UNITED NATIONS

ECONOMIC
AND
SOCIAL COUNCIL

GENERAL

E/CN.12/922
October 1971

ENGLISH
ORIGINAL: SPANISH

ECONOMIC COMMISSION FOR LATIN AMERICA

THE TRANSFER OF TECHNICAL KNOW-HOW IN THE STEEL INDUSTRY IN BRAZIL

prepared by

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Note: This report forms part of a study undertaken by the Economic Commission for Latin America (ECLA), the Interamerican Development Bank (IDB) and the Division of Public Finance and Financial Institutions of the United Nations Department of Economic and Social Affairs on the problems of the transfer of industrial technology in Brazil.

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Chapter I

DEVELOPMENT OF WORLD STEEL PRODUCTION TECHNOLOGY

1. Introduction

World output of steel in 1940 amounted to approximately 150 million tons. Ten years later - in 1950 - it had risen by 50 million tons, and in the next few years it grew at an even faster pace, reaching 526 million tons in 1968, or 376 million more than in 1940. A large proportion of this production increase, as will be seen later, was undoubtedly due to the use of oxygen in the Siemens-Martin and other steelmaking processes and to the development of the basic oxygen process.

However, the fairly rapid increase in world production of pig iron may be ascribed not to a single technique, but to a number of technological improvements. In the case of the blast furnace - the main classic process for the reduction of iron oxides, which is responsible for about 98 per cent of the world's production of pig iron - the following techniques facilitated not only an increase in production and a smaller consumption of solid reductants, but also smoother and more regular operation: beneficiation of the burden, use of high temperature blast, water vapour injection, auxiliary fuel injection, use of pre-reduced material, enrichment of the blast by oxygen, and use of top pressure.

In the United States, for example, from 1950 to 1966 the average output of blast furnaces rose from 850 to 1,440 tons of pig iron per day, which represents a 60 per cent increase. Reduction equipment of more suitable size was responsible for 50 per cent of this increase and the use of new techniques for the other 50 per cent. During the same period the average consumption of coke also dropped sharply from 835 kg/ton to 590 kg/ton of pig iron, owing mainly to the use of the above-mentioned techniques. For the same reasons, the productivity of blast furnaces in Japan also increased substantially between 1955 and 1966. The average productivity of Japanese blast furnaces - in terms of daily output per cubic metre of internal volume - rose from 0.81 t/m^3/day in 1955 to 1.54 t/m^3/day in 1966; in other words, it practically doubled over that period, while the average specific consumption of coke during that time fell from 711 kg to 505 kg/ton of pig iron.

/2. Blast furnace

2. Blast furnace

a)1 Raw materials

Before 1945, the metal charge in most blast furnaces all over the world consisted of iron ore with a high content of fines (less than 3 mm), and in many cases the ore contained chemical combinations of water and carbon dioxide in the form of hydroxides and carbides. By means of tests, it was found that screening the ore and sintering the fines with other components which constituted residues from the plant (mill scale, flue dust, etc.) would increase the permeability of the blast furnace burden and make for better contact between the solids and the gases. Therefore, the coke rate would diminish and production would increase. In the United States, for example, the reduction in the quantity of ore fines in the burden resulted in a saving in the coke rate of about 11.3 kg/ton of pig iron, while the elimination of water in chemical combinations and of carbonates by means of sintering was responsible for a further saving of 11.3 kg/ton of pig iron. Another significant improvement in sintering is the addition of limestone or dolomite to the mixture. When the flux is added to the mixture, it is precalcined and subsequently combined with the silica in the ore or concentrate, preventing the excess formation of an undesirable compound, owing to its low fusion point and resistance to reduction. This diminishes the amount of heat required in the blast furnace and increases the reducing capacity of the gases by the elimination of carbon dioxide, which occurs if limestone is used in the burden. For example, most of the sintered ore now used in Japan is self-fluxing and its basicity (CaO/SiO_2) ranges from 1:3 to 1:8.

The development of this agglomeration process was instrumental in pushing up world production from about 50 million tons in 1950 to nearly 360 million in 1965, which means that it increased almost seven-fold in sixteen years. Most of the sintering facilities are equipped with chain grates, in line with Dwight Lloyd's invention some time ago. These machines are constructed in a wide range of sizes, from units with a few square metres of usable area producing a hundred tons of sinter per day to large units of about 300 square metres, which are in process of construction in the Fuji plants in Japan.

