Ic called "complexity index" which represents the most significant and characteristic quantity of the machining difficulties.

This Ic index may be defined as the sum of various categories of simple or compound machine elements, as:

$$Ic = a_1 + a_2 + a_3 + a_4 + a_5$$

where:

a_1 Indicator number of the quantity of gears, internal and external splined profiles, pulleys and flywheels;

a_2 Indicator number of transmission shafts, racks, movement screws and motors. The transmission shafts are related to the bearings and consequently to the precision borers for the bearings and bushes seat;

a_3 Indicator number of the quantity of couplings, clutches, brakes, internal and external levers, all sorts of cams, and other programmers of a kinematic type. This group of elements is indicative of the degree of mechanical automatism attained by the power and control or programming transmissions;

a_4 Number of plane surfaces and slides that support those parts which being either in movement or blockaded are indispensable to determine a work cycle;

a_5 Number of final and intermediate apparatus, filters pumps and tanks belonging to the circuits of lubrication, refrigeration, pneumatic, hydraulic and mixed;[1]

a_5 Number of pistons and rotors.[1]

It is obvious that on counting the different parts and pieces from a_1 to a_5 abstraction has been made of the varying degrees of machining difficulty among the elements: but it is also true that the simplification facilitates equationing the problem without altering its nature.

Figure 2 presents the estimated Ic indices for some machines: the great Ic variation occurring on the same type of machine is observable. On the basis of the estimated results of Ic indices for different machine models (without accessories or auxiliary equipments), it is possible to subdivide the variation field of Ic into five groups (Ic_1, Ic_2, Ic_3, Ic_4 and Ic_5) which would be equivalent to:

Ic_1 Kinematically very simple machines;

Ic_2 Kinematically semi-complicated machines;

Ic_3 Kinematically complicated machines;

Ic_4 Machines with complicated kinematic, hydraulic, pneumatic and lubrication circuits;

Ic_5 The same machines as Ic_4 but with programming of the work cycle through perforated, magnetic band and other advanced methods not dealt with here.

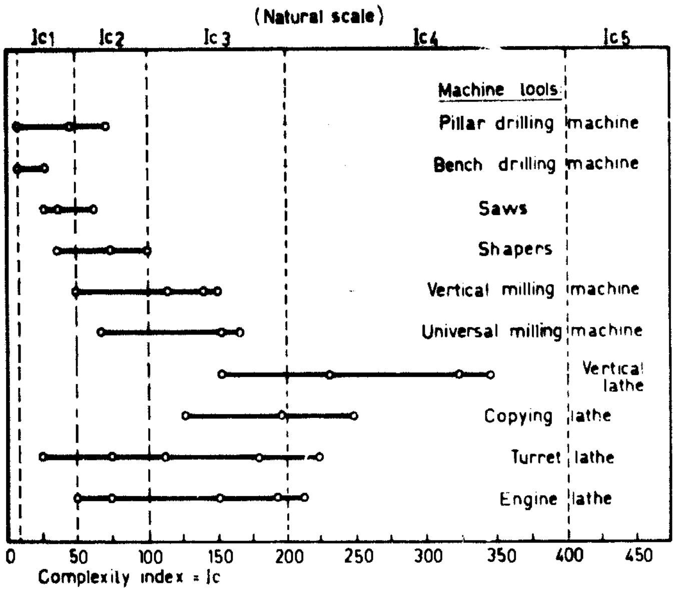
In numerical terms, the four groups could be fractionated as:

Ic_1 from 10 to 50
Ic_2 from 50 to 100
Ic_3 from 100 to 200
Ic_4 from 200 to 400

Weight of machines

The weight of machines is another variable factor which constitutes an important characteristic for the manufacturers. As already demonstrated by practice, at equal complexity the machining of large pieces with a high degree of accuracy is in some ways more difficult than the smaller pieces. Actually, the heavier machines present specific problems of deformation, alignment, perpendicularity and others, proving arduous for the producer despite the implicit admission that when augmenting its size the machine tool loses in precision as compared with the smaller ones.

[1] For a_5 and a_5 0.5 of each element is considered when they are bought from third parties, and 2 for those machined by the same producer.



Note: Only a limited number of machine-tool models was considered

Figure 2 — COMPLEXITY INDEX CORRESPONDING TO SELECTED MACHINE TOOLS WITHOUT ACCESSORIES

Of course it is evident that for each size of enterprise considered further on, the same productive capacity as regards the average weight of machines cannot be assumed, as the heavier ones need a determined managerial infrastructure on equipment, technical experts and transport which can only be found in factories of certain dimensions. Practice suggests then to attribute the maximum weight of the machines they are able to produce to the different manufacturing structures. This limitation is particularly valid and applicable to the small enterprises.

Quality of machines

The quality factor is also a significant variable that should not be ignored when analysing this sector. The verification of the quality of a machine according to Schlesinger and Salmon standards constitutes the most accepted method. It is only by means of such standards that it will be known afterwards whether the machine was manufactured within or outside the specifications. This checking is, however, not sufficient for the purpose of these notes, as no account is taken of the degrees of difficulty the constructor confronts when producing at different quality levels.

It is convenient in the first place to separate the quality of machines into four possible and real classes:

Q_1 Quality of those machines in which the results of the tests are always inferior to the recommendations of maximum error in the standards;

Q_2 Quality of those machines satisfactorily passing only one part of the standards tests or which, owing to inadequate materials or deficient design as a whole or in detail, work with their initial precision for only a short time;

Q_3 Quality of machines always in accord with the standards and in condition to maintain the initial precision for a long time, requiring only normal maintenance;

Q_4 Quality of high precision machines such as the jig boring machines, not included in this outline.

A criterion might be established right away to determine the existing relationship between the final quality of the product and the technical attention to which its components would be subject, taking as an example the number of controls performed on each machined part.

It is a well-known fact that in order to achieve Q_1 quality the use of calibres with a range from 1/20 to 1/50 millimetre is enough; also that the accuracy on the elaboration of couplings or plane surfaces is generally left to the operator. Category Q_2 demands further knowledge on the part of the constructor with regard to metrology, the greater number of measuring instruments and a minimum of quality controls including even the phase of elaboration of pieces. So as to attain category Q_3 manufacturers must make significant efforts, as in general the control of all machining operations is carried out in the section of specialized metrology. Naturally these three cases differ in the instrument utilized, personnel technical level and the indirect hours employed on the quality controls.

Taking now as a point of reference the number of controls the manufacturer usually performs on the components and considering tentatively that the operations may range between 4 to 6 for each part, the result is: for Q_1 one control per piece; for Q_2 from two to three controls per piece; for Q_3 from four to six controls per piece.

These data may also be transcribed thus:

	Q_1	Q_2	Q_3	
one piece of four operations	1	2	4	controls
one piece of six operations	1	3	6	controls

The number of controls reflects in good measure the final result envisaged once the pieces are assembled, as well as that stricter control corresponds to more rigorous design specifications which must be verified.

From another point of view, a certain correlation may be admitted between Q qualities of the machines and ISO work tolerances with regard to the more responsible parts and pieces forming the product. According to information gathered from various producers, that correlation could be approximately: Q_1 quality corresponding to grades 10 and 11 of ISO tolerances; Q_2 quality corresponding to grade 8 of ISO tolerances; Q_3 quality corresponding to grade 7 of ISO tolerances.

To pass from precision degree 7 to degree 8, the field of tolerance of the first piece must be multiplied by 1.56, and from degree 7 to degrees 10 and 11 by multiplying by 4.0 and 6.2 respectively. Supposing now a certain identification among the tolerance degrees and the manufacturing difficulties for obtaining the pieces under consideration, which in practice is partly confirmed, it might be said that other factors being equal, quality Q_1 is 4.0 or 6.2 times easier to obtain than quality Q_3 and 2.6 or 4.0 times easier to obtain than Q_2. If the tolerance criterion is combined with that of the control of pieces with similar values, and adopting intermediate situations, it will be possible to formulate comparisons, which though abstract, lead to the meaning of starting the manufacture of products of different quality.

On the basis of the above it may broadly be admitted that: Q_1 is three times easier to machine than Q_2; Q_1 is five times easier to machine than Q_3; Q_2 is 1.7 times easier to machine than Q_3.

