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STUDY ON PRODUCTIVE CAPACITY IN THE MECHANICAL INDUSTRIES *

MEXICO

by

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Introduction

In the activities of the Capital Goods Project in Mexico, as mentioned in F. Fajnzylber 1/, the focus has gradually been displaced from general issues to concrete subjects, and based on accumulated experience it has been possible to move on to the promotion of significant projects with an important bearing on the development of this industry in Mexico.

However, even the first general step, the preparation of the framework for a development strategy 2/ in which macroeconomic problems were conditioned with the rôle to be played by the Mechanical Industry, required a previous knowledge on the productive situation of this industry. An enquiry of the 90 leading companies that are active in capital goods production was carried out in that preliminary stage.

Gradually the knowledge of the productive capacity of this industry was built up in a more refined form and this enabled the publication of a general summary as well as other monographs on the more important branches 3/.

1/ F. Fajnzylber "Capital Goods Program in Mexico". October 1979

2/ NAFINSA/UNIDO Joint Project "México. Una Estrategia para Desarrollar la Industria de Bienes de Capital". Mexico 1977. (An Strategy for the development of the Capital Goods Industry.

3/ Joint NAFINSA/UNIDO Capital Goods Project in Mexico. Sectorial Monographs on the Capital Goods Industry:
1. "La Oferta Nacional de Bienes de Capital" (The National Supply of Capital Goods). Mexico 1978.
2. "La Producción de Compresores en México" (Production of compressors in Mexico) Mexico 1979.
3. "La Fundición en México" (The Foundry Industry in Mexico)Mexico 1979
4. "La Industria Electrónica Profesional en México"(The Professional

It was then possible to compare the previously mentioned studies on the Capital Goods Supply (published and unpublished) with the corresponding studies on its demand 1/. From this comparison a clear contrast emerges between Mexico's needs and present possibilities, and therefore a clear and quantifiable background on which new projects could be established and negoticted.

The mechanical industries have some peculiarities that make them quite different from other industrial activities, for example the correspondence between the need for a certain product and a project to serve this need is by no means as clear and direct as in, say, the process industries. Capacity can be increased stepwise by introduction of additional machinery. Subcontracting and multiproducts play an important rôle. Therefore, in order to formulate new projects it is of the utmost importance to be well acquainted with the possibilities of the preexisting industry, not only due to the requirements of complementation and inputs -both related to subcontracting- but also due to the possibility that a reinvestment may be more advisable then a new project. It may also well be that success in a new and important project requires launching a group of related projects, i.e. a program to mobilize a critical mass that could really obtain a coherent advance in industrial development.

1/ The paper on demand by A. Bozzolo and R. Truffello, summarizes most of these demand studies.

Some important aspects of the productive capacity have been stressed in this paper. Mexican as well as international examples have been used in order to be able to convey a wider view.

Qualitative aspects, such as the determining machinery and equipment have been considered (largest sized, more powerful equipment), along with the related concept of productive frontiers. The shift in these frontiers has an important bearing on the technological and productive development of the engineering industries. It is remarkable that some developing countries have been able to sustain a rapid advance in this regard and are placing themselves very close to achievements that corresponded until recently to developed countries.

Productive frontiers and determining machinery, are separable from high-volume, high-series production, at least in principle. Large size equipment is more closely related to production based on specific orders, ad-hoc design and similar concepts, in contrast to high-volume production which is more catalog and stock oriented. This large size jobbing or ad-hoc production is more labour intensive (qualified labour, however) and also technology intensive.

As a matter of fact it seems to be precisely the focus of technological growth in developed countries, and it seems very significant that some developing countries have been able to keep up a fast pace in this field.

1) *Requirements and objectives in Studying Productive Capacity.*

When studying the Mechanical Industries, and especially the production of Capital Goods, its importance implies that the analysis of its productive capacity serves a variety of purposes.

One of these objectives is to obtain a general economic view of the sector (Capital Goods) and of its position within the mechanical industries, and to follow its effects on the overall industrial activity, balance of payments and investment. This is a typical macro economic approach, which in developing countries still reveals a clear pattern characterized by a high proportion of merchandise imports in capital goods (near 40% is frequent), a low or negligible proportional of exports, and as a consequence, a vital share of the internal demand must be obtained in foreign countries. In other words, imports are much more important than production. This is a well established patter; actual proportions vary according to the industrial maturity achieved in each case.

An effect of this situation is clearly discernible when the developing economics are confronted with the problem of increasing their growth rate. For this it is necessary to step up investment, i.e. requirements for machinery and equipment. Then, as a result of lack of productive capacity or reactive slowness, a motable increase in imports takes place 1/, an increase in financial commitments, and the portion of

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1/ Brasilian imports of capital goods from 1965 to 1978 grew 2.6% times more than the gross internal products, which expanded at 8.4% per year in that period. When the Mexican economy recovered from a previc recession in 1978, and an economic boom started to unfold it reached a similar elasticity of 3 for capital goods imports.

demand which was previously satisfied by local production diminshes significantly. To some this looks like a deviation from "normal" po ssibilities.

However, this frequent combination of results reveals something else about the local production of capital goods. Notwithstanding a noticeable margin of unused capacity, producti on lags behind demand when substantial increases in investment take place. This points not only to lack of dynamism, but also to the inability to supply specific production goods demanded be it in terms of dimensions capacity, delivery time or price.

Symmetrically, if the additional resoruces in foreign ex_ change required for growth are no. available, or if their limit is close, growth will be paralysed.

Therefore, to identify these deficiencies, questions as to why some specific and important equipment cannot be supplied locally, or why its demand was not foreseen in due time, provide more definate inforamtion. Precisely, the analysis that these questions provoke should supply useful indications that lead to an understanding of the degree of development of the mechanical industry in developing countries.

These commentaries also point to the care that should be exercised when dealing with the usual aggregate figures that are employed in global or macroeconomic studies. These figure tend to hide several different aspects of capital goods, that may react fast or slowly or that may be limited, for physical reasons, to very small increments.

In any case, the macroeconomic reasoning is also vital for orienting analysis. It does illustrate the role of this industry in economic development. It is easy to loose sight of this important aspect in detailed studies. In other words, the relationship between the capital goods industry and the national economy and the possibility of consulting some valid indicators on the sectors performance, is one of the results of the macro-economic study.

An overall view and a knowledge of the linkage with the general economy are important, since the capitalgoods industry is one of the most diverse and extended industrial activities. The were fact that it should supply investment goods to all the economic activities confers to it a special character and responsability. Since the local industry evidences its inability to fulfill this objective, the proportion of imports in the supply of capital goods (or of investment) becomes an important economic indicator, which, even disregarding local price distortions, is very revealing. Even among the most advanced developing countries, the proportion of imports in investment goods (from, say, non-electrical machinery and equipment,) easily reaches 60%.

In non-electrical machinery and equipment it is usually more difficult to attain a higher share of local content, since the nucleus of specific machinery for every investment where technology plays a vital rôle, is classified there. In metallic products, that usually enjoy some natural protection, or in electric equipment (for other reasons) the share of imports tends to be lower.

Simple indicators such as those just mentioned are required for macroeconomic purposes, as are other related indicators for sectorial growth and its relative position to demand, product and investments.

In developed countries, simple economic indicators are to be regarded differently from the same indicators in developing countries. In the former case, the existence of a mature and well stabilised structure of production can be assumed and therefore, indicators evidence its variations, relative lags between countries and similar problems, but continuity to some extent is guaranteed by the preexisting base.

A different thing happens in developing countries. Base figures and structure tend to differ from the needs of growth. The discrepancies that arise while increasing development growth should not be surprising. Continuity is far from assured in the development of the economy and of the capital goods industry. To avoid its worst effects, new projects should span the gaps.

Even when confronted with simple names such as electric motors or machine tools, their meaning and content in developing countries is usually very different from the equivalent concepts in developed countries.

It seems therefore, that it is necessary to examine and use finer indicators that makes it possible to tell which products can be manufactured or not, what periods of time may be required or which complementary projects should be carried out, and how they will contribute to the industry's maturity. The names of products or industrial branches may be deceiving not only in the sense just mentioned, but also because a mere assembly may be implied rather than integrated production. This assembly in its turn can be an initial transitional stage -sometime unduly long- in which imports and assembly coexists in or through the same company.

2) General Characterization of the Productive Situation.

a) The producing sectors (selection, characteristics, importance).

The producing sectors to be studied will be presented herewith, along with the main arguments for their relevance. Two main groups will be differentiated: base industries and the machinery, equipment and component industries.

It should be mentioned that the problem of classification in this industry is far from being trivial. Usual classifications reflect a mixture of compromises between theoretical criteria and real economic differentiation. Foundry, for example, is one of the basic metallurgical techniques and it has its own place among mechanical industries, but in some cases foundry may refer to · captive activity related to the finished production of capital goods like pumps or agricultural machinery. A similar thing may happen in fabrication or platework; besides, from a fabricating industry such diverse products can be obtained as structures for electricity transmission towers or pressure vessels for oil refineries.