/Pelletizing is

Pelletizing is the newest agglomeration process and its development in recent years has been highly successful. The first industrial plant began operating in 1955, and by 1968 its annual production capacity had already reached 90 million tons. In the period 1955-1959 the industrial application of pelletizing was confined essentially to the United States and Sweden, but today Canada, Peru, Japan, Italy, Norway, Brazil and other countries also have pelletizing facilities. The reason why pelletizing was initiated in the United States and Sweden is that this was the only way to agglomerate the ultra-fines obtained from the concentration of their low-grade ore, which require a considerable degree of grinding. The subsequent spread of this process to other countries was facilitated by the following circumstances: (a) in countries known to possess considerable reserves of excellent quality iron ore, there are large quantities of high-grade fines in addition to sized ore; (b) pelletizing is possible not only for magnetite but also for hematite or a blend of the two; (c) the production of pellets is not dependent upon the availability of solid fuel as in the case of sinter. The notable progress made in the field of oxidized pellets was the starting-point for the production of self-fluxing pellets (basicity 1:3) on an industrial scale in Japan's steelmaking industry.

Briquetting is probably the oldest known process for agglomerating iron ore or concentrates. At present, the processes consist essentially in pressing between moulds the particles of ore or concentrate, either cold or pre-heated, with or without agglomerants in the mixture. Although briquetting has the advantage of not requiring prior grinding to ultra-fines, it is still an expensive process because of the considerable wear of the steel moulds in which the briquettes are made. Another difficulty that has yet to be solved relates to the physical characteristics of the product obtained, since the briquette usually does not withstand much handling. The first plant to enter into operation on an industrial scale will be that of Orinoco Mining in Venezuela, with an annual production of 1 million tons of briquettes made of fines obtained from pre-reduced ore, according to the process developed by U.S. Steel. Three other plants installed in England, the United States and Canada are pilot plants with capacities ranging from 1 to 6 tons per hour.

/The steady

The steady decline in world reserves of suitable coking coal for the steel industry, combined with the effect of the cost of coke on the price of pig iron, is an increasing inducement to steel manufacturers to seek new ways of reducing the specific consumption of coke in their blast furnaces. The countries members of the European Coal and Steel Community have succeeded in reducing the traditional figure of 1,000 kilogrammes of coke per ton of pig iron. Some blast furnaces in Japan have already reduced their specific consumption of coke to less than 450 kilogrammes per ton of pig iron by fuel oil injection and the use of a prepared charge. According to a document of the European Coal and Steel Community, the specific world consumption of coke per ton of pig iron in 1967 was 620 kilogrammes, and must have ranged from 470 to 510 kilogrammes in 1970.

Technology has made great strides in the last few years in the use of the system of petrographic analysis to determine the coking properties of coals or mixtures containing them. This brought down the number of types of coal to be studied on a pilot scale, which is aimed not only at the production of a good coke but also at obtaining the best possible yield. For example, every 1 per cent reduction in the volatile matter contained in the mixture represents approximately the same increase in yield, and it is certainly a much more attractive proposition to produce coke than by-products which are daily losing their value.

The characteristics which the blast furnace operator establishes in order to specify the ash content in the coke depend on the type of iron ore used. If, for example, a high-grade iron ore or agglomerate is used, the resulting volume of slag may be very small (about 200 kg per ton of pig iron), which limits the desulphurization capacity of the process. It should also be remembered that a high proportion of ash in the coke means not only a smaller fixed-carbon content, but also a higher specific consumption of coke in the blast furnace. The sulphur would increase, and the higher the proportion of this element the more limestone will be needed, which once again pushes up the specific consumption of coke. One of the techniques used by the steel industries to achieve the best possible results in relation to these problems is the use of blends. In Poland, for example,

/there are

there are plants which use as much as eight to ten different types of coal. Countries which have no high-quality coking coal are continuing the search for methods that will enable them to reduce the proportion of imported fuels. Successful results have been obtained through the use of such fuels as petroleum coke, coke fines, semi-coke, etc. With a view to increasing the density of the burden and at the same time improving the quality of the coke and the productivity of this system, small quantities of petroleum are also being used with excellent results.