This preliminary equation of the problem has been made with the sole purpose of illuminating how difficult it is in practice to advance on the qualitative field from an inferior quality towards another of international level. Also, that it is not possible to pass from a qualitative situation of elaboration to a superior one without changing the structure of the manufacturing equipment or extending the corresponding technical services.

Size of enterprises

With a view to analysing the sector in its most general aspect, it seems advisable to consider different sizes of manufacturing enterprises from the artisan to a factory with adequate technical resources available for the production of various types and models of machines.

Five typical sizes of enterprises (*Te*) have been selected. The first two (Te_1 and Te_2) with 20 and 50 persons occupied, are characterized by the high percentage of direct or productive hours in relation to indirect or unproductive ones. They dispose of precarious production means and may therefore manufacture simple articles of low quality and low price per kilogramme. These enterprises are justified especially in those consumption areas where the demand for machine tools is still at a primary stage and maintenance and manufacture of metallic devices of elementary composition are predominant. Size Te_3 with a hundred persons, has greater technical capacity than the previous and may elaborate Q_3 machines of low I_c index. In this dimension, the proportion of indirect personnel may even reach 28 per cent of all the personnel, favouring the quality of the product as well as the organizational structure. This size, Te_3, represents, however, a stage of transition in the evolution of the enterprises, rather than a well-defined point of techno-economic equilibrium. It is through sizes Te_4 and Te_5 with 250 and 500 persons that more complete manufacturing structures are feasible from a technical and organizational point of view. The percentage of indirect labour increases as referred to Te_3 thus enabling the projection, study, testing and construction of complex products of high responsibility in Q_1 quality.

For sizes above Te_5 not dealt with in these notes, it must be thought that the increase in the number of persons and machines would be related to more important and diversified production volumes rather than to the weight, quality and complexity factors already indicated. Certain observations and results regarding Te_5 may then be valid for these enterprises.

The subdivision of direct and indirect personnel derives from data collected in Argentina, Brazil and Western Europe from enterprises that concentrate their activity on machine-tool elaboration and work exclusively by means of their own designs and research, as shown in table 2 and figure 3.

The lack of a classification that allows for the exact differentiation between direct and indirect personnel might lead to various interpretations. This is the reason why in table 3 the activities here considered as indirect

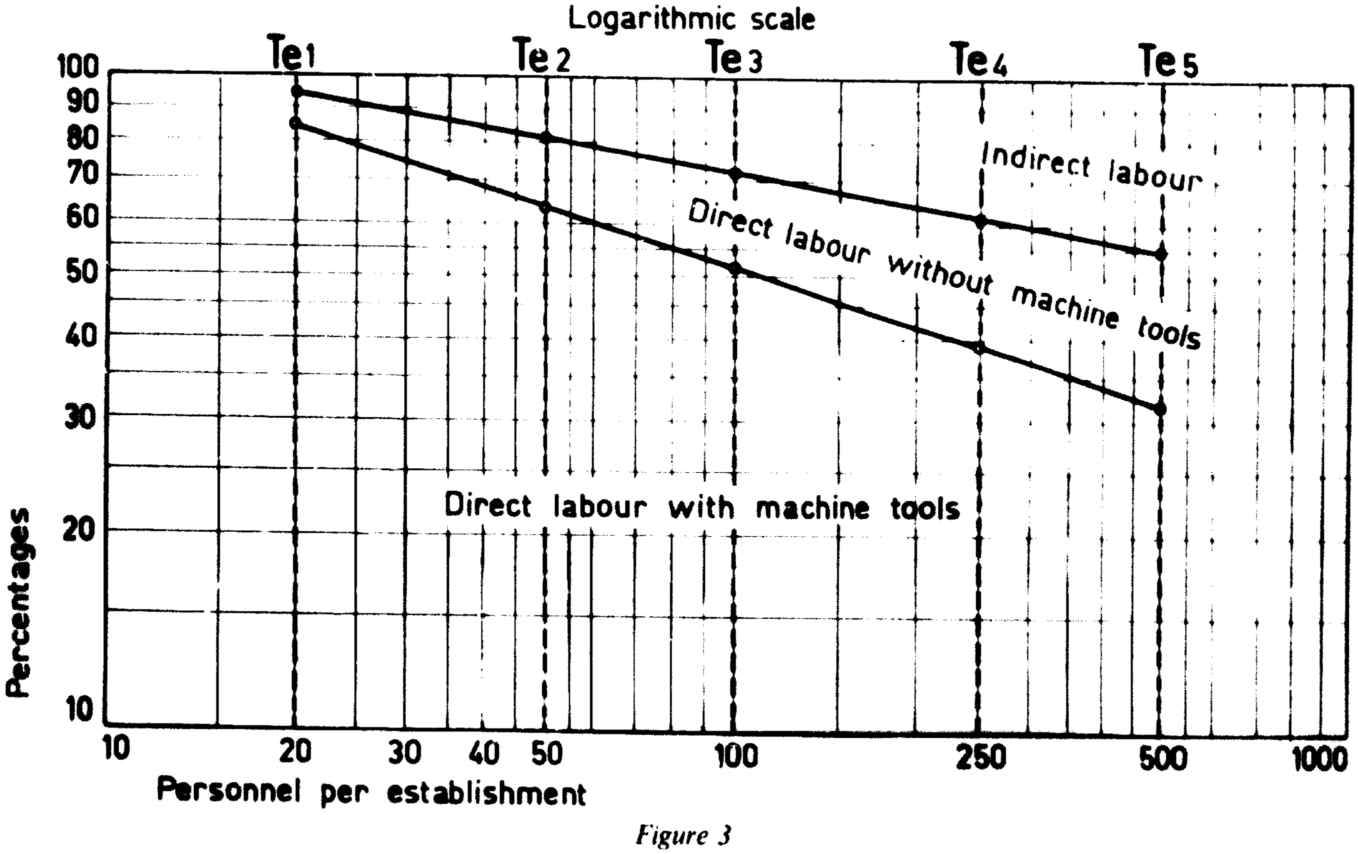


Figure 3

PERCENTAGE DISTRIBUTION OF DIRECT AND INDIRECT LABOUR

Table 2

DIRECT AND INDIRECT PERSONNEL IN THE FIVE SIZES OF ENTERPRISES

		Direct personnel						Indirect personnel	
		With machines		Without machines		Total			
Te	Total personnel	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Te_1	20	17	85	2	10	19	95	1	5
Te_2	50	32	64	9	18	41	82	9	18
Te_3	100	52	52	20	20	72	72	28	28
Te_4	250	98	39	57	23	155	62	95	38
Te_5	500	160	32	115	23	275	55	225	45

have been classified, pointing out the existence or absence in each size of enterprise. The other activities have been taken as direct or productive and are so accounted in order to know the real time of elaboration by pieces, assemblies and machines.

Table 3

DESCRIPTION OF INDIRECT ACTIVITIES

Denomination	Te_1	Te_2	Te_3	Te_4	Te_5
Workshop *(workers and foremen)*					
Assistant machine operator				x	x
Preparation of work on machines					x
Manual internal transports	x	x	x	x	
Mechanized internal transports			x	x	x
Maintenance	a	a	x	x	x
Tools	a	a	x	x	x
Construction of jigs		b	b	x	x
Tool warehouse			x	x	x
General warehouse			x	x	x
Metrology section				x	x
Baling and packing				x	x
Delivery	c	c	c	x	x
Person in charge of auxiliary services			x	x	x
Foreman	x	x	x	x	x
Labour foreman		x	x	x	x
Workshop *(employees)*					
Engineers				x	x
Technical office for piecework estimate					x
Technical office for jigs design				d	x
Office for production planning				x	x
Office for distribution of production cards				x	x
Co-ordination of purchases				x	x
Tests, laboratory and research					x
Office *(employees)*					
Technical	e	e	x	x	x
Accounting	e	x	x	x	x
Costs			x	x	x
Administration	f	e	x	x	x
Sales	f	f	x	x	x
Purchases	f	f	x	x	x
Exports					x
Management			x	x	x
General services					
Cleaning	a	a	x	x	x
Conciergerie				x	x
Outside services				x	x
Outside transport				x	x
Guards				x	x

[a] Operations by the same worker who performs productive functions.
[b] Work executed by direct operators.
[c] Uses the same assembly personnel.
[d] Elaborated by the employees of the central technical office.
[e] Collaboration of third parties part time.
[f] Activities personally executed by the owner.