If the purpose consists of having homogeneous products from the point of view of its utilization, another classification should be employed. All of this points to the complexity of the subject, which far from-being in a satisfactory way. The solution of this problem requires methods of analysis that would be very useful for a better kowledge of this industry.

The simple separation in two groups that has been attempted illustrates in the base industries, some common inputs (foundry, forge), components or equipment and techniques which are usually shared by all the mechanical industries. The second refers mainly to finished products, be they of specialised use or not.

Base industries.

Fabrication (platework)

This is one of the primary or basic sectors, in the sense that it does group and use some of the fundamental techniques, such as metal cutting deformation and welding. Besides, its demand arises in the early stages of development linked to tanks, vessels in general, simple equipment for the chemical and cement industries, mining and metallic structures. Its products tend to be bulky and of low unit price, which gives them a certain degree of natural protection.

In its different developments it may reach the production of steam generators, distillation towers, reactors, specialized furnaces for hydrocarbon processing, heat exchangers and a wide assortment of pressure vessels for the chemical industry. In its maximum development stage it may produce heavy equipment for nuclear power plants. In these cases, the techniques are more sophisticated and such plants are quite different from the initial ones.

Foundry

As already mentioned, this industry corresponds to one of the basic metallurgical techniques. The production of small parts in large series (with some degree of automation) should be differentiated from the production of heavy parts on order or jobbing foundries. High series production is usually related to the automotive industry, and in this relationship tends to be rather specialised. Medium series can be attained in the production components for reailroad equipment, mining equipment, valves, pumps and rolls for steel rolling.

Heavy parts in small series are strictly related to important capital goods.

Forging

Forging represents another basic metallurgical technique. It refers to the deformation of hot metal with plastic properties. Again a clear dividing line should be established between high series of small parts (stamping) linked with the automotive industry, fasteners and similar parts, and open-die forging of heavy parts in large, specialized hydraulic presses employing ingots of the best metallurgical quality. These ingots and the forging techniques have been considerably refined to satisfy modern requirements in the production of turbines, shipbuilding, nuclear power equipment, and similar heavy parts of high quality.

Machine tools

This is again an industrial sector that also represents one of the basic techniques of the mechanical industry. Machine tools are the specific machines of the mechanical industries.

The initial division in this case is between metal cutting and metal forming machine tools. Then, within each type, general types of machine tools are differentiated, such as lathes, drills, milling machines, gear hobbing machines, etc. Another complementary differentiation should be established according to their automatic production capabilities, type of control (automatic lathes, numerical control machines, transfer machines, etc.) or especialised design.

Machine tools should not only be considered from the point of view of production, but also from the point of view of use and availability. This aspect is frequently analysed through machine tool inventories and specially through detailed examination of what may be called the "determining" machine tools, i.e. those that fix the limits of productive capacity in the different branches of the mechanical industries.

The volume and production structure of machine tools in a developing country as well as the availability of "determining" machine tools are some of the best indicators of the maturity of the capital goods industry.

At least an important part of the most advanced especialised engineering knowledge related to capital goods production, an be found associated with the design and production of machine tools.

Machinery and Components Industries.

Whilst in machine tools an important percentage is bought by the mechanical industry itself, the machinery and components industry refers to finished equipment and vital components which constitute the investment of all the economic activities (except the mechanical industries). Sometimes a certain machine has a single and well defined final use (wearing machines - textile industry), in other cases there can be a wide diversity of final and intermediate destinations, for example an electric motor can be incorporated in another machine (machine tool, pump, etc.) and then sold to the user for assembly or replacement.

Agricultural machinery

This case deals with series production. Therefore, the volume of production is an important indicator, and its relation to the arable land in the country. However, qualitative characteristics of production should also be examined as well as the degree of local content (integration. If production is well integrated it will have a positive effect on the local production of diesel engines and transmisions.

Oilfield drilling equipment.

Characteristics such as derrick's height, depth to drill and local integration define in general terms what can be produced. It is also necessary to analyse accesories and auxiliary equipment (special valves, mud pumps, drillbits, kellys, etc.).

Ore crushing and milling equipment.

This type of equipment is used by mining, cement, aggregate, chemical and other industries. The range is wide and varies from light easy to make equipment, to very heavy, with parts that weight 60 tons or more. In this case therefore, the specific characteristics of the equipment and the degree of local integration should be studied.

Earth-moving machinery.

The largest equipments are not only used in construction and large public works, but also in mining (open pit), forestry and some agricultural activities, as well as in materials handling in several industries. As in the case of ore crushing equipment, the equipment type and size should be established.

Metallurgical Equipment.

In the case of furnaces, several types can be differentiated. However, some of the more common types, used both in steel making and non-ferrous industries, a e quite similar.

Rolling equipment has to be studied apart, and it entails a more complex number of types and components.

In this productive branch agains sizes and types of equipment should be clearly established in order to be able to fix where the productive limits are.

Pumps.

It may be thought that this refers to simple products, and to some extent this is true. However, the simple centrifugal pumps that are produced in the initial stages of development, for urban or agricultural series of production tend to be light products in high series of production. Multistage pumps for deep weels are usually close to that stage. Modern high pressure and high power multistage pumps for boiler feed and oil pipelines, as well as axial and mixed-flow pumps for modern electricity generation and storage, all of them in powers above 500KW, are much more interesting products and are found less frequently the production of developing countries.

Production of specialized pumps, such as slurry pumps, gear pumps for viscous liquids, pumps for hydraulic circuits, are also of interest.

Compressors.

Reciprocating, vane and Rootes types and even screw type are relatively simple achievements (except for some components such as the screws themselves) and their production is extented in low capacities in terms of air volumes and relatively large series (provided there is no excess of competition).

The next step, with more important implications and a better and more practical solution for the oil, petrochemical and many other industries are the turbocompressors, which are from the technical and productive point of view akin to turbines. These are usually missing or only incipient in developing countries. Attention should be directed precisely to turbocompressors.

Gears and reducers.

Gears are components of virtually every machine, and are the basic components of mechanical transmissions. Their production requires exacting precision, specialized machining and careful metallurgy both for the blanks and their heat treatment. The gear hobbing and grinding machines are expensive as the measuring machines. The diameter of the gears is a major point, as well as their precision and complexity (other than spur or helical gears.).

In the case of reducers, those applied to turbines for their speed and high power of main interest. If many of the specialised high power reducers used in the steel industry, sugar industry, and shipbuilding are imported, this should be considered as a clear sign of weakness of local production, even though most of the catalog reducers below say 200 KW are locally produced.

Valves.

This is a wide field. According to the needs of electricity generation, chemical and oil industries, it seems that those valves with diameters above 16" and high pressures are of additional interest. Specially very heavy large-diameter valves for oil and gas ducts. Also, due to their increased complexity automatically operated valves are of interest.

Diesel engines.

Diesel engines for transport vehicles and general machinery usually have a market that permits high series production. If these engines are classified by power ranges, the first group will fall mostly in the up to 200 HP range. Engines from 200 to 1 000 HP are used as prime movers for heavy machinery, medium sized boats and electricity generation. Engine above 1 000 HP are used for locomotives and the shipbuilding industry. The problems of production, series and components differ in each case.

Turbines.

Usually the initial question is whether there is any production at all. Their requirements in terms of cast and forged parts are a taxing demand for suppliers. Its engineering represents one of the most advanced and interesting. In case production has started, their size and main characteristics should be known. Here hydraulic. gas and steam turbines are included.

Bearings.

Bearings generally pose stringent requirements in terms of steel quality and its production implies specialized machinery. It is important to identify their dimensions and types.

Electric motors and generators.

Three main groups may be established based on their power and main characteristics. Fractional horsepower (below 1 HP) and integral horsepower (above or equal to 1 HP) may be the initial division. Within integral horsepower motors, at least two main groups should be considered. Those according to usual norms and specifications up to aprox. 200 HP and those above 200 HP which usually are not comprehensively covered by norms of standards, and usually built for a specific customer's order.

According to their characteristics, at least induction motors, synchronous and direct current motors should be differentiated. Synchronous motors are usually of high power, and therefore, a small number of them have a higher share of the value of production. Generators can be classified with motors, but form a class by themselves since high power is a main consideration.

Transformers.

Power (or apparent power) and operating voltage are the main characteristics to consider.

Professional electronics.

This industry should be examined from at least two points of view, production and use.

Production can be studied through such important products as power rectifiers, instruments, LSI circuits, data processing equipment and electronic components.

Applied professional electronics are fairly spread all over the mechanical industry, in motor and equipment controls, servomechanisms comanding and automatic mechanisms, sensors, measuring and positioning devices, etc. In this sense electronics plays a rôle in the mechanical industry which resembles the rôle of the latter in the economy. It extents to all its products, modernizing and refining them, and contributes to its new efficiency and reliability.

The importance of professional electronics is then beyond any doubt. However its study isn't simple and it brings its own problems of classification as to whether it refers to captive activities or disparate industries.

The presence of this activity in relation with the capital goods industry is an important sign of maturity, even if its volume or investments are not too significant.

Railroad equipment.