The system of pre-drying and pre-heating the coal was successfully developed in France. The pre-drying method is being satisfactorily applied in the Hagondange plant in France, and a plant is being constructed in the United States where the pre-heating process is to be used. In both these processes, devised by CERCHAR, experiments have shown that by means of these techniques it is possible to increase the proportion of low-coking coal in the blend.

Specialists have long condemned the conventional process of producing coke in vertical recovery-type ovens for the following reasons: (a) too high an investment per ton of coke produced; (b) the method is both slow (14-18 hours) and discontinuous; (c) the process is limited as regards the type of coal, since it requires good coking coal of which the world reserves are shrinking; (d) the product obtained has little granulometric uniformity and a low physical resistance, resulting in the production of fines which are often not easily marketed. It is worth while noting that in the past forty years there has been no significant technological progress, unless account is taken of the automation of some auxiliary equipment and the increase in coke production capacity. These increases in capacity amounted to about 20 tons of coal per oven, but any further expansion is unlikely because of evident structural limitations. Specialists in the United States, Germany, the United Kingdom, France and other countries, are at present studying new coking processes based on completely new principles, such as the production of formcoke, which is being obtained on a semi-industrial scale.

/With regard

With regard to the use of coke in the blast furnace burden, it has long been the practice to eliminate sizes smaller than 18 or 12 milimetres from the raw material used. There is now some control over the larger sizes which, in the opinion of some specialists, should be no bigger than 50 milimetres, and should be more uniform within the established range.

There is little information available about charcoal. Mention is made here only of certain plants in Brazil which use charcoal as a source of thermal and chemical energy, while taking advantage of the fines produced, through the process of briquetting. IPT of São Paulo is currently studying the results of briquetting a mixture of charcoal and domestic coal, in the proportions of 40 and 60 per cent respectively.

b) Injection of liquid or pulverized reducing agents and regulation of the blast

The injection of auxiliary fuels into the tuyeres of blast furnaces has been studied since the nineteenth century. The first patents for the tar and gas injection process were applied for by W. Barret in 1838. Coal injection was used in France in the period 1840-1845. In 1900 a blast furnace in Scotland was operating with oil injection. In 1918 the process was tried out in copper metallurgy, with a view to replacing all the coke in the mixture bed by the injection of coal. In the years 1920-1930, the injection of coke fines was tried out in ARBED and HADIR blast furnaces. None of these efforts was really successful, however, mainly for the following reasons: (a) the object of the first attempts was to heat the blast furnace when it cooled, but the effect is precisely the opposite; (b) the blast temperatures were too low and the price of the auxiliary fuels was too high; (c) at that time there were no proper mechanisms for ensuring the safety of the installations. According to the studies carried out, if the air temperature is increased far above the normal in a particular blast furnace, the coke rate is substantially lowered. However, a smaller quantity of reducing gases is produced per ton of iron, and the reduction process is not completed until the ore reaches the lower hotter regions of the reduction furnace. This reduces the permeability of the burden owing to the mixture that is formed of part of the iron oxide, the silica and the lime. Therefore, if higher

/blast temperatures

blast temperatures are to be used, an additional source of reducing gas is required. This source could be steam, which was the first injection technique to be industrially successful. The use of steam has little effect on the coke rate, since the gain in calories owing to the increase in blast temperature is practically absorbed by the dissociation of the steam.

Auxiliary fuel injection is a logical sequel of the injection of steam, since it provides the blast furnace with a supplementary fuel, i.e., carbon. The system of injecting hydrocarbides in the tuyeres developed rapidly. The first successful research was carried out in 1958 in the low-shaft furnace at Liège and in the Pompey plant. At present, an ever-increasing number of blast furnaces are being industrially equipped for injection in the tuyeres of natural gas, coke gas, liquid hydrocarbides or solid fuels.

In 1966, the system of injecting natural gas was used in sixty-six blast furnaces in the United States, oil in twenty-one, coke gas in five, tar in two, and coal in two. The predominance of natural gas injection in the United States reduction furnaces is mainly attributable to the low cost of natural gas and of its injection equipment. In Europe and Japan, however, oil is used almost exclusively, since it is cheaper than natural gas.

With a view to increasing the productivity of the blast furnace, considerable attention was paid to the use of industrially pure oxygen instead of air. Although this technique had satisfactory results in terms of improving the efficiency and productivity of blast furnaces for ferromanganese (where a very high range of temperatures is required), it is only since 1958 that successful results have been obtained in the production of pig iron.