In this way the profound structural differences of the diverse *Te* sizes stand out, and consequently the diverse human technical potentials they have available to operate. Thus, after establishing criteria to define the *Q* qualities, *Ic* complexity indices and *Te* sizes of enterprise, and also taking into account the machines and equipment mentioned elsewhere, it is possible to delimit the most adequate field of action for each industry, using logic compatibility and practical experience as co-ordinating elements among the multiple variables considered.

Table 4 summarizes the most probable situations which may actually happen.

Data registered in table 4 may be transcribed in the following way, bringing out the limit values of *Ic* information of *Q*.

	Ic values for		
Te	Q_1	Q_2	Q_3
Te_1	10–125	10–62	–
Te_2	10–200	10–100	10–50
Te_3	100–250	10–175	10–125
Te_4		100–300	50–250
Te_5			100–400

Another observation derives from the work field of the enterprises: that it is necessary to differentiate between the possibility and the convenience of elaborating certain products. This situation is modified according to the size of the enterprise; relating it to the quality factor it might be said that:

Te_1 may manufacture products	Q_1 Q_2 —
Te_2 may manufacture products	Q_1 Q_2 Q_3
Te_3 may manufacture products	Q_1 Q_2 Q_3
Te_4 is only interested in products	— Q_2 Q_3
Te_5 is only interested in products	— — Q_3

within the previously determined *Ic* complexity indices.

It is understood that Te_4 and Te_5 are manufacturing the products of the smaller enterprises though it does not seem advisable as their prefixed structure would render this uneconomical given their high operational cost. On the contrary, the field of action defined for the first three *Te* corresponds to the maximum technological limits they may achieve as functions of *Q* and *Ic*.

Production series

Among the factors analysed, production series are perhaps the most variable, as in practice they are influenced by innumerable causes. Attention has already been drawn to the fact that the order of magnitude of the series is maintained low even for *Te* enterprises. The diversification of types and models together with the number of different pieces comprising the machines constitute elements so characteristic of the construction of capital goods and of this sector in particular, that they prevent the serial factor from receiving the same approach as, for example, the durable consumer goods.

In order to furnish some arguments on the subject which may be applicable to several producers, the factors indicating the elasticity with which this sector should operate are:

(*a*) During the past fifty years, statistics have systematically shown that in diverse countries the machine-tool demand has almost always been variable in weight and in quantity;

(*b*) Each time, the producer tends to study the most adequate machine for the user's different "economies of scale";

in different models which is obviously reflected upon the annual series of fabrication. It may also be added that as a rule this sector tends to fractionate its total production many times in the course of the year, which naturally reduces the order of magnitude of the repetitive series. As a matter of fact, the manufacturer always tries to defend himself against the too low series, on the basis of:

(*a*) Launching the fabrication of small pieces once or twice a year. The storage of such pieces does not involve a significant immobilization of capital;

(*b*) Studying the products in order that the small mechanical pieces are common to various types and models of machines (internal unification);

(*c*) Maximum standardization of pieces bought from third parties (less variety of tools for their applications), including electrical material;

(*d*) Unifying as much as possible diametrical measures, screws, splined profiles, threads, tolerances and pieces of all types;

Table 4

WORK FIELD OF THE ENTERPRISES

(*Average conditions*)

Size	Te_1			Te_2			Te_3			Te_4		
	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3	Q_1	Q_2	Q_3
Te_1	10-50	10-50	—	50-100	50-62	—	100-125					
Te_2	10-50	10-50	10-50	50-100	50-100	—	100-200					
Te_3	—	10-50	10-50		50-100	50-100	100-200	100-175	100-125	200-250		
Te_4	—	—	—	—		50-100		100-200	100-200		200-300	200-250
Te_5	—	—	—				—		100-200			200-400

(*c*) As a consequence, the manufacture of complementary and special equipment, sometimes more complicated than the machines themselves, assumes an increasing importance since the constructor will have to take care of them in some way, even if he does not integrate them in his production;

(*d*) In front of a fluctuating demand, the manufacturer shows his interest on the elaboration of different models of the same type of machine, thus ensuring a more regular sale;

(*e*) For the same reason, the producer's preference may be inclined towards the fabrication of more than one type of machine;

(*f*) The elaboration of one type of machine in various models gives the user the impression that the manufacturer has a more thorough knowledge of his field of specialization and that therefore he is not improvising;

(*g*) When manufacture is divided into several models it constitutes a much stronger incentive towards the introduction of structural or marginal modifications and innovations on the products than if the case were of elaborating a unique model, since then it is not necessary to intervene on the whole production;

(*h*) Lastly, it may be said that the construction of one type of machine in more than one model is always a sign of prestige for its manufacturer.

From the above it is apparent that the machine-tool producer should elaborate at least one type of machine

(*e*) Unifying at a maximum the modules and numbers of teeth of gears;

(*f*) Conceiving the machines as a composition of compact groups and subgroups for the power transmission chain as well as for that of the controls, be they kinematic, hydraulic, pneumatic, of lubrication, etc., which may be joined to a carrying and functional structure having in mind their eventual adaptation to machines manufactured in different models but within the same technical line;

(*g*) Abandoning the traditional idea of incorporating into one-piece structures all the non-powered transmissions, that is, of low potential, to apply them externally. This would simplify in a sensible manner the machining of heavy pieces, giving at the same time more scope for possible modifications;

(*h*) Reducing the use of the unique source of power and installing various motors giving among other advantages simplification derived from the diminution of distance transmissions;

(*i*) Designing similar pieces to perform the same function with different potentials.

The production means generally utilized on the construction of machines are almost always of a universal type. Consequently, in order that the products may be elaborated within a reasonable number of direct man-hours per 100 kilogrammes (Hs/100), the manufacturer also is compelled to give maximum attention to the auxiliary production equipment and tools.

The difficulties met when trying to establish a criterion to determine the minimum economic series of fabrication which may be equally valid for the different product levels thus are revealed clearly. The estimate methods adopted for this purpose would only be applicable to homogeneous groups of machines and specific manufacturing situations. Furthermore, in practice, several combinations are offered to the same constructor (produce, for example various types or models of machines, each one with a different series).

As an illustration, some data are transcribed which have been provided by machine-tool manufacturers in connexion with the minimum production series for machines up to five tons. It is understood that these values do not prevail for the total production of the enterprise but only for one or a few types or models of machines.

Te	*Minimum repetitive series (tons)* 5	2 to 5	1 to 2	0.5 to 1	0.5
Te_1			4	9	12
Te_2			5	11	15
Te_3		3	6	14	18
Te_4	3	4	12	20	26
Te_5	4	8	16	24	32

Production of the enterprises

Productive capacity expressed in tons per year

It is possible to estimate the annual tonnage of finished products for each enterprise. Consider on one side, the total number of direct man-hours (Hs) available during one year in each *Te* enterprise and, on the other, the number of direct man-hours necessary to manufacture 100 kilogrammes of product (Hs 100).

Purposely, no specification has been made previously in order to do it now. The activities considered as direct owing to their closer linkage to the Hs 100 are examined herein. These are summed up for each enterprise in table 5.