The production of locomotives is of prime inportance. In the next place, production of freight and passenger cars as well as cars for underground transport should be considered.

Shipbuilding industry.

The effects of this industry on the development of capital goods is significant, both due to the amount of subcontracting and to the weight and size of components, together will the personnel qualification and availability of large-sized machinery. It is therefore necessary to know the required capacity of ships and their main characteristics.

Airplane Industry.

Undoubtedly is one of the most modern branches of capital goods, and in addition to the engineering which it requires it puts to puts to test the quality of materials and components all of which enable the development of a more mature supplier industry. Furthermore some of its engines are complementary to previous sectors.

The sectorial structure

Once that the more important production branches have been mentioned, it is of interest to consider its structural relationship.

The relation between the productive branches in the intermediate demand is easier to establish through ordered input-output matrices. Their relation to investments and final demand has not been evaluated in such clear ways.

If the mechanical and corresponding metallurgical industries are ordered, into a tringular input-output matrix a distinctive pattern and hierachy emerges. This ordering requires that those products (branches) of an advanced economy that sell less intermediate goods be followed by those that sell increasing amounts of intermediate goods (See table 1).

This result illustrates a structural difference between such products as ships, locomotives, office machines, earth moving machinery and specialized machinery for various industries, all of them mainly destined to final demand, from other branches that sell to the previous ones and to intermediate demand in large proportion such as engines, turbines, electronic components, electric motors, mechanical components.

Table 1

Input - Output Matrix of the Mechanical Industry (Illustrative)

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	Aircraft and parts	1	X																								
	Ships, trains, traylers and cycles	2		X																							
	Motor vehicles and equipment	3		X	X																						X
B	Office machines	4				X																					
	Service industry machines	5					X	X																			
	Houshold applyances	6					X	X																			
	Radio, television and telecommunication equipment	7							X			X															
	Batteries, X-Ray and engine electrical equipment	8			X					X	X		X	X			X										X
	Electric lighting and wiring equipment	9							X		X	X							X								X
	Electronic components and accesories	10							X			X															
C	Materials holding machinery and equipment	11											X														
	Special industry machinery and equipment	12												X													
	Construction, mining and oil field machinery	13													X	X											
	Farm machinery and equipment	14													X	X											
	Engines and turbines	15		X									X		X	X	X				X		X				
	Machine shop products	16													X		X	X									X
D	Optical, ophtalmic and photographic equipment	17																	X								
	Scientific, controlling instruments and clocks	18	X				X	X												X						X	
E	Electric apparatus and motors	19		X		X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X			X	
	Metalworking machinery and equipment	20	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	
	General industrial machinery and equipment	21	X		X		X	X		X			X	X	X	X	X	X			X	X	X			X	X
	Hardware, plating valves and wire products	22	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Stamping, screw machine products and bolts	23	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Heating, plumbing and structural metal products	24		X																			X			X	
	Automotive repair services	25																									

A - Transportation equipment
B - Electrical equipment
C - Non - electrical equipment
D - Instruments
E - General metalworking

Note: The x correspond only to those transactions of 1% or more of the total sales of the column

Source: The Position of Metalworking Industries in the Structure of an Industrializing Economy W. W. Leontief and A. P. Carter.
Development of Metalworking Industries in Developing Countries Moscow, 1966.

Goods, such as those described, which are mainly assigned to final demand, correspond to a single or few final demand sectors. Ships and locomotives belong to transport activities. Specialized industrial machinery have a similarly close correspondence, printing machines - printing industry, spinning and weaving machines - textile industry, crushing equipment - mining, cement, chemical industry, etc. However there are some complications to this simple description. For example, many industries may have their own transport equipment. Also, aggregation in the productive branch may have effects on the correspondence.

Machine tools, even if destined to almost all economic sectors (for repair and maintenance) their more important destiny is the mechanical industry itself.

Other products such as pumps or compressors have been classified as of extended use in the whole economy, but this can be shown to be an approximation due to aggregation. When different types and sizes of pumps and compressors are considered the situation is considerably altered.

All these arguments point to the need to consider a certain hierachy and overall view that considers its unity in studying the

the mechanical industries. These industries are clearly not independent from each other, even if the basic engineering and technological common factors are disregarded. Subcontracting is a basic fact of everyday life. However, this does not mean that something that could be called a subcontracting stage could have some realistic base.

The production of finished capital goods for final demand requires a whole series of related industries to supply them with basic inputs, equipment and even, to some extent, markets. Its development, in order to avoid painful mistakes and lags, should in many ocasions be undertaken as a whole, with the extension and diversity that the national economy allows.

An almost total escape, however artificial, from the above mentioned integral approach is by means of assembly. By importing all the parts and components and leaving only the final assembly to local activity, most of the development and subcontracting problems can be ignored for a while. At least from the point of view of the company that is introducing the assembled equipment in the market. Assembly allows it to elude all the structural relationship. However, from the national point of view, or that of the supplier of some input, a different reasoning emerges. This share of the market should be integrated with similar markets to attain reasonable economies of scale.

Lets examine, for example, the case of heavy foundry and forging. Both activities supply important components for most of the heavy capital goods. But, both require a rather extensive market to become economical. That is, the market for electricity generating equipment should be integrated with that of steel mills, sugar plants, etc. This is typical case, which has been illustrated for heavy components.

In the case of investment goods, such as machine tools or intermediate goods like electric motors, a similar situation develops. Especially regarding small series production, most of the market should be integrated to reach reasonable economies of scale.

Conversely, if heavy castings or forgings are not available, the degree of local integration that can be obtained is small, that is production comes close to assembly. However, this kind of assembly if duly oriented may lead to future integration including the local availability of castings and forgings.

Orientation is important, because distortions are frequent. Low investments associated with assembly along with a high tariff tend to originate an excessive number of assembly plants which sometimes call themselves producers. This leads to difficulties in standardizing equipment inventories, reduced volumens for spare parts production, diversified suppliers, and the next steps leading to higher local integration become politically more complicated.

These kind of dilemmas - initial assembly leading to higher integration or not vs initial production requiring inputs from complementary plants - are typical in the development of the capital goods industry. The main considerations seems to be to keep in mind the important objectives, this will make it possible to follow different policies provided that the attainment of the main goals is not jeopardized.

All the types of production that have been mentioned have similar implications, the growth of the capital goods industry does not only depend on the demand for investment that originates in the rest of the economy, it also depends to a large extent on the specific decisions taken on how to develop the mechanical industry itself. The possibility of these decisions and the various alternatives available as to trajectories to be followed, illustrate that the structural relationships in developing countries are much more flexible than in mature economies.

The decision regarding what may or may not be produced in a developing country, cannot be only based on the simple empirical observation that other countries have or have not been able to produce the same equipment. Production functions are subject to dynamical shifts in this field. In a certain category of developing countries such as Brasil, Mexico, Korea, India, these shifts can be clearly observed. It is necessary to carry out and update continously a detailed examination of possibilites and objectives, and then to transform these studies into concrete projects, in this way the dynamism in the productive frontiers may be extended to other exonomies as well.

b) The Productive Frontier and its Displacements

Sectorial Frontiers

In general, productive capacity is closely associated with certain machinery or equipment when due to this fact could be called determinant.

Reference can be made to atleast two types of productive capacity in this industry, and this, is again a differential characteristic of capital goods, one of its multiple characteristics.

The first type of productive capacity to be distinguished is the usual concept , that refers to production volume, which may be represented by a certain tonnage or number of products per year. When dealing with repetitive production of a single type of product this brings no further problems . But when --as is usually the case -

It must deal with an assortment of products, be they similar or not, then the determination of productive capacity has a new complication. Production is associated with the proportion of each of the products in the assortment, since each product has different requirements in terms of production time and also has a different weight. If products are dissimilar, the use of different machines may be required.

Annex 1 illustrates a typical case of an assortment of similar products in a large diameter pipe plant based on the UOE process This type of production has much in common with fabrication and it illustrates the problem of production capacity for these cases.

It can therefore be appreciated that even the traditional concept of capacity in terms of volume requires some additional conditions in the mechanical industry. Capacity is rather a combination of capacity, according to the proportion of different or similar products in the total.

These qualifications represent one of the differential characteristics of this industry that is, the fact that it is posible to produce a multiplicity of products, similar or not, in the same plant. The detailed calculation on what will be the pricise production of each product how to the different machines, is part of the detailed programming and project preparation in this industry.

Attention now should be addressed to another aspect of capacity which is of particular interest, not so much for series production but for production of capital goods on order. It refers to the larges sizes, weights, maximum power or similar extreme characteristics. This concept of capacity corresponds to what may be called "limiting products" and is linked to the determinant machinery mentioned above.

Some examples may illustrate this point, the case of the electric overhead travelling cranes which usually play a critical role in this regard may serve this purpose. If complete steam generators are to be fabricated, usually the heaviest part is the steam dome with a weight that easily goes beyond 100 tons. If the crane lifting capacity is only 100 tons, it is easily understood that it will be difficult or unfeasible to fabricate that part. In case the lifting capacity is adequate then we must look to the capacity of the plate forming machines (bending rolls, special presses, etc.) to evaluate if the thick walled dome (thicknesses in excess of 7 inches) can be fabricated by these machines.