It is generally admitted that if the blast is enriched with 1 per cent oxygen, productivity increases by 5 per cent. This method is in use in plants with large oxygen-producing units, which makes it fairly inexpensive.

/It is

It is a well-know fact that 90 per cent of the pig iron produced in the USSR is obtained from blast furnaces operating with a high top pressure of 0.6 to 1.5 atmospheres, which results in faster operation and a 10 per cent saving in the coke rate. The high top pressure was originally developed with the object of improving the performance of the blast furnace, operating with an unprepared burden, because of the consequent increase in the quantity of reducing gases in the bosh. Forty per cent of the pig iron produced in Japan comes from blast furnaces using this technique.

c) Use of pre-reduced material

At the recent Evian congress, according to an article in Iron-making Tomorrow, the technical and economic aspects of the use of pre-reduced material in the blast furnace charge were analysed in considerable depth. From the metallurgical standpoint, the following main conclusions were reached on the basis of the results of theoretical studies and industrial experiments carried out in Japan, France and the United States, which were presented at the meeting: under existing blast furnace operating conditions, the charging of a certain quantity of ore concentrate or pre-reduced agglomerate reduces the coke rate by about 7 per cent for each 10 per cent metallic iron in the burden, while at the same time raising production by 7 per cent.

It should be added that, from a metallurgical point of view, there is a peak point for the use of pre-reduced material in the blast furnace charge, above which the percentage of pre-reduced material would cause drastic changes in the operation of these reduction furnaces and their thermic profile would be practically the same as that of a cupola furnace.

d) Automation

The discussion of modern blast furnace techniques would be incomplete without some mention of the system for controlling the composition of the hot metal. Both in France and in the Netherlands there are special facilities in the blast furnace where the top gas is under constant inspection by a computer which controls the changes in temperature caused by variations in the proportion of direct and indirect reduction. Whenever the temperature alters, the computer indicates what change should be made in order to correct the injection of fuel.

/3. Electric reduction

3. Electric reduction furnaces

It may be inferred from the bibliography that the electric reduction furnace, like the blast furnace, is in process of development. Powerful units are already in operation, such as the 33 MVA furnace in Matanzas, Venezuela. However, the greatest technological progress is in the preparation of the metallic charge. After the use of agglomerates, in particular self-fluxing material, pre-heating and pre-reduction have been widely used on an industrial scale. These techniques enabled the electric furnace to maintain its competitive position vis-a-vis the processes used in the great steel plants, where, logically enough, the cost of electric power is fairly low. The development and use of self-fluxing sinter in the burden of electric reduction furnaces made it possible, as with the blast furnace, to achieve excellent results. The advantages of the application of this technique in electric furnaces are similar to those obtained in the blast furnace and can be summed up in the following points:

the virtual elimination of evaporation and decomposition of the water contained in the burden and the dissociation of the fluxes, which means a saving of 230 to 300 kWh;

better reducibility because of the more suitable size of the burden.

In short, the use of pre-reduced and pre-heated burdens in electric reduction furnaces represents the main technological progress in this reduction process. Pre-heating and pre-reduction of the charge occur simultaneously through the utilization of gases obtained from the crucible of the electric furnace, e.g., through the Elektrokemisk process.

4. Direct reduction process

During the Second World War, a number of metallurgical research centres intensified their studies and research with a view to improving and developing the non-conventional methods of reducing iron oxides, known

/as direct

as direct reduction processes. These processes were basically designed to suit specific conditions in certain enterprises or regions as regards the physical and chemical characteristics of the raw materials, the volume and nature of the product required and the economic factors involved.

It should be noted that the term "direct" as applied to these reduction processes does not refer to the chemical reaction obtained through the reduction of iron oxides by means of solid carbon. It is intended rather to describe the processes whereby on the basis of ore or agglomerate, steel is obtained in a single operation instead of the usual two operations (blast furnace and steel furnace).

In practice, however, the use of most of these new processes showed that, from the steelmaking standpoint, they were more indirect than direct, since in many cases, besides the preparation of the metallic charge being the same as for the blast furnace, the pre-reduced material or sponge iron still had to be processed in the steel furnace.

It is interesting to note that the application of only some of the hundreds of non-conventional reduction processes that were patented proved technically and economically viable on an industrial scale.