Table 5

DESCRIPTION OF DIRECT ACTIVITIES

(M minimum; S scarce; R regular; N normal)

Denomination	Te_1	Te_2	Te_3	Te_4	Te_5
Cleaning and preparation of cast iron pieces	M	S	R	N	N
Marking	N	N	N	N	N
Operators with direct machines	N	N	N	N	N
Scraping	M	S	N	N	N
Assembly	N	N	N	N	N
Painting	N	N	N	N	N
Break in		M	R	N	N
Final controls according to standards	M	S	R	N	N

The annual production right lines *P* marked as a function of Hs 100 are indicated in figure 4. The extension covered by them is observable as well as the superposition on the tonnage produced between one enterprise and another, which in practice is difficult to admit. Meanwhile, considering that it has been verified that the production per occupied person (direct and indirect personnel) and per year normally fluctuates between

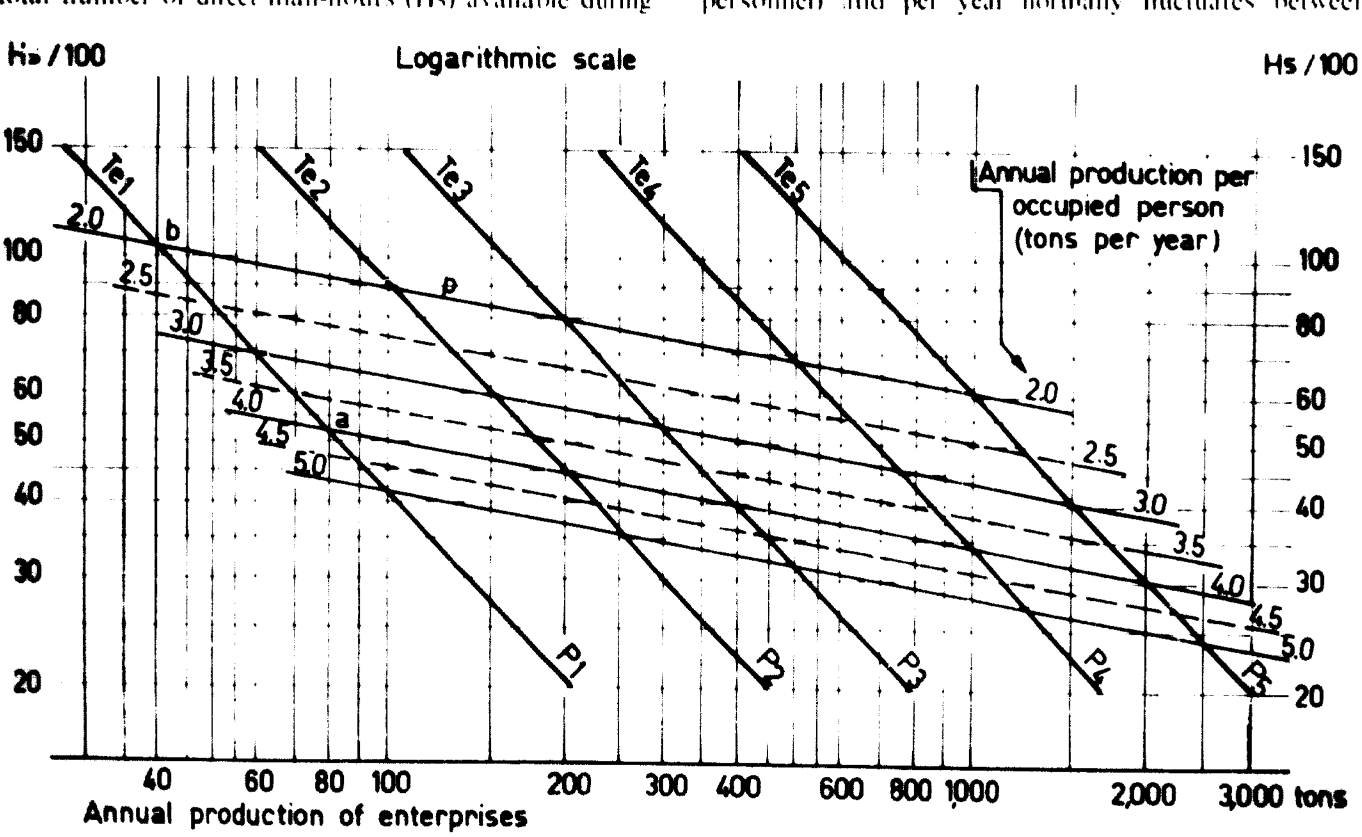


Figure 4

ANNUAL PRODUCTION OF ENTERPRISES AS A FUNCTION OF PRODUCTIVITY

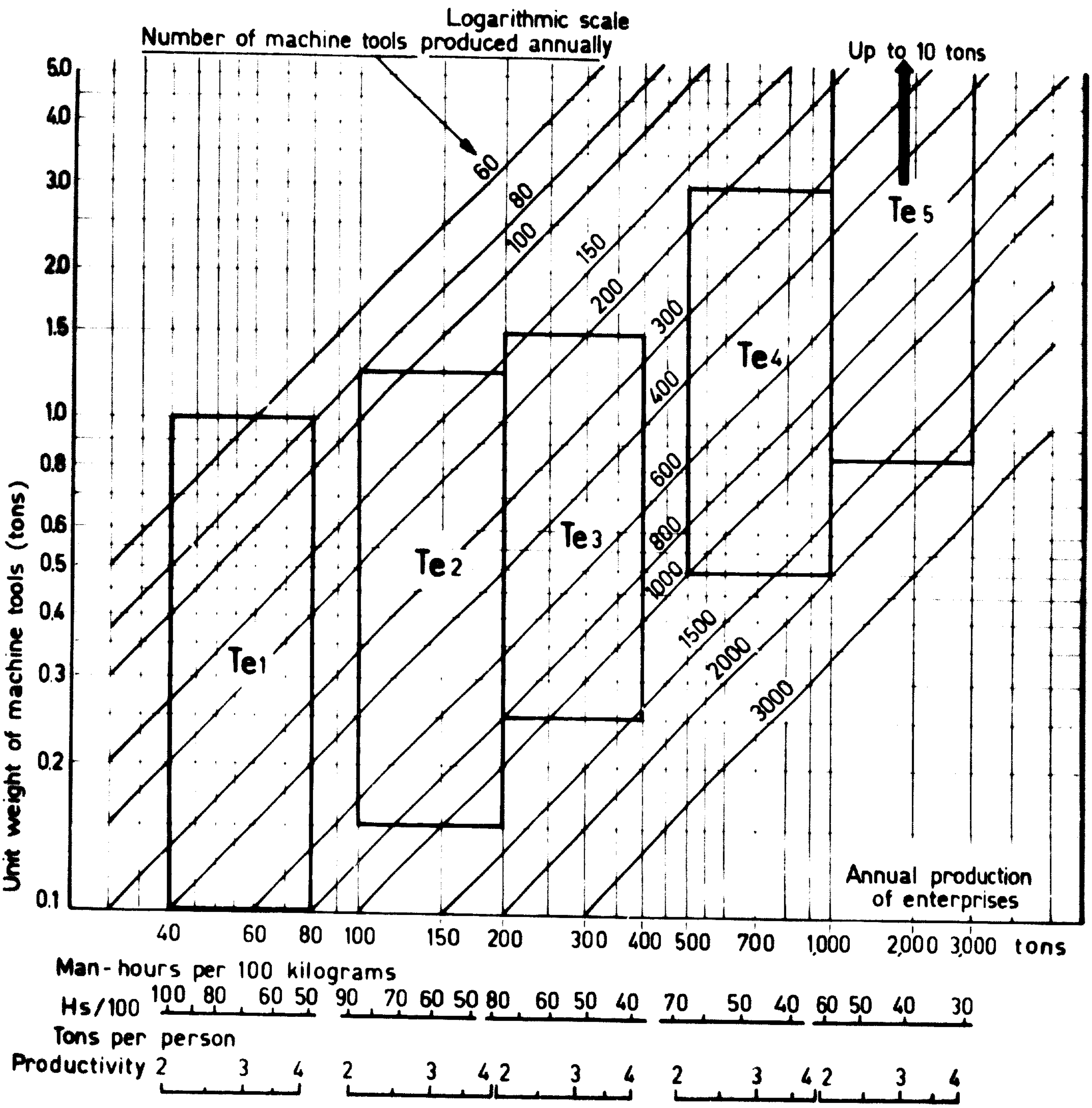


Figure 5 NUMBER AND WEIGHT OF MACHINE TOOLS DERIVED FROM ANNUAL PRODUCTION

two and four tons, it is possible to delimit the production field of the enterprises. It will then be enough to overlap to the right lines *P* a faggot of right lines *p* representing the different production values per person and per year that, when located between two and four tons, leads to the elimination of production interference between one enterprise and another. The problem thus defined gives a clear idea as a whole, enabling at the same time a glimpse of the panorama presented by those sizes above *Te*$_5$.