In the case of a turbine housing, both for joint and internal surfaces, where diaphragms will be placed or the blades will spin, the machine tool to consider is the plano-milling machine to judge the physical dimensions that can be machined.

That amounts to say that the geometry of the parts and their measurements should be in accordance with the determinant machine: The restrictions to production are of geometrical nature (measures, form, thicknesses, related weights, relative position of surfaces to be machined), and then in a less important way, other considerations appear such as productivity, precision, equipment, age, etc.

Each important producer, tries to convey in its catalogs a clear idea about the main characteristics of the determinant machines, precisely in order that potential clients can make their own assessment as to what limiting products can be produced.

In order to carry out a comparative study on limiting products and determinant machines, it may be useful to consider a table as the one to be described (see table 2). The columns of this table include all the main production branches and the lines cover the determinant machines, although in some cases, the purpose is rather to keep track of high-series production too. The purpose of such a table is to enable a quick quantitative estimate on the relative position of a country in the capital goods sectors, to point to lags in certain types of equipment, and with some additional experience, it may contribute to signal to what can or cannot be made.

The machinery to be included in such a table will be described and some relevant examples will be provided. It should be reminded that due to the fact of captive foundries, forges, or captive fabrication and similar cases, some determinant equipment that appears as specific for a certain branch may well be found in others.

Table 2

(Illustrative)

<u>For example: Fabrication Foundry Forging Agricultural Machinery, etc.</u>

<u>Determinant Equipment</u>

<u>Metal cutting machine tools</u> a/

<u>Metal forming machine tools</u> a/

<u>Melting and refining furnaces</u>

- Cupolas (tons/h)
- Induction (tons/charge)
- Arc (tons/charge)
- VAD and vacuum degassing systems (max. capacity in liquid metal and max. weight of cast part)

<u>Heat treatment furnaces</u>

- Annealing (measures, capacity, temperature)
- Heating (same)
- Heat treatment (same)

<u>Welding</u>

- Welding machines (type current)
- Manipulators

<u>Overhead travelling cranes</u>

- Maximum lifting capacity (each and combined capacity

a/ To be described in the following pages.

Metal cutting machine tools

Lathes

- *Large engine lathe*
  (turning diam. x lenght between centers)

- *Vertical lathe (vertical boring machine)*
  (turning diam. x working height)

- *Automatic lathes*

- *NC lathes*

Horizontal boring machines

- *Table type (spindle diam, table size)*

- *Floor type (same)*

Plano - milling machines

- *Portal and other types*
  (measures)

NC Machining centers

Grinding machines

- *Cylinder grinding*
  (diam x lenght)

- *Plane surface gr.*
  (sizes)

Drills

- *Radial drills*
  (diam bit x diam arm)

Gear making machines

- *Gear hobbing (spur and helical gears)*
  (pitch diam. x thickness and module)

- *Gear grinding (similar)*

- *Measuring machines*

Transfer machines

Metal forming machine tools

Plate bending rolls

(max. thickness cold x width)

Brake presses

(length, force)

Forging presses

- *Mechanical forging presses*
  (force strokes per min)

- *Hydraulic forging presses (open die forging)*
  (type, measures, force, strokes per min)

- *Forging hammers*
  (similar)

Mechanical presses (forging excluded)

(type, force, measures, strokes per min).

Hydraulic presses (forging excluded)

(similar)

With the purpose of illustrating the contrast and relation between large-sized products and annual volume implicit in table 2, the case of electric furnaces may serve as an example. If the objective is to cast very heavy parts or heavy ingots for forging, the maximum available weight of liquid metal is the sum of the corresponding capacities of all the available furnaces. But here a duality arises, since each furnace according to its size may turn out a certain yearly output then the capacity to cast heavy parts is linked to a sizable annual volume of production. This volume may not be absor ed by the demand for large parts, in this case, the production of heavy barts must be continued with medium-sized or even small parts in order to absorbe the productive capacity of the furnaces.

The plant lay-out of course will reflect a compromise between the different objectives. However, one way to reduce the conflict is through the use of the modern systems of VAD (vacuum arc degassing) and AOD (argon oxygen decarburizing) that allows the transfer of the refining of steel from the arc furnaces to the holding furnaces, thereby increasing the capacity of the system but, which is more efficient than the case of adding other arc furnaces. The following figures illustrate this situation.

Electric arc furnaces

Nominal capacity tons	15	35
Capacity range:		
min.	12	28
max.	20	42
Productivity (refered to the maximum capacity, tons/hour)		
carbon steels	4.6	9.7
alloy steels	4.0	8.2
Productivity (now, refining of the steel takes place in the VAD furnace, tons/hour)	6.7	13.0

The capacity in tonnage per year, with the assistance of the VAD furnace, in this case, increases by 50%, but the maximum availibility of liquid steel increases by around 100%.

The maximum capacity in casting large forging ingots and its relation to the available forging presses is a clear indicator not only about the situation in forging plants, but also-due to the presence of vital forged parts in all heavy equipment - it leads to a clear assesment on the maturity of the capital goods industry in a country and also reveals the advance of its metallurgy.

In 1977, the largest forging inputs availa le in the world were[1]

Country	Company	Max. ingot weight, tons
Japan	Nippon Steel	500
	Kobe Steel	500
United States	Bethlehem	330
	United States Steel	330
Germany (F.R.)	Reinstahl (Thyssen)	300
Italy	Terni	240
United Kingdom	British Steel Corp. (River Don)	230 - 240
Germany (F.R.)	Klöckner	230
France	Creusot - Loire	170

The largest ingots of 500 tons correspond to 13 000 tons pre and those around 250 tons to 10 000 tons presses.

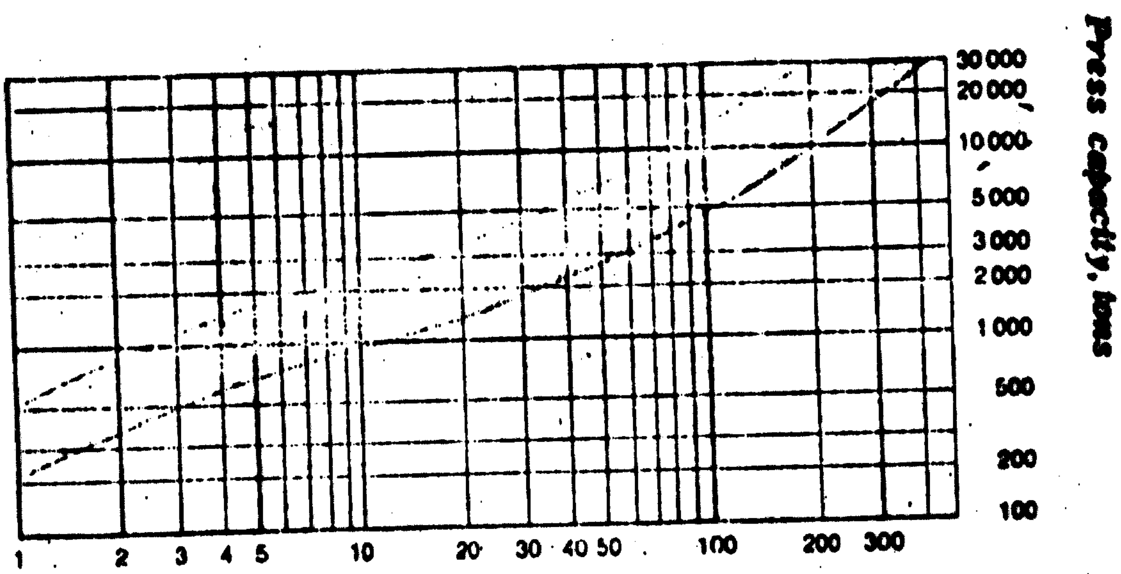
It should be pinted out that Brasil has set to itself the target reaching 200 tons forgings and it already has a 7 500 tons press, while South Korea, where a new forging plant is being installed is already considering the installation of a 10 000 tons press.

1/ Acording to W. Bailey. "Refining and Casting of Large Forging Ingots" Iron making and steel making No. 2. 1977. with small modifications.

These figures indicate how fast can middle sized dinamic economies aproach some of the important achievements of the developed countries. If should also be reminded that the present stage of technology for casting and forging such heavy inpots is a relatively recent development that originated in the 1960 s.

The case of hydraulic forging presses illustrates again the conflict between size and volume. Graph 1 presents the relationship between ingot weight and press capacity. However, the larger the press, the larger its production capacity. This again requires adding all the sectorial market and if possible some international markets in order to insure a reasonable utilization of the available capacity.

Graph 1



Relationship between forging press capacities and ingot weight.

Source: Schloemann

All the previous arguments point to the fact that information on the main characteristics of equipment such as arc furnaces and forging presses leads to the maximum weights of parts that can be cast or forged. Of course, due consideration must be paid to other complementary equipments such as cranes, etc.