Some studies on the subject show that the production of pre-reduced material should reach the figure of 29 million tons in 1980, of which 10 million would be used for the production of pig iron.

Among the plants which use these processes and are currently in operation, only the Mexican plants using the HyL process and Swedish plant using the Wiberg process operate on a commercial scale. The Krupp Renn process used in Czechoslovakia did not have the desired results; the Strategic-Udy process was not successful in Venezuela and had to be discontinued. Two plants using the SL/RN process have entered into operation in New Zealand and Korea. The Oregon plant in the United States, based on the Midland-Ross Midrex method, and the Orinoco Mining plant in Venezuela, which will use the process developed by US Steel, are expected to start operating shortly. The Puerofer and FIOR processes developed respectively in Germany and the United States are still in the pilot stage.

/5. Development of

5. Development of steelmaking processes

The whole history of steel mass production covers two different periods:

a) The period of development of new types of furnaces, which were tried out and adopted on an industrial scale, from 1856 to 1900;

b) The period of conceptual improvement of production processes and the expansion of steelmaking all over the world.

In the hundred years since steelmaking was initiated on a large scale, barely three processes can be considered to have contributed new revolutionary concepts: the pneumatic process invented in 1856, which involved blowing in air at the bottom (Bessemer furnaces); the reverberatory process, devised in 1860 by W. Siemens and now known as the open-hearth or Siemens-Martin process; and the arc furnace, developed by Herout in 1900. However, owing to the fact that oxygen steelmaking has become so widespread since the first operations on an industrial scale twenty years ago, it has earned special recognition as a pneumatic steelmaking process.

In the last analysis, therefore, the three basic steelmaking processes are represented by four separate and different methods.

It was only after the Bessemer process was introduced in 1858 that world production of steel increased substantially, reaching 1 million tons in 1873. However, the fact that 95 per cent of the burden consisted of liquid pig iron which at that time was obtained from ore with a high phosphorus and sulphur content, and that the basic refractories were unknown, seriously limited the use of this process and the quantity of the product obtained. In spite of these disadvantages, the Bessemer process accounted for 80 per cent of total world output in 1880. In 1966, however, its share was only 5 million tons, or less than 1 per cent of the world total.

This decline in the importance of Bessemer furnaces in the production of steel was due to the introduction of the Thomas process, operating with linings and basic slags, which permitted the elimination of the phosphorus and sulphur. This process attained its climax in 1910, when it was used to produce 25 per cent of the world's total output. From

/that year

that year onwards its importance diminished and in 1966 it rated about 7 per cent, or approximately 34 million tons.

The production of steel in SM (Siemens-Martin) furnaces still accounts for a large share of world output, but it reached its peak in the period 1937-1957 when 75 per cent of the entire annual output was obtained by this process.

Although world production of steel by the Siemens-Martin process had risen to some 60 million tons since 1957, the intensive use of the oxygen process, with an output of approximately 90 million tons during the same period, brought down the former's share to a little over 60 per cent of the world's total production.

The progress made in the production of steel in Siemens-Martin furnaces over the past fifteen to twenty years is due mainly to two technical innovations:

a) The construction of a fully basic furnace;

b) The widespread use of oxygen for melting and refining.

Neither of these developments can be considered to be more important than the other since they are both jointly responsible for the excellent performance obtained in open-hearth furnaces in different parts of the world. Although the two methods have been widely used in the last ten years, the first attempts in this direction were made over forty years ago. At present, about 75 per cent of the Siemens-Martin furnaces operating with a liquid metal charge in the United States are of basic construction.

Since steelmaking is essentially a process of oxidation at high temperature, production speeds are basically dependent on the rate at which the charge can be supplied with heat and oxygen. The sources of oxygen are iron ore, limestone, air and industrially produced oxygen. The quantity of oxygen depends on the type of heating used (fuel or electric power) and the proportion of liquid metal in the charge.

In Siemens-Martin furnaces, 0.5 tons of oxygen are required to burn the necessary fuel for melting the charge in a furnace operating with 50 per cent liquid metal. Moreover, the chemical oxygen required to refine the metal is 50 kilogrammes per ton under the same conditions.

/Up to a short

Up to a short time ago, the oxygen for chemical reactions was obtained mainly from the charge and the iron ore, being supplemented by the oxygen contained in the furnace gases and, in small quantities, in the scrap iron used in the charge.