Different observations may be formulated in connexion with figure 4. In the first place, it may be supposed that one goes from *a* to *b* along right lines *P* when the *Ic* and *Q* indices increase. The same happens assuming that *Ic* and *Q* remain constant if bad use is made of machines and installations, or a production is fractionated in too many types and models of machines, or both things at a time. Going from *b* to *a*, the appreciations are equal and opposite. Attention should also be drawn to the fact that 2,200 effective work hours per year have been admitted for each direct person, which is equivalent to one work shift.

Productive capacity expressed in number of machines per year

If a determined weight unit is attributed to machines, it is easy to estimate the number *Te* may elaborate on the basis of already available production data in tons per year.

This situation is illustrated in figure 5 where Hs 100 scales and those of productivity per person have also been adapted for each enterprise. The action field of the enterprises is defined when possibility or convenience limits are established regarding the weight of machines, in accordance with the size of industries and taking into account:

Te_1

(*a*) The means for lifting and for internal transport are exclusively manual, thus making it difficult to remove heavy volumes such as cast iron bodies of machines of more than one ton;

(*b*) The machines used are more adequate for light production;

(*c*) Should the constructed machines weigh more than one ton, their fabrication number per year would be low. In that case, annual invoicing would be subdivided into a few fractions, which is incompatible with the economic-financial structure of the manufacturing artisan;

(*d*) In order to ensure a more regular invoicing, Te_1 should elaborate larger quantities of light products susceptible of being launched into production twelve times a year (monthly frequency);

(*e*) It may be noted that Te_1 has possibilities of producing Q_2 machines only if their unit weight is reduced.

In view of the above, the manufacture of products with a unit weight of more than one ton does not seem advisable for Te_1.

Te_2

Generally speaking, the observations made for the former enterprise are also valid for Te_2.

(*a*) However, unlike Te_1, this enterprise is able to produce Q_3 machines provided their weight is not high, for example up to 0.5 0.75 ton.

(*b*) It seems convenient that when this enterprise elaborates its products in two models, the maximum weight be limited to around 1.25 tons.

Te_3

(*a*) Figure 5 indicates the existence of a wider field of manufacturing possibilities as regards the weight of machines. It is assumed that Te_3 is interested in the construction of at least three models of machines and for that reason the production of machines above 1.5 tons is not desirable.

(*b*) The technical capacity of the enterprise might allow for even heavier manufactures but with Q_1 quality.

(*c*) For financial motives, the launchings should not be fewer than six per year when it is the case of producing only one model; for other cases, eight launchings would be recommended.

Te_4 and Te_5

Within the high *Te* and *Q* patterns assigned to them, these enterprises permit the most varied conditions of operability in respect of weight and number of machines. The limitations on the unit weight of products for these sizes refer to the minimum weight of the machines they are interested in constructing. Otherwise, should this weight be reduced in extreme, productions would result in less technical and commercial significance in contrast to prefixed structures which are considered normal within the sector.

Repetitive series

By repetitive series of manufacture is understood the results from the division into fractions of the annual production of a given type or model of machine as a consequence of the number of launchings in the course of a year.

Machine-tool fabrication, as with other capital goods, is characterized by discontinuity which derives from the number of times the series is repeated during the year. The most frequent quantity of launchings is in practice exactly one, two, three, four, six, eight and twelve, figures deserving some additional comments.

Generally speaking, launchings of one, two and three times a year are not acceptable for the production as a whole because the circulating capital would in such cases attain excessively high values in comparison with the economic structure of the enterprise, altering costs in a sensible manner.

For Te_4 and Te_5 the most usual frequencies are four, six and eight, while eight and twelve seem more suitable for Te_1, Te_2 and Te_3. Due to a series of variable factors, among them demand which may differ according to the type and model elaborated by a single constructor, different launching frequencies may coexist within a given factory. Hence it becomes practically impossible to take into account all the probable combinations that may occur.

Nevertheless, starting from already known data in figure 6 permits calculation of the magnitude of the construction series as a function of the number of launchings and the quantity of models.

This is of course valid for estimating the average of a manufacturing situation as well as for facilitating some of the combinations which may derive from the subdivision of total annual production for each *Te*.

INVESTMENT AND COSTS

Investment on machines for the five enterprises

Machine tools represent the greatest part of fixed total investment. The number of direct operators working with machines has already been determined for each size of enterprise; as usual, they have been assigned a machine per person. If this relationship is taken as starting-point, it is easy to compile an inventory for each enterprise which although hypothetical may be sufficiently representative regarding the form of operation of the sector. Even if not referred to the construction of given types or models of machines, it must be acknowledged that these conditions are nearer the ideal equipment for the manufacture of metal-cutting machines than for that of metal-forming machines, since the first ones exist in a larger variety of types and models.

The selection of the production equipment is also made, taking into account the factors, quality, complexity and weight of the machines, in agreement with the positions adopted in this outline. Generally, the smaller firms use machines of low price and less technical resources. Te_3 utilizes machines of medium value together with others of inferior quality, while for Te_4 and Te_5 the category of the machines integrating the inventories is of high level in terms of quality, operative resources and Te and Q and with equal equipment and investment, it is possible to achieve different Hs 100 values only through the more or less rational utilization of the auxiliary production equipment which in its turn depends upon the technical, imaginative and creative capacity of the indirect personnel in charge of this task.

It also may be said that if a smaller percentage of indirects is admitted for Te_4 and Te_5, numerically more