That is, the determinant equipments will fix the ma imum capacity of castings and forgings that can be obtained. By deducing all the incurred losses during the manufacturing prccess, the final weight of the maximum finished parts can be calculated (losses proper, upper and lower discards from ingots, scales, feeders and risers, machining losses). A correspondence can be established between the finished weight of a part -according to the design and utilized technology- and the capacity of the equipment in which that part is incorporated. This is illustrated by table 3, where for a certain well known design, the quantity of liquid steel available is correlated with the power of the steam turbines that can be made with main components obtained from that liquid steel. This is an example of the relationship between determinant equipment and limiting products.

TABLE 3

FORGED AND CAST PARTS FOR POWER EQUIPMENT THAT CAN BE PRODUCED ACCORDING TO STEEL MELTING CAPACITY
(Power of equipment in MW)

Melting capacity, tons	80	100	120	170
Weight of finished parts aprox., tons a/	30-40	35-50	45-60	56-85
Forgings				
Rotor, low pressure b/	160	200	250	450
Rotor for turbogenerator	190	300	400	600
Rotor, high pressure	500	620	-	-
Rotor, hydraulic turbine	100	200	300	520
Castings				
Steam turbine housing	300	380	450	620
Runner for hydraulic turbine	140	170	200	270

a/ The lower weight refers to special and much more delicate products such as steam turbine rotors. In this cases the relationship between ingot weight and finished part weight can be as high as 3:1. In more common products the corresponding ratio 15 about 2:1

b/ Conventional steam turbine.

Regarding furnaces for stress-relieving of fabricated parts, used mainly for pressure vessels, their dimensions determine the size of pressure vessel that can be handled. For very long vessels, stress relieving can take place by placing each time one half of the vessel in the furnace. For example a furnace of 4.5 x 5 x 15 meters cannot deal with vessels longer than 30 meters.

Bending roll is a metal forming machine designed to form plate into cylindrical or conical sufaces and therefore its use is normal in the manufacture of pressure vessels, heat exchangers, ball mills, steam domes, cement kilns, etc. Large and powerful rolls can handle plate of aroind 10 inches thick. For very thick plate rolls are usually complemented or replaced by special presses.

If the largest bending roll available can only handle 3 inches thick plate for a reasonable width of say 3 meters, the range of pressure vessels or thick components that can be made will be severely restricted. The thickness to be rolled can be increased by heating the plate but this is not an advisable permanent solution

The maturity of the capital goods industry will therefore imply more powerful bending rolls. For modern equipment of the above mentioned types, ending rolls will be required with a capacity no less than about 8 inches.

There are several types of specialized hydraulic presses that must be identified in each case and which also correspond to other limiting products or components. Among them plate-bending presses for very thick plate used in shipbuilding and pressure vessels, dishing presses used to fabricate the emispherical or semielliptical heads of pressure vessels. In these cases, capacity in tons and dimensions determine the range of products. For a modern petrochemical and petroleum refinery industry, this presses should usually have capacity above 2 500 to 3 000 tons and adequate size.

For metal-cutting machine tools the main requirements are of geometrical nature. The length betweeen centers available in the largest lathes should correspond to the largest parts to be machined in them plus perhaps a certain margin to provide for future growth. If generator rotors and low pressure turbine rotors are to be produced, length will be inmediately in the range of 10 to 15m. If shafts for ship-building are involved length become larger. Diameters are obtained from the same parts to be machined and together with the length provide the basic characteristicas of the lathe.

Table 4 presents some typical diameters and weights for generator rotors and low pressure steam turbine rotors.

Table 4

Steam turbines and generators. Roto

diameters and weights

MW	Rotor, low pressure [a]			Rotor, generator		
	weight tons	diam. in.	diam. mm.	weight tons	diam. in.	diam. mm.
3 000 rpm						
60	13.1	48	1219	21	35	889
120	24.4	60	1524	33	37	940
200	29	61	1549	42	41	1041
500	35.7	64	1626	66	45	1143
660	47	64	1626	87	46	1168
1300	70	72	1829	125	51	1295
1 800 rpm						
540	79	78	1981	123	64	1626
680	103.3	78	1981	133.5	64	1626
840	125.4	90	2286	155	64	1626
1300	150*	90	2286	205	68	1727

a/ Unbladed rotor
* Estimate
Source: M.R. Graham. "The future supply of Large Rotors" Parsons Materials Symposium. Newcastle, Nov. 1976.

Note: For 3 000 rpm, the following relationship con be adjusted to the diameter of generator rotors (in inches).

$$D = 21.02\ (MW)^{0.12} \qquad r^2 = 0.99$$

and for their weight, at 3 000 rpm

$$W = 2.06\ (MW)^{0.57} \qquad r^2 = 1.00$$

and for weight at 1 800 rpm.

$$W = 2.79\ (MW)^{0.60} \qquad r^2 = 0.99$$

When the ratio diameter: length comes closer to one then in the case of rotors and shafts, for example, in the case of rotating components for hydraulic turbines and large pump components, ball mill heads, housings for several types of equipment, etc., it is more advisible to consider vertical boring mills. In a large pump and small hydraulic turbine factory in Japan the vertical lathe is able to machine diameters of 11.5 m and 4.1m vertically. The largest pump factory in Mexico can only machine 3 M in diameter. This difference clearly limits the size of pumps which may be produced. If we add to this limitation the difficulty in obtaining heavy castings, certain qualities and related problems, it is then easily understood that advances in terms of diameter should be paralleled by corresponding advances in other branches of this industry.

The case of the floor type horizontal boring machines (for weights above 70 tons) and the portal type plano millings machines clearly illustrate the degree of maturity and the sheer sizes that can be producedin the capital goods industry. These machines are appropiate for prismatic shapes, and again the limitations are of geometrical nature. A turbine housing or a large diesel engine component must be within the working dimensions of the machine. The value of these machines rapidly grows above million dollars, but their presence and use is a pre condition for the production of heavy capital goods. There are some new and modern varieties of these machine tools that are able to machine following complex curves and patterns, apt to develop and aeronautical *industry and adequate for the improved designs that appear in several industries.*

NC machining centers, and in general NC machine tools appear significantly in medium sized and small series, the former in more varied and complex machining. Their proportion in the machines tool inventory reveals much about its modernity, flexibility and productivity. However since this paper places its emphasis on limiting products and determinant machinery, only a passing reference is made to NC machining centers.

Gear hobbing machines constitute a special case that also reach high prices as soon as about 1 m in diameter is exceeded. Their number is scarce and their diameters small in developing countries. There is some availability of gear hobbing machines in the range 3 to 5 m in diameter, but these are usually obsolescent and second hand machines, that produce low quality gears, adequate only for low speeds.

If quality in large diameters is to be improved, it is necessary to have a corresponding gear grinding machine which substantially increases the required investments.

The gear dimensions and quality determine the type of speed reducers or of large gears for equipment that can be made. Speed reducers are used in all industries and in many types of equipment. High power reducers are abundant in the steel industry, sugar plants, cement, mining, and materials handling, and are also important in the shipbuilding industry. The highest requirements in terms of quality and power are related to the reducers for turbomachinery. Usually above 200 to 200 KW as in the case of electric motors, speed reducers are not so well standerdized and are not callog products, that is they are manufactured on specific orders and sometimes with special designs according to the applications. This example reveals that there is a clear andimmediate overlap between heavy equipment, specialized design and engineering knowledge. It can be realized, how important it is to combine the availability of large-sized equipment with an integral technical capacity.

It is a common ocurrence that even though relatively well integrated machinery for sugar plants or steel mills is made in some countries, all the gears in the speed reducers (for turbines and high power) have to be imported from abroad. This is again a clear indication of the necessity to advance in this field.

Probably high quality gear making is one of the productive branches, were the lags in the capital goods industry become more evident.

For smaller gears, specially those produced in high series such as the case of mechanical transmissions, the productive problems have usually been solved mainly in relation with the automotive industry but frequently neglecting other equipment markets that also required medium or even large series (for example agricultural tractors). An adquate analysis of this situation may prevent similar neglects or could provide ad hoc solutions.

Some specialized and determinent machine tools will frequently appear and have to be individually assesed an their own merits. For example, special NC deep drilling machines which case the manufacture of heat exchangers of all types, specialized milling machines for grooving rotors for turbogenerators, etc.

<u>Limiting Products</u>

In the previous review of determinant machining it has been shown that from its knowledge the limiting products can be inferred. However, it seems convenient to review independently each sector's limiting products in order to verify if the degree of local integration is small (by contrast with what can be effectively produced), to link precisely determinant machines and limiting products (which is not always a sharp relationship) and in order to enable the carrying out of comparative analysis bewteen different countries.

In the case of fabricated platework, some of the determinant machines have already been mentioned but of course the direct question can be raised as to what is the weight (or plate thickness of the largest pressure vessels.

For example, a study on pressure vessel producers in the United Kingdom 1/, each producing above 200 thousands pounds sterling per year; established the following figures. (see table 5)

Table 5

United Kingdom. Maximum pressure vessel that can be fabricated (tons)

Maximum Vessel	1-25	26-50	51-75	76-100	101-125	126-150
Number of Companies	3	8	3	6	4	1
Maximum Vessel	151-175	176-200	201-300	More than 300		Total
Number of Companies	1	4	2	3		35

Presently, heavy fabrication shops in developed countries necessarily reach unit weights of the order of 1000 tons. This weight is linked to the requirements of the nuclear power industry.