The use of the oxygen contained in iron ore for refining has the disadvantage that it produces highly endothermic chemical and physical reactions between the ore and the liquid steel, with considerable absorption of heat. In this case, 660 to 830 cal/kg of iron ore are required. The reaction between oxygen obtained from the air or pure oxygen with the liquid iron for combustion of the carbon not only produces enough heat to keep the reaction going, but also liberates heat. During the past ten or fifteen years, therefore, the use of gaseous oxygen has been universally adopted in Siemens-Martin furnaces, and also in other types of steel furnaces in order to obtain rapid decarbonization and high temperatures in the bath.

Besides these two technical advances, there are a great many new ideas about methods, equipment and projects designed to improve Siemens-Martin furnaces. Examples of these are the Ajax furnaces of US Steel, which use slag pockets that can be changed without interrupting the furnace operation; and the dual-hearth furnaces, with oxygen fuel lances in the roof for heating and rapid melting of the slag.

The industrial use of electricity for steelmaking dates from the beginning of the century, but it was somewhat limited during the first forty years owing to the high cost of electric power. Its use was virtually confined to the production of high-quality alloy steels. After the Second World War, the electric furnaces were considerably enlarged and now have capacities of over 180 tons. Moreover, significant improvements were made in the mechanical and electrical equipment which, added to the reduction in the cost of electric power, enabled these furnaces to be used to produce not only alloy steels but common steels as well.

As in the case of the Siemens-Martin furnace, the use of oxygen in electric furnaces was tremendously successful. Compared with, for example, iron oxide, the reaction of gaseous oxygen and carbon is exothermic, liberating about 1 kWh of energy for every 8 cubic feet of oxygen

/(0.227 cubic metres),

(0.227 cubic metres), while the reaction of iron ore and carbon is endothermic and therefore absorbs heat (approximately $\frac{1}{2}$ kWh per pound of ore). The use of gaseous oxygen also has the following advantages compared with the use of oxygen contained in the ore: faster decarbonization, less oxidation of metal components, lower consumption of electric energy, smaller consumption of electrodes, longer-lasting refractories, better quality steel, and a more efficient control of the temperature and composition of the bath.

A system for the continuous feeding of the electric furnace with materials in the form of particles has recently been developed. At present it is being used on a commercial scale in Vera Cruz, Mexico, and by the Steel Company of Canada. In Canada, the continuous charging of metallized pellets (90 per cent iron) lasted 153 minutes compared with 205 minutes for a similar run with 25 tons of cold scrap iron. The 25 per cent saving in time was due to the use of a continuous charge, and at least half the saving in time (52 minutes), to the use of a pre-reduced charge. According to a study on the production and use of pre-reduced ore presented by Sibakin at the congress held in Evian (France), when pre-reduced materials are used, the usual refining time is virtually reduced to nothing; the volume of slag diminishes; the consumption of electrodes is the same as or a little higher when scrap iron is used; the consumption of refractories is considerably smaller; and owing to the "virgin" nature of the pre-reduced material, more ferro-alloys have to be added. According to the same document, "through the combination of direct reduction in electric furnaces and the continuous charging system, large quantities of steel can be produced more economically (including capital and operating costs) than through the traditional combination of blast furnace and oxygen steel shop".

Trials in the use of pure oxygen in steelmaking were carried out in many countries, such as France, Germany, the USSR and the United States about 1920. In some of these experiments, the process was successful, but the low level of production and the high cost of pure oxygen at that time did not encourage its use on a commercial scale.

With the initiation of the production of pure oxygen at a reasonable cost it was possible to develop the method of refining pig iron by means of

/the LD, Kaldo

the LD, Kaldo and other processes, which represented the greatest technological progress in world steelmaking in the past two decades.

The first oxygen steel plant began operating in Austria in 1952, and there are now 135 plants in operation in thirty-four countries, without counting about twenty which use the Kaldo-type furnace. There are also thirty-one LD steel plants under construction, and forty well advanced in the project stage. It is estimated that as from 1971 refining on the basis of pure oxygen will be the most widely used steelmaking process, and that from 1972 onwards it will account for over 50 per cent of world's total steel production. The consequent parallel growth of electric steelmaking will help to reduce the share of steels produced by means of the Thomas and Siemens-Martin processes. Projections show that in 1977 world production of steel by the pure oxygen process will equal the whole output obtained by all the processes in use in 1969.