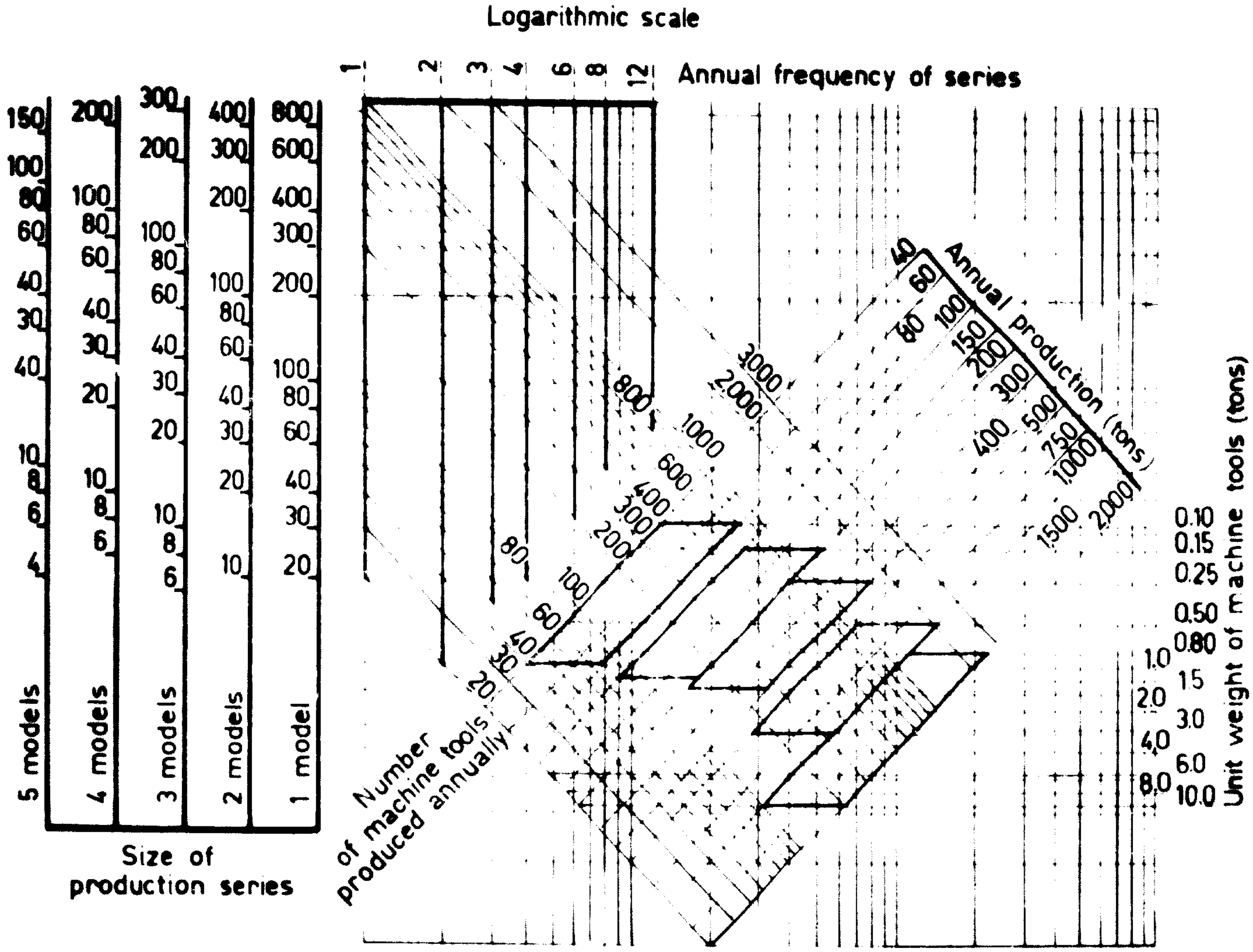


Figure 6

SIZE OF THE REPETITIVE SERIES ACCORDING TO ANNUAL PRODUCTION VOLUME, MANUFACTURING FREQUENCY AND MACHINE-TOOL WEIGHTS

prices. Here an almost always valid observation concerning the sector under analysis should be pointed out: As the importance of the series is variable at least between the limits considered, the machines do not differ much from the universal types. Hence, automatic and semi-automatic machines are not included in the manufacturers' inventory. This is easily understood when account is taken of the great variety of pieces and the large number of different operations required by the fabrication of a machine in respect to the repetitive series. Standing out once more is the importance that must be attributed to the quality of tools and to a wider use of jigs and special equipment for obtaining low Hs/100 values. This is equivalent to asserting that at parity of important inventories than those selected can be conceived. Such would be the case, among others, of enterprises working exclusively or partially through licences of foreign firms, since then the indirect personnel devoted to research studies, product and equipment projects might be replaced by productive personnel once these services would be in the charge of the industry providing the licence. Thus the number of direct hours available in one year could be increased between 15 and 5 per cent over the values adopted. As these cases fall out of the scope of the present outline, they have not been considered further. However, it would not be difficult to adjust the respective corrections within the context of these notes.

The variety of the machines usually utilized in those manufactures may be appreciated in table 6, together with the distribution for the different enterprises. Here it is naturally understood that the displacement of Te_1 towards Te_5 implies an improvement of its quality with repercussions over the price.

In order to facilitate the interpretation of the table, some comments are added in connexion with each type of enterprise.

Machines for Te_1 enterprise

The list of the machines required by this enterprise is extremely simple and offers few variants. As in this size there are no specialized sections, machines are used for direct as well as for indirect services. There are no machines to carry out special services: this is a workshop where labour is exclusively artisanal and where it is normal that the same worker executes different functions, passing from one to the other with relative facility.

Machines for Te_2 enterprise

This size is also characterized by the employment of a reduced number of indirect personnel. Its inventory of machinery is of some importance and allows it to construct machines with *Ic* and *Q* features which favourably meet the demands of the industrial inventories of such countries which are just starting to develop mechanical industries. As a rule, the technical and commercial guarantees which this type of enterprise may provide are not in sufficient demand to subscribe fabrication agreements through licences from foreign firms. For them it is more common to subcontract some project services. The equipment itself as well as methods of utilization still reflect elementary technical levels.

Machines for Te_3 enterprise

The evolution of enterprises from Te_1 to Te_4 and Te_5 is accompanied by increasing technical and organizational capacities, starting from the artisanal system for Te_1 and progressing to a complete structure, already possible for Te_4 and consolidated for Te_5, Te_3 offering diverse interpretations of machines, equipment and organization. This means that Te_3 may represent as much of an enterprise of Te_2 type, though somewhat larger, as an enterprise which is trying to develop its general structure taking as a point of reference the organization and the techno-productive results that may be achieved in superior sizes. In the present case, the selection is made with a view to the latter hypothesis which implies that beginning by Te_3 it is interesting and feasible to work with licences from specialized firms.

Machines for Te_4 enterprise

When a machine-tool enterprise reaches Te_4 size, the structure of almost all its sections is well delineated and the firm is in a position to elaborate products of a certain complexity and of its own design. Such an enterprise may therefore contribute in some measure to the technological evolution of the sector.

Machines for Te_5 enterprise

In this size of enterprise, the preferential selection of equipment for the manufacture of metal-cutting machines is more evident. It may also be observed that in Te_5 enterprises indirect machines can attain almost 9 per cent of the total, which allows internal construction of complex auxiliary production equipment. Under these conditions, rational employment of installed machinery, together with efficient administration and organization of the different sections, make possible productions with low Hs 100 values although *Ic* and *Q* might be high.

Other investments

This denomination covers mainly the following items:

(*a*) Indirect and complementary production equipment;
(*b*) Internal mechanized means of transport;
(*c*) Trucks and vehicles;
(*d*) Furniture and office machines;
(*e*) Equipment for laboratories;
(*f*) Industrial installations;
(*g*) Terrain;
(*h*) Buildings.

Before evaluating the probable amount of investment, the position of every enterprise with regard to these points should be defined. This is summarized in table 7.

This scheme expedites the discrimination on capital density among the different *Te*. On the basis of available information and taking average conditions within those normally registered in practice, it has been possible to estimate total investment by types of enterprise, as indicated in table 8.

In practice, within the same size of enterprise varied situations coexist especially as to terrain, buildings and installation values. Moreover, these values differ between one zone and another within the same country, as well as in the different countries. It is estimated, however, that the values adopted for total investment in table 8 are sufficiently indicative of the structural differences that separate the several enterprises.

Cost of direct man-hour

One of the more accepted methods for calculating hourly costs consists of relating all fixed expenses registered in one year with direct or productive man-hours actually available. Given its simple structure, in the smaller enterprises it is enough to assume for the direct hour an average value equal for all sectors of the factory. For Te_4 and Te_5, it is preferable to establish average values for the direct hour for each group of similar machines and for the different production sections, as in these cases the hourly cost is diverse either owing to the stronger or weaker incidence of labour or to the degree of intensity of the applied capital.

According to the purpose of this outline, it is enough to present the average cost of direct hour for each enterprise so as to reduce the number of variables, already high. In this respect, the following should be kept in mind:

Table 6

INVENTORY OF MACHINERY REQUIRED BY THE DIFFERENT TYPES OF ENTERPRISES

Denomination	*Te*1	*Te*2	*Te*3	*Te*4	*Te*5
Production machines					
Parallel lathes of various dimensions	6	9	13	18	24
Screw-cutting lathe	—	—	—	1	2
Vertical lathe	—	—	—	—	1
Turret lathe	—	—	1	6	9
Copying lathe	—	—	—	—	1
Universal milling	1	1	3	5	5
Vertical milling	—	1	2	3	4
Special milling	—	—	1	2	3
Horizontal milling	—	—	—	—	1
Screw-cutting milling	—	—	—	—	1
Planning	1	2	3	4	4
Planemilling	—	—	—	—	1
Slotting	—	—	1	1	2
Shaping	3	3	3	5	3
Horizontal boring	—	1	2	3	3
Vertical boring	—	—	—	—	2
Pillar and bench drilling	3	6	8	12	14
Column drilling	—	—	—	—	6
Radial drilling	1	1	2	4	6
Universal cylindrical grinding	—	2	2	4	7
Internal cylindrical grinding	—	—	—	2	3
Plain grinding	—	1	2	2	4
Plain grinding for slides and large surfaces	—	—	—	1	1
Grinding for splined profiles	—	—	—	—	1
Gear cutting, Fellows type	—	—	1	2	3
Gear cutting, Maag type	—	—	—	—	1
Gear cutting, Pfauter type	—	—	1	1	2
Gear cutting, Barber-Colman type	—	—	—	—	1
Conical gear cutting	—	—	—	—	1
Grinding for gears	—	—	—	1	2
Bevelling gears	—	—	—	1	2
Broaching	—	—	—	1	1
Threading, CRI-DAN type	—	—	—	1	2
Straightening for shafts	—	—	—	—	1
Saws	1	3	4	6	7
Machine for sheets	1	1	2	3	4
Welding	—	1	1	2	[illegible]
Hydraulic press	—	—	—	—	2
Honing and lapping	—	—	—	—	1
Dynamic balancing	—	—	—	—	1
Centre hole grinding	—	—	—	—	1
Centring shafts	—	—	—	—	1
Dividing and engraving	—	—	—	1	2
Special[a]	—	—	—	4	7
Others	—	—	—	2	8
Total direct machines	17	32	52	98	160
Machines for tool manufacture, maintenance and construction of jigs and special production equipment					
Jig boring	—	—	—	1	2
Precision milling	—	—	—	—	1
Universal milling	—	—	1	1	1
Universal grinding	—	—	—	1	1
Precision parallel lathe	—	1	1	2	3
Tool grinding	1	1	2	3	4
Shaping	—	—	1	1	1
Drilling	—	1	1	1	2
Welding	1	—	—	—	—
Total indirect machines	2	3	6	10	15
Total inventory	19	35	58	108	175
	(United States dollars)				
Total value of machines[b]	36,000	105,000	244,000	663,000	1,356,000
Average value of machines[c]	1,900	3,000	4,200	6,140	7,750