If a developing country has a corresponding maximum lifting capacity of 100 tons, the gap is clearly shown.

1/ Ministry of Technology. "Report of the Committee of Enquiry on Pressure Vessels". 2 Vol. HMSO. 1969

The distribution of pressure vessels according to plate thickness in the United Kingdom (from the same source) is presented in Table 6. This Table shows that an important proportion of pressure vessels are at least 4 inches thick, and this is a thickness not frequently reached in developing countries.

Table 6

United Kingdom: Distribution of Pressure Vessels according to Plate Thickness

Plate thickness inches	All Companies in the enquiry		Companies with sales a/ above 200 thousand pounds	
	A	B	A	B
Up to 1	66	34	21	23
2	18	19	21	18
3	6	11	21	14
4	4	13	14	16
5	2	6	7	8
6	-	-	-	-
7	1	11	3	14
8	1	1	3	1
9	1	1	3	2
10 or more	2	3	7	4
	100	100	100	100

A - % Number of companies

B - % of sales

a/ of pressure vessels

Where it becomes clear that an important proportion corresponds to thicknesses over 4 inches which are scarcely reached in developed countries.

The distributions that have been indicated suggest that heavy production must be concentrated in a small number of enterprises. In México, from a sample of 27 enterprises, the following results were obtained:

Table 7

Mexico, 1975. Sample of Major Platework Enterprises

Production range Thousands of tons/yr.	% of Production In tons	 In value	% of number of enterprises
More than 15	71	37	15
From 5 to 15	5	4	4
From 1 to 5	21	45	48
Less than 1	100	100	100

which, in effect, reveal concentration even within limited group of chosen enterprises.

The significance of this concentration for further study of the industry is clear; it implies that for the study of limiting products, in many cases it will be sufficient to restrict production to a small number of firms.

It must be taken into account as well, that because the platework industry has its own natural protection and, as was stated previously, an early development, its growth in developing countries has not been based exclusively on the traditional kinds of platework equipment, such as pressure vessels, but has also included specialized heavy equipment for industry. Platework plants have developed machining, complementary installations and everything that might be needed for producing much more complex machines than the customary platework products; in such plants may be found, for example, production of heavy earth moving equipment, large diesel engines, steelmaking equipment and many other kinds of specialized machines.

In foundry work, the question once again is of the maximum weight of castings. Castings in advanced countries often reach a weight of over 200 tons when finished, such would be the case of large presses, turbines parts, naval components, etc.

Some of the developing countries that have been mentioned previously as having larger markets, are rapidly moving toward that capacity in castings as well as in forgings.
Nevertheless, in other developing countries it is considered remarkable to find parts as heavy as 30 or 40 tons.

For products manufactured in greater quantity, such as agricultural equipment, it is more important to look at volume in relation the possibilities of arable lands than at the limiting products. Within such volume it is necessary to know the limiting models and whether or not there is an excess of models and plants which would lead to inefficient production levels.

In the case of pumps or compressors it is necessary to differentiate bewteen different kinds. If, for example, only reciprocating compressors are manufactured (which is the usual case) it is likely that the situation can be analyzed with criteria similar to those proposed for agricultural machinery. That is, what is their capacity in terms of air volume or power? But the next question would be," are turbocompressors being produced? If the answer is affirmative, this alone implies a more advanced category of manufacturing and engineering.

For pumps, the most importants areas to examine are the high powered and specialised pumps, multistage pumps for pipelines and boiler feed, axial flow and mixed flow, double suction. In many cases it can be said that there is both manufacturing capacity and testing capacity for producing pumps over 1MW in some of the models mentioned; however, the number produced may be very small. It is assumed that the problem is one of consumer preference for foreign products (sometimes supplied by the very same enterprises in its dual rôle as importer and producer), or because there is a small demand. In such cases it often is true that even when such pumps can be produced, production conditions are somewhat doubtful in terms of the precision and productivity of equipment quality and delivery times of necessary materials and the lack of engineering experience. That is to say, a more detailed study of production capacity in that range would be required, which could easily lead to a new project for pumps or an expansion of existing plants.

Electric motors present a similar case. It is necessary to differentiate among several kinds, induction motors, synchronous motors and direct current motors, especially in high power ranges. But, as in the case of pumps, it is necessary to know how many high powered motors of each kind have been produced.

In the United States, for example, in recent years, while polyphase induction motors over 500 HP have been made up 0.3% of the total number of induction motors (from 1 HP on or integral horse power motors), they represent 16% of sales in value. In México, sales of such motors of local originin are under 8%, but significant numbers are imported both directly, in terms of high powered motors, and indirectly as motors included within equipment. The case for direct current motors over 200 HP is similar in that they constitute 15% of all DC motors produced, but 30% of sales. In relation to the total number of induction type integral horsepower motors, synchronous motors represent only 0.06%, but their sales reach 5% of the other motors. All of these facts indicates fairly clearly that both direct current and synchronous motors sell a higher proportion of their production in higher power ranges than do induction motors.

That is, in total sales of motors over 500 HP in the U.S., it is probable that synchronous motors represent close to 30% in value, direct current motors, less than 10% and the remainder, induction motors.

This is congruent with technical considerations; at speeds under 1 800 rpm and high powers (over 700 HP), synchronous motors are usually preferred.

The above is a good illustration of the way in which an analysis changes when the focus moves from low powered ordinary motors to high powered motors. As usual, it is a case of products which although belonging to the same general family of electric motors, from the point of view of engineering and manufacturing are very different in terms of technical characteristics, sizes, and differences in series. Once again, if attention is focussed on powerful motors, the number of producers is more limited and the analysis is much simpler. Going beyond 1000 HP in induction motors or in synchronous motors or direct current motors, is an indication of a more advanced stage in the industry. The next step, with greater complexity in design, voltages, and more demanding markets, is the production of motors over 2000 or 3000 HP.

The same pattern can be used for analyzing the limiting products in other industries, a few significant examples have been presented in this report.

Displacement of the limiting products

The advanced countries have an intense "tempo" in the advances of their limiting products in capital goods. This is true in terms of quality and quantity, as well as in occasional development of completely new products.

Some indications have already been given in regard to the growth of turbine-generator assemblies for the generation of electrical energy. The maximum sizes in 1948 were around 60 MW, going to 500 MW by 1968 and 1 300 MW at the present. The technical progress involved in such development was not just a question of the introduction of concepts leading to greater thermal efficiency, nor nuclear energy generation, additionally but of an extensive array of integrated technological know-how in materials and equipment manufacturing. In the plants where such equipment is manufactured, many of the essential machine tools are quite new., since previously they were not even necessary. The same has occured with testing equipment and installations.

It is evident that one of the advantages that the advanced countries enjoy is that of maintaining the initiative and staying at the forefront of such activities, since this enables them to obtain more markets and consolidate the situation of their more advanced industries.

The dynamism of the production fontiers is a sign of progress not only in the machine industry but in the user sectors as well, since, in utilizing equipment with scale economies and better technical characteristics, they in turn, present increasingly demand specifications to the machine industry.

If the borderlines of the limiting products and determinant machines are moved ahead in the developing countries as well, it is a sign of such double progress.

A few indications have been given of the way in which, in some cases, growth has taken place in the developing countries and this was illustrated by the case of forge and foundry which provide a good example since all large equipment involves these processes.

If that advance is followed, it provides a good index for estimating requirements in large-capacity machine tools. For example the fact that China manufactured steam turbines of up to 12 MW in 1956, 50 MW in 1965, 125 in normal production and up to 300 MW as a new development in 1973-74 is a basic factor for estimating the requirements for all the related machine tools and equipment, once the productive limits of the country in such machine tools are known.

Another illustration of the same point is the advance in Brazilian naval industry from cargo boats of up to 18 thousands TDW with 8 400 BHP diesel motors in 1965, to a wide range of vessels, which in the case of tankers reaches some 150 thousands tons of gross register tonnage at the present time.

Dynamaism in the displacement of limits, in many cases linked with production capacity, is then , a vital indicator of progress in the machine industry.

It would seem that the production frontier advances with new and bigger machines whose geometry or capacity make it possible to make larger or more powerful equipment. Nevertheless, as has been explained, behind this situation lies a much more complex set of factors such as technological advances, market , size, national supply of components, compatibility with other complementary production, etc.

Since it is often found that small, medium and large sized equipment, are manufactured by a single enterprise, although in different bays, sometimes the extension of the production frontier is a simple matter of adequate planning on the part of the enterprise in order to foresee the need for new bays and all of their requirements. In other cases it is necessary to move to new installations. In advanced countries, many installations have become confusing in their lay-out and even obsolete through trying to grow by accretion. This is, at least one of the advantages that developing countries have: the design of plants can be more functional and modern from the very beginning.

c) Relation equipment size-production volume

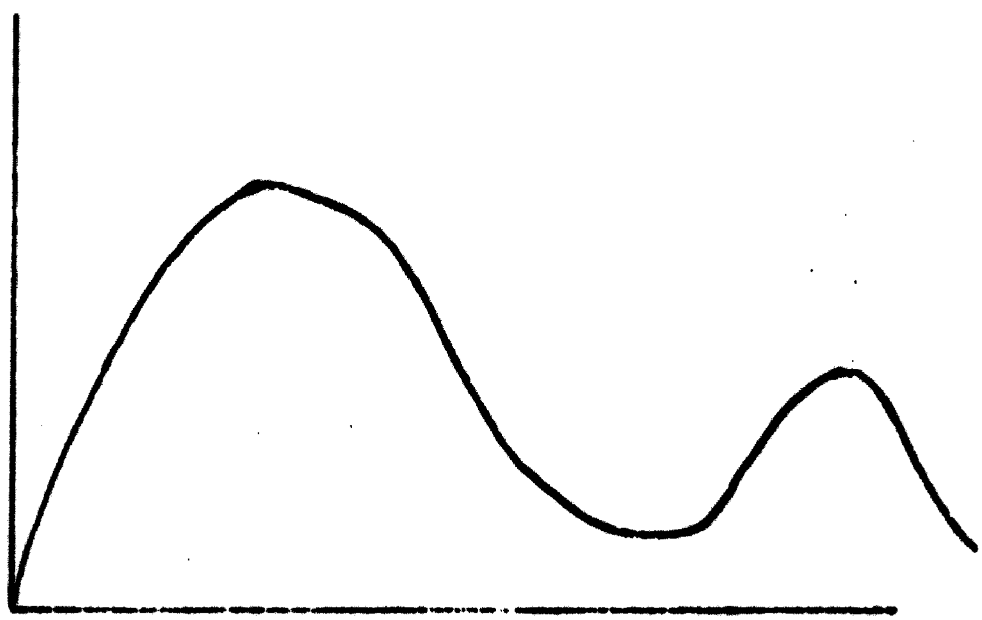
Almost all of the kinds of production dealt with up to now can be represented by the same figure, relating production volume with equipment sizes, as can be seen in the following graph.

Graph 2

Size - Production - Ratio

(illustrative)

Production frequency, in number of machines



Equipment size

(power, capacity, sizes, for example)

According to the curve, it can be observed that there is a greater frequency or proportion of equipment in small sizes (or low power) which usually permit a degree of mass production, and there is a lower frequency of large sized equipment, (which has its own local maximum frequency) requiring smaller scale production whether it be ad-hoc, made to order, by buyer specifications.

If, instead of considering the number of equipment units, the weight or value of production were plotted, the local maximum of large equipment is seen to be more important in relative terms and several examples of this type are given in this report.

It is interesting to observe that it is necessary to consider large equipment as very different than small equipment, from the point of view of production, since they are produced in different plants or bays. Their prices also very considerably, as might be expected.

The production of large equipment, however, involves smaller series or batches and thus provides more opportunities for flexible production processes which have a larger skilled labour content.

As scale economies have been growing in the user industries, the machine industry has had to produce increasingly larger equipment, that is, the curve shifts toward the right, at least in the local maximum, and this movement is accompanied by other kinds of technical progress.

It seems that in many developing countries, production is begun from the left side of the curve without touching the right side, a situation that is justified with often fictitious arguments regarding market size. In contrast, in advanced countries, mass production is complemented by production of large equipment and scale economies are achieved with this integration and an integral utilization of engineering capacity.

Still, in some cases the advantages for developing countries may precisely be in the right side of the curve, and in some cases this situation has been adequately exploited.

In other words, the relation between market size and production possibilities cannot always be interpreted in a rigid way, since these antecedents show the possibility of various alternatives that depend on the country and on its technical know-how in a specific field.

The fact that larger sizes of equipment, in the right side of the curve, are associated with the determinant equipment explains the diversified production of some large units in plants in developing countries, so that better utilization of larger equipment can be achieved.

Moreover, for some developing countries market size is not usually a limiting factor, at least if it is compared with the market of centroeuropean countries. There is some difference, of course in the large proportion of exports carried out by the latter countries.

Although the market basis might be smaller, the growth rate compensates for it. Growth rates of from 10 to 15% in electrical energy generation, or in machine tools demand, easily lead to significant annual increases in volume. The dynamism of import substitution can be added to the former consideration and growth rates can be obtained of 30% or more, during several years. Market agreements can permit a combination of the internal market with some exports of products of special interest.

A. Note regarding some distinctive characteristics of the mechanical industry.

In itself, the presentation made regarding limiting products and production frontiers is an illustrations of one of the differential aspects of this industry. It has been considered useful to add some additional remarks on the topic in order to place productive capacity in a broader context and to explain, briefly, some other contexts that have been presented in the text.

Perhaps the first, though elemental, important characteristics of the mechanical industry is the heterogeneous nature of each kind of equipment, i.e., that they are made up of parts and subsets. This leads to the necessity of assembling parts and the possibility of making them in separate shops, if deemed convenient, or to buy them.

In addition, the industry's own specialized machines, machine tools, are generally conceived for making the parts (in some cases, complex sets of machines can manufacture subsets) in contrast to the equipment as a whole.

But it is also important to point out that a generic type of machine may be produced in very different sizes, (modules, preferred numbers) and also with design variations which may be better adapted for differentiated functions (different kinds of pumps, electrical motors, etc.)

The combination of different sizes, each with a different production line, lead to the need for bays or shops where equipment can be produced separately in certain size ranges, and, on the other hand, defines simultaneously the limiting products and determinant machines. It is also to these differential characteristics that a certain kind of machine, over a certain size, can be considered as a different machine than the smaller versions of the same machine from the production point of view although technically and in terms of design they may be similar.

Since the production machines are intimately linked with the parts of equipment rather than with the whole unit, similar parts for different machines can be produced in the same shop; thus, there is a kind of production unification. On the other hand, production unification can also be achieved although products may different, through a common engineering basis. All of this leads to the fact that multi-products are common in the mechanical industry.

Parts may be subcontracted as may be machining operations carried out on them (out-of-shop subcontracting).

Although many innovations appear in these kinds of machines, this does not affect the basic fact that their function refers to a certain geometry or type of machining; rather than the innovations improve machine performance in terms of speed, flexibility, precision geometrical complexity and automatic control.

There are other machines, linked to large production-line operations, which are more specialized in terms of their functions. In reality they are sets of machines conected one to the other through transfer mechanism, where the total machine is designed for a specific result. There are also machines for intermediate specializations.

Almost all large-sided machines, however, are manufactured with conventional-type machine tools, although in these cases they are larger and more precise. The same machine tools generally have the production flexibility previously mentioned.

Large volume production .(production lines) naturally results in lower costs, permits product stocks to be maintained and "catalogue" production to be carried out. Large machines, on the other hand, because of their manufacturing cost or time, or other special characteristics, must be produced by request or on a made-to-order basis with special buyer specifications; it is not probable that they could be found in stock. In developing markets this factor makes the multiproduct concept more attractive.

Multiproducts in a single shop, however, have high engineering and cost requirements for the production of each equipment unit. This can easily lead to deficient engineering capacity, as well as to a simple types of subcontracting and assembly operations.

The above considerations explain the assertion that there is no strict product-project relation in this industry as there is others. It is an error (which is frequently committed) to assume that because a given product is needed, a project can be formulated and a plant installed to fill that need. The whole set of products that would justify the installation of such a plants must be examined. That set of products may have varying reasons for being associated with the kinds of plant in question. In some cases it may prove more adequate to expand an existing plant, which in this industry is a feasible and often necessary alternative.