[a] Constructed or adapted in the same industry.
[b] For simple machines, the types and prices prevailing on the Argentine and Brazilian markets have been considered.
[c] For machines of non-Latin American origin, an overcharge of 10 per cent over the f.o.b. value for transport and insurance, and another of 20 per cent for internment expenditures and others have been considered.

(*a*) Accounting of all direct man-hours already determined, that is those considered as productive; this is done by means of the cards enclosed with the work during its execution. The sum of all direct hours accumulated in the course of a year should coincide with the theoretical hours available, which are deduced in accord with the number of direct persons working in an enterprise. It is understood that passive times of work preparation as well as of the operational cycle proper should also be accounted for, charging them to the respective piece or machine;

Evidently each *Te* will be characterized by a different *Ch* value that will increase as long as *Te* augments.

Table 9 presents relevant data that should be kept in mind when calculating the cost of direct man-hour on the basis of average situations occurring in the Latin American countries, with special reference to Argentina and Brazil. Once *Ch* has been determined, it is easy to arrive at the fixed cost per 100 kilogrammes of finished product Co 100, which if other conditions are maintained equal will be different and variable according to its productivity in each size of enterprise. In agreement

Table 7

SCHEMATIC DISTRIBUTION OF INVESTMENT, EXCLUDING MACHINE TOOLS

Item	Te_1	Te_2	Te_3	Te_4	Te_5
(*a*)	almost nil	scarce	medium	complete	complete
(*b*)	...	tackles	tackles	bridge crane and lifting tackles	complete
(*c*)				yes	yes
(*d*)	negligible	scarce	medium	complete	complete
(*e*)	...	—	...		medium
(*f*)	almost nil	primary	scarce	medium	complete
(*g*)	yes	yes	yes	yes	yes
(*h*)	yes	yes	yes	yes	yes

Table 8

ESTIMATE OF TOTAL INVESTMENT BY TYPES OF ENTERPRISE

(*Values in thousand dollars*)

Denomination	Te_1	Te_2	Te_3	Te_4	Te_5
1. Direct and indirect machines (see table 6)	36.0	105.0	244.0	663.0	1,356.0
2. Other investment (see table 7)	5.4	23.0	69.0	387.0	984.0
3. Total investment	41.4	128.0	313.0	1,050.0	2,340.0
4. Relationship of 1 over 3	87%	82%	78%	63%	58%
5. Investment per occupied person	2.07	2.56	3.13	4.20	4.68
6. Investment per direct person	2.18	3.12	4.35	6.78	8.50

(*b*) Accounting of all expenses during the year in connexion with wages and salaries, social taxes, general expenses of operation and indirect material for consumption by the office and the workshop, as well as other expenses except raw materials, sales and banking expenditures;

(*c*) Amortization of all investments. In the following estimates an annual amortization of 10 per cent over the total value of investment has been considered. In fact, part of the amortization, that of indirect manufacturing equipment relative to a determined model, measurement calibres, cast iron models and others, should refer to inferior times, while the other, that of buildings and installations, allows for longer periods.

It derives that the cost of direct man-hour (*Ch*) will be:

$$Ch = \frac{b + c}{a}$$

with the average figures adopted, it may be pointed out that Co 100 values fluctuate between $45 and $150. Owing to the method followed to estimate Co 100, this represents only part of the cost, the rest being constituted by:

(*a*) Raw materials (cast iron, steel bars, sheet, etc.);

(*b*) Eventual machining subcontracted to third parties;

(*c*) Parts and pieces bought in the market and used directly on the assembly line;

(*d*) Propaganda and sales expenditures;

(*e*) Banking expenditures.

The sales value is obtained through the addition of gross profit to these expenses and to those indicated in table 7.

If Co 100 cost is related to the sales value of 100 kilogrammes of product (Vv 100), it follows that although an optimum unique value cannot be attributed to this rela-

Table 9

BACKGROUND DATA FOR CALCULATING DIRECT MAN-HOURS

(Values in dollars)

Denomination	*Te₁*	*Te₂*	*Te₃*	*Te₄*	*Te₅*
1. Persons occupied in the enterprise	20	50	100	250	500
2. Directs (with and without machines)	19	41	72	155	275
3. Indirects	1	9	28	95	225
4. Annual hours per direct person	2,220	2,200	2,200	2,200	2,200
5. Total direct man-hours per year	41,800	90,200	158,400	341,000	605,000
6. Annual wages of direct labour	10,500	27,000	55,400	126,000	242,000
7. Annual wages of indirect labour	2,400	9,000	28,000	114,000	315,000
8. Total wages (6 + 7)	12,900	36,000	83,400	240,000	557,000
9. Social taxes and insurance (percentage of 8)	60	60	60	60	60
10. Total annual expenditure on personnel	20,640	57,600	133,440	384,000	891,200
11. Annual amortization (see table 8, 10 per cent)	4,140	12,800	31,400	105,000	234,000
12. Fixed general expenses per year	6,000	20,000	45,000	100,000	250,000
13. Consumption material per year	5,000	12,000	30,000	70,000	140,000
14. Total fixed expenditure per year (10 + 11 + 12 + 13)	35,780	102,400	239,840	659,000	1,525,200
15. Cost of direct man-hour (14:5)	0.86	1.14	1.51	1.93	2.52

tionship, given the general terms under which the problem is framed, it is true that such a relationship keeps within practical limits of further operative feasibility of the order of 30 to 50 per cent. These are applied in figure 7 to each *Te*, together with the already defined data on total annual production in tons, Hs 100, *Ic* and *Q*. Thus, starting from favourable and or possible factors, the field of action of the five enterprises is clearly delimited.

As regards the correlations amoog quality, complexity of the product and sales value of the same, it is evident as illustrated in figure 7 that this is an empirical accommodation whose objective is to gather into a single panorama the free play of the several techno-economic variables characteristic of the sector. Furthermore, it may easily be seen that the right lines which define the percentual relationship between Co 100 and Vv 100 are