ANNEX 1

Capacity of a UOE pipe plant

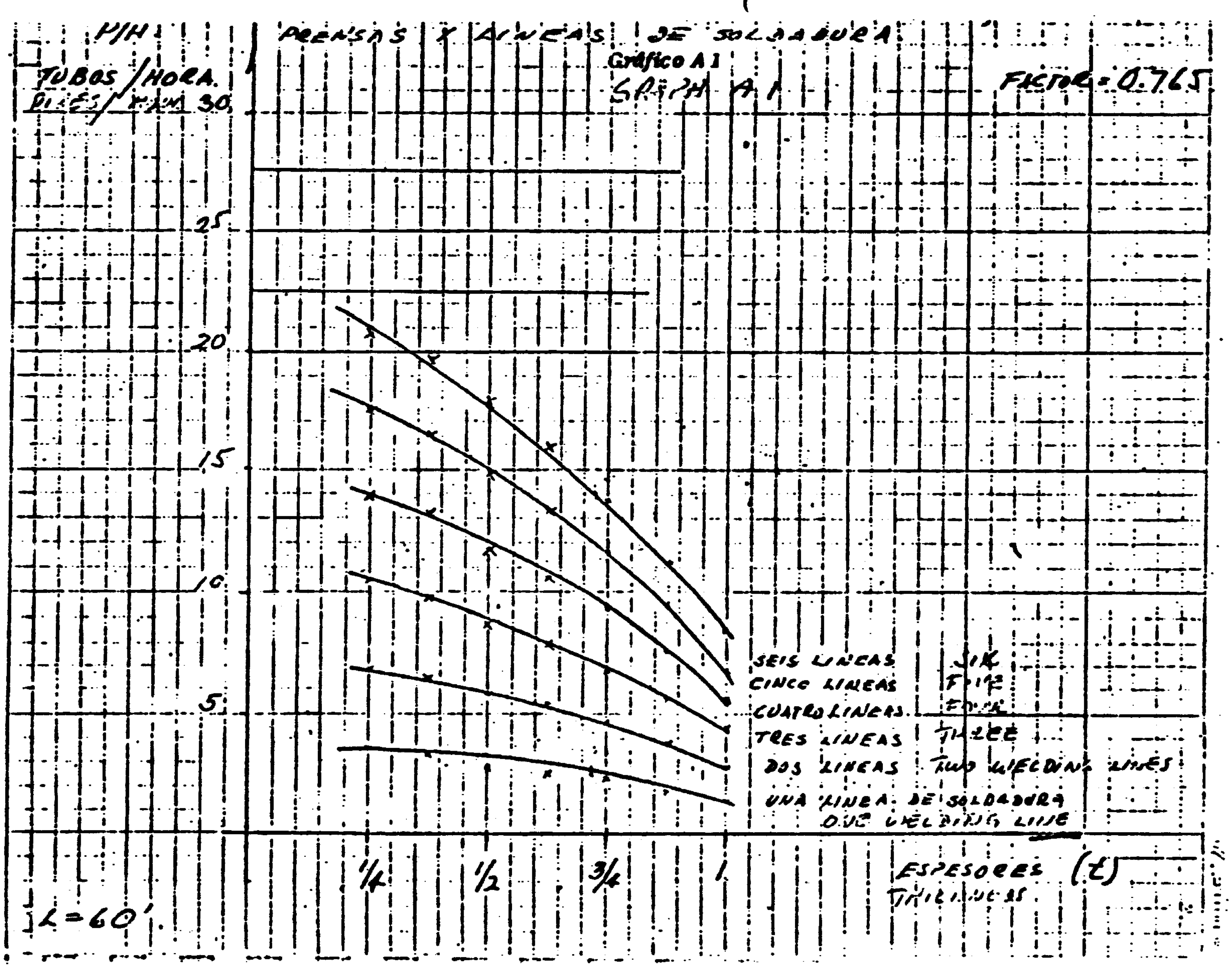
The mechanical characteristics of UOE piping makes it the most suitable type of pipe available for gaslines and oil pipelines.

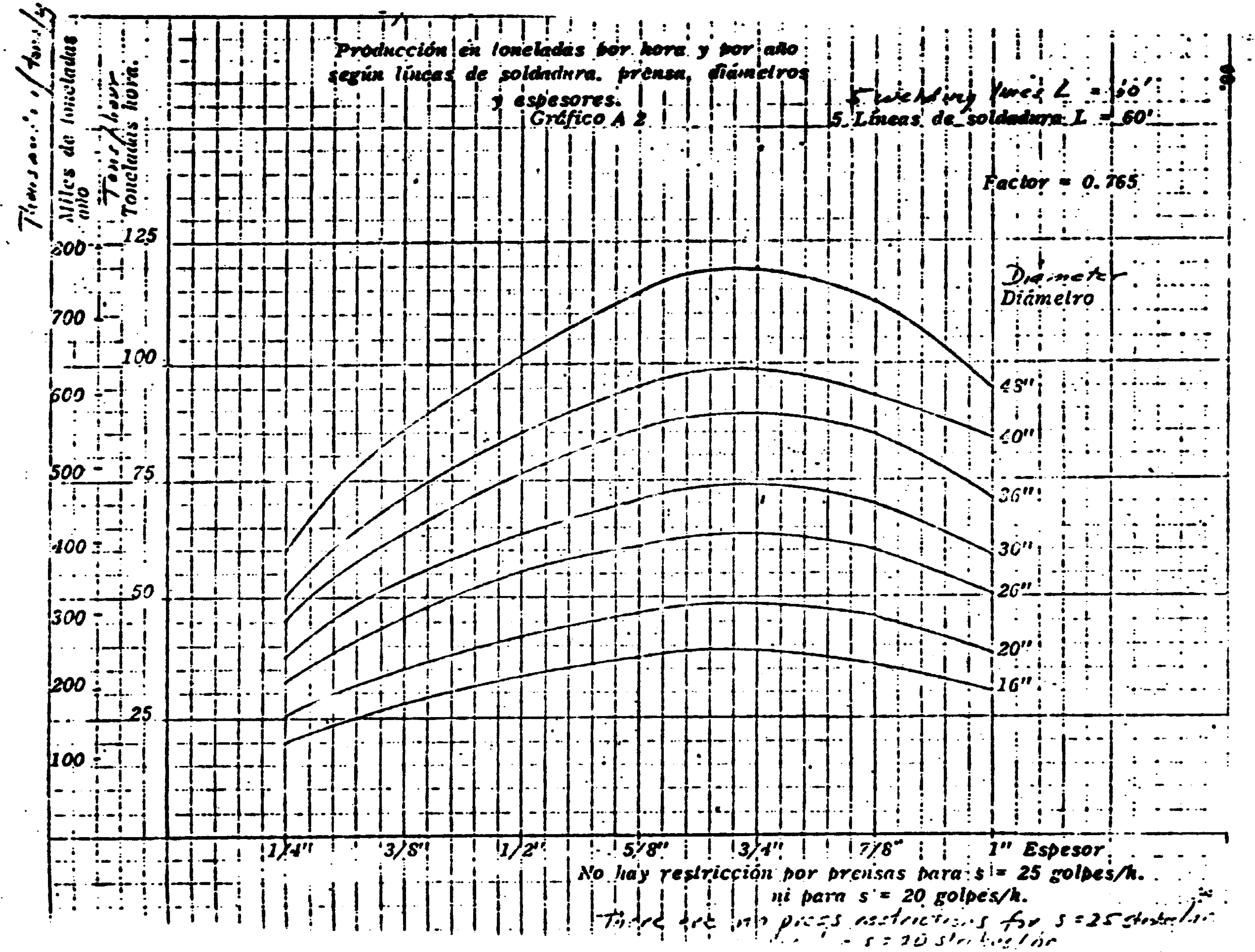
Its manufacture consists of a line of presses which first form the plate to an U Shape and later an O shape; the pipe is then welded by submerged arc and later expanded (E) in order to recover mechanical characteristics.

This pipe is almost representative of a typical platework product and thus serves to illustrate how the calculation of capacity can depend on the product mix and how, in turn, the product assortment can depend on the presses or welding equipment in the plant.

Two figures or graphs may be used in order to illustrate this: one for the number of pipes produced per hour, and the other for tons of pipes per hour.

Graph A1 presents production capacity in terms of pipes per hour and Graph A 2 presents the tons per hour production capacity of 5 welding lines. The case being dealt with is that of pipes having a length of 60 ft. and diameter up to 48 inches.


P/H
TUBOS/HORA
PRENSAS Y LINEAS DE SOLDADURA
Gráfico A1
FACTOR = 0.765
30
25
20
15
10
5
SEIS LINEAS
CINCO LINEAS
CUATRO LINEAS
TRES LINEAS
DOS LINEAS
UNA LINEA DE SOLDADURA
1/4
1/2
3/4
1
ESPESORES (t)
L=60'



Producción en toneladas por hora y por año según líneas de soldadura, prensa, diámetros y espesores.
Gráfico A 2
5 welding lines L = 60'
5 Líneas de soldadura L = 60'
Factor = 0.765
Diameter
Diámetro
48"
40"
36"
30"
26"
20"
16"
Thousands of tons/y
Miles de toneladas año
Tons/hour
Toneladas hora.
125
100
75
50
25
800
700
600
500
400
300
200
100
1/4"
3/8"
1/2"
5/8"
3/4"
7/8"
1" Espesor
No hay restricción por prensas para s = 25 golpes/h.
ni para s = 20 golpes/h.

Graph A 1 shows that the press line is not restrictive, even at a capacity of 20 pipes per hour (20 strokes per hour of the presses) and that capacity is determined more by the number of parallel welding lines that can be used.

In turn, the speed of the welding lines -- which has been very thoroughly studied in order to reach the optimum level -- is linked to pipe thickness.

Graph A 2 shows that, on passing from pipes per hour to tons per hour or per year, weight (which is also linked with the pipe diameter and thickness) is quite varied. If only one type of piping is manufactured, production could vary from 800 thousand tons per year (for pipes of 48 inches in diameter and 3/4 inch thick) to somewhat more than 100 thousand tons per year (for thin, small diameter pipes). Intermediate capacities could be calculated for any combination of pipes required for satisfying demand.

Thus, this is a clear example of how the product assortment determines capacity in the mechanical industry.

Note: Factor E= 0.765 seen in the graphs refers to the effective proportion of time the equipment is used, in relation to the total utilizable time.

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