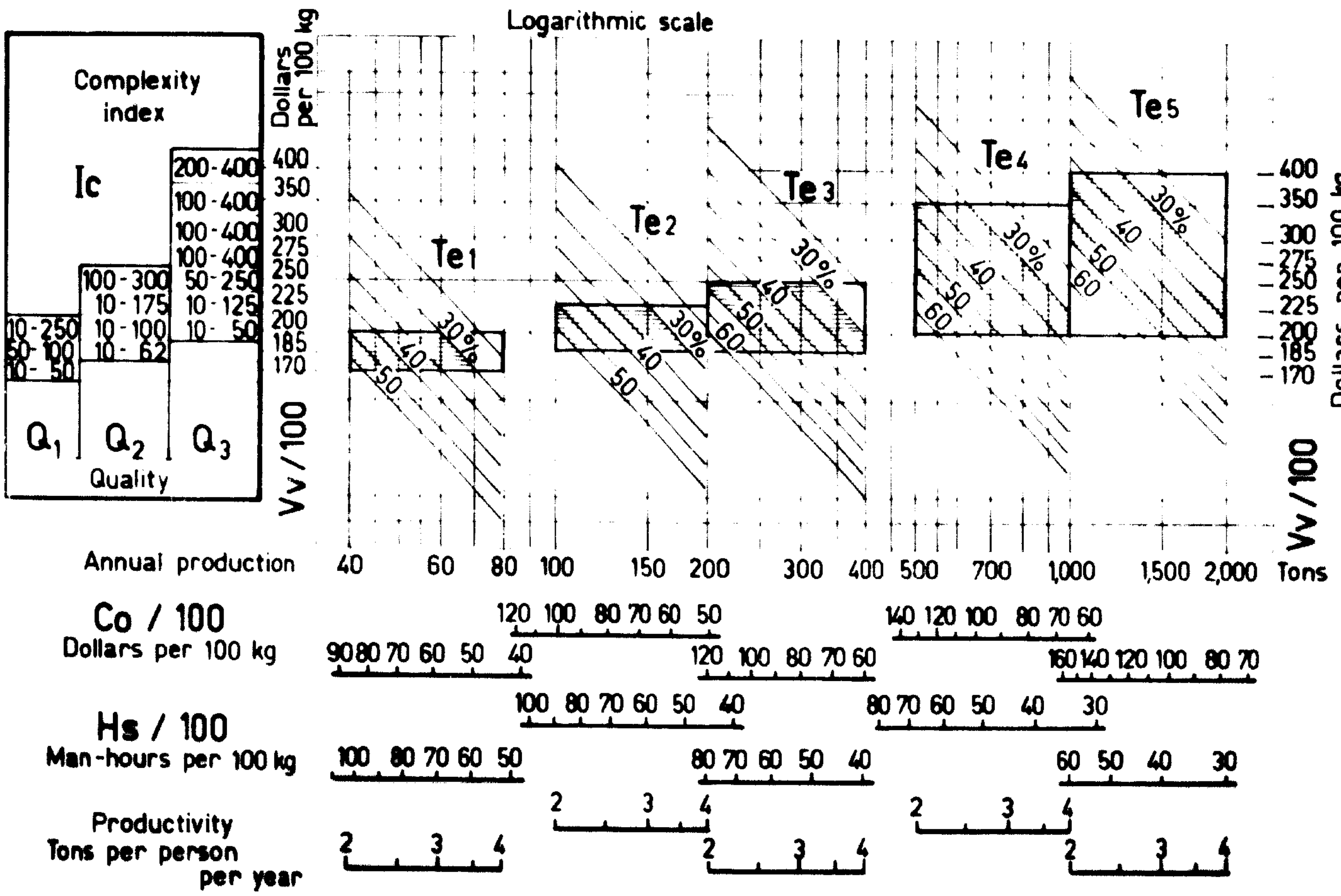


Figure 7

TECHNICO-ECONOMIC FEASIBILITY OF ENTERPRISE OPERATIONS

lines of "equi-invoicing", that is, of equal economic effect **for different** technical conditions of operation.

An observation here is that Te_1 and Te_2 enterprises **would** find obstacles to productivities of the order of **four** tons a year per person, and this in practice is con**firmed** by the Argentine and Brazilian cases. In return, **the** other sizes of enterprise offer possibilities in this field, **which** is in agreement with the structures assigned to them.

RELATIONSHIP BETWEEN MACHINE-TOOL MANUFACTURING ENTERPRISES AND THE INFRASTRUCTURE OF THE REST OF THE MECHANICAL INDUSTRY

It is usually admitted as a general rule that the pro**ducer depends** to a greater or lesser extent upon auxiliary **industries** that provide him with services, specialized parts and pieces for the manufacture of his products, whose existence has been transformed into an indispensable infrastructure for the development of the sector. It is obvious that the magnitude of such a structure as a supporting element for machine-tool construction is enlarged, complemented and complicated in the measure that quality, complexity and sometimes even the weight of the machines increase: in other words, on direct account of the installation of firms of growing size.

Thus, the presence of factories of type Te_1 and Te_2 does not necessarily imply the existence of an important auxiliary industry as they produce quite simple machines. But for the products attributed as feasible by the rest of the enterprises, the assistance of other specialized enterprises is imperative.

It is understood that the comparison among different Hs 100 will be valid as long as the manufacture is integrated in the same manner. It must be pointed out that in practice the integration variables are not many, as the producers usually buy the cast iron material, machine it, purchase in the market the parts and pieces indicated on table 10, and machine the remaining pieces.

The group of raw materials and services mentioned in that table constitutes a point of reference about that which has been defined as infrastructure and which should consequently be considered as a domestic activity. In accordance with the qualitative hypotheses connected with the size of the constructor, the quality demands of cast iron material go together with the increase of *Te*. Hence, the importance of an iron foundry, as cast iron is the basic raw material for the manufacture of machines (from 50 to 80 per cent in gross weight with regard to the weight of the finished machine). The second group of parts and pieces presented in table 10 and its respective qualitative appreciations in relation to the enterprises, deserve further comment.

In the first place, it is not indispensable that the availability in the market of all the items is conditioned by their being nationally manufactured. On the contrary, it is admissible that some of them—bearings, complex

Table 10

LIST OF MAIN INTERCONNEXIONS BETWEEN MACHINE-TOOL MANUFACTURING AND AUXILIARY INDUSTRIES

Denomination	Te_1	Te_2	Te_3	Te_4	Te_5
Raw materials and services					
Cast iron (quality)	medium	regular	good	perfect	perfect
Relief of stresses	no	sometimes	sometimes	always	always
Variety of cast irons	scarce	scarce	sometimes	high	high
Hardness demand of cast iron	scarce	scarce	sometimes	rigorous	rigorous
Foundry of non-ferrous (quality)	medium	regular	good	perfect	perfect
Use of common steels	scarce	scarce	regular	normal	normal
Use of special steels	different	reduced	reduced	normal	normal
Heat treatments	very scarce	scarce	insufficient	normal	normal
Commercial parts and pieces					
Electric motors	common	common	common	special	special
Simple elements for electric circuits	medium	almost regular	regular	good	good
Complex elements for electric circuits		—	sometimes	normal	frequent
Elements for hydraulic circuits			sometimes	correct	good
Elements for pneumatic circuits	—		sometimes	correct	good
Elements for circuits of lubrication	elementary	elementary	almost normal	good	complete
Elements for circuits of refrigeration	elementary	almost regular	normal	good	good
Clutches, brakes, torsional, couplings, etc.	—	elementary	scarce	sufficient	complete
Screws, screw nuts, washers and similar items	elementary	almost regular	normal	good	good
Use of precision bearings	no	no	irregular	normal	normal
Springs of every type (quality and variety)	scarce	scarce	almost regular	complete	complete
Non-metallic accessories (use)	scarce	scarce	regular	complete	complete
Non-electric accessories of machines (quality)	medium	elementary	almost normal	normal	complete
Electric accessories such as magnetic plates, etc.	—	—	sometimes	normal	complete
Simple non-metallic elements (use)	scarce	almost regular	regular	complete	complete

elements for electric and hydraulic circuits, clutches and others highly specialized, for example depend upon importation. In this group, several less complicated products may also be included which are bought from local industries. Nevertheless, it is interesting that the exaggerated dependency of domestic industry upon the incorporation of certain accessories for machines would affect the elasticity of the productive process up to the point that it would be more convenient for the producers to take charge of the manufacture of parts of such elements until finding someone who could elaborate them. Similar situations have occurred in Argentina and Brazil where, only recently, firms capable of designing and constructing accessories under strict specifications are starting to emerge from the mechanical industry.

Owing to the limited equipment available to Te_1, Te_2 and Te_3, it is a normal practice for these enterprises to subcontract services for specialized machining such as gears, splined shafts and machining of heavy pieces. Within the flexibility with which it has been intended to define the most probable field of action of the different Te, minor cases of subcontracting of services other than usually considered would be contemplated. In general, elementary and simple machines do not need the addition of highly specialized and technically advanced elements, and that their respective unit values of sale are not too influenced by the pieces bought in the market. However, as long as the machine becomes complicated in its diverse aspects, the producer will certainly begin adding to it, in growing quantities, complements from other specialized machines, thus substantially altering the relationship between his work and the value of pieces and equipment purchased from third parties: in some very complex machines, the correspondingly high values of Vv 100 are achieved through the important contribution by other provider industries of parts and pieces.

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