The following refining processes are among those based entirely on oxygen:

The LD process, which is very widespread and owes its success to the simplicity and economy of both the equipment and the operation.

The LD-AC and OLP process, with injection of fines and lime, - and possibly ore - by the oxygen jet. The maximum kinetic and operational advantages are obtained when the huge quantity of lime to be injected is adequately portioned out throughout the operation, which occurs in the refining of pig iron with a high phosphorus content.

The Kaldo process, in a rotating converter, facilitates the burning of CO and CO_2 inside the converter itself without too much damage to the refractory. The saving in heat makes it possible to melt more ore.

The LD-Pompey process, whereby pig iron is refined through the formation of two slags, the second being retained in the converter for the next operation.

The Rotor process, which uses the submerged lance. Owing to operational difficulties, its use is confined to a few isolated cases.

Of the oxygen processes, only the LD process has been widely adopted. The use of the Kaldo converter, which is less simple mechanically and consumes almost four times the quantity of refractories, is justifiable only on such

/economic grounds

economic grounds as may relate to the use of certain raw materials (scrap, iron ore, etc.). A notable technological improvement on the intermittent processes of refining with pure oxygen is the continuous steelmaking process which was developed recently by IRSID in France. A pilot plant at Maiziens-les-Metz, France, is currently producing 10 to 15 tons per hour from high and low-phosphorus pig iron.

Broadly speaking, the process comprises the following stages:

In a first container, called the reactor, a metal-slag-gas emulsion is formed on a small metal reserve which is continuously refed into the system. Refining takes place within this emulsion. When the emulsion goes down and the gas bubbles rise, the emulsion passes through an outlet into a second container, called the decanter, where the slag is separated from the metal.

The crude steel is collected by means of a continuous process in a third container, where the usual materials are added to complete the process (ferromanganese, de-oxidant products and recarburizing addition agents).

6. Development of continuous casting and vacuum casting of steels

a). Continuous casting of steels

For steel producers, this new technique holds the magic appeal of the word "continuous", since it has long been the industry's goal to convert the original intermittent processes into a continuous process. In the metallurgical sector of the steel plant little has been done in that direction. It is only in the last three years that IRSID, in France, has developed a continuous steelmaking process. Curiously enough, the earliest metallurgical equipment - the blast furnace - has the most continuous type of operation. Only certain details of the operation of the blast furnace itself prevent the production of pig iron from being a fully continuous process. In steel rolling, the operation is already continuous in the finishing mills. Large-scale plants use continuous hot and cold rolling mills not only for sheets but for shapes, wire, etc. as well.

The pickling and annealing lines are also continuous. In addition, continuity has been achieved in the process of coating steel with other metals

/or miscellaneous

or miscellaneous products, notably in electrolytic processes (galvanized sheets, etc.). It is also being introduced in the primary stage of rolling, i.e., in blooming, thus eliminating the conventional ingot casting. In some plants, the blocks obtained from continuous casting proceed immediately to the finishing mills, through continuous intermediate heating or even without it. When the steel is poured into the casting machines in an uninterrupted operation, this is called "continuous-continuous casting".

The merit of this process lies not only in its continuity but also in its simplicity and increased efficiency, owing to the elimination of the "ingot" stage involving costly moving and processing.

Continuous casting began to arouse real interest in the steel industry before 1930, following the experiments by Junghans in Germany and Williams in the United States. Junghans, who is regarded as the inventor of the process, registered the first patents incorporating the principle of the oscilating mould in Germany in 1933 and in the United States in 1938. The process developed more rapidly in Europe, particularly in steel plants in Austria, Germany and the United Kingdom. While the western world was developing the process, the Soviet steel industry made great strides in the practical application of these same principles, and today the USSR is the country with the largest number of continuous casting machines. Up to the end of 1967 there were 177 continuous casting machines in operation in the world, and about 30 in course of installation and expected to start operating in 1968/1969. The largest plant, owned by the National Steel Company in the United States, has a capacity of 1 million tons per annum.

The adoption of a new technological process by the steel industry depends, in the last analysis, on the proven capacity of the process to manufacture a product of the quality demanded by the market at a price which allows a profit margin at least equal to that obtained with the processes already in use. Continuous casting has the following economic advantages:

The simpler equipment requires less investment, which has dropped by 20 to 40 per cent;

A saving of 8 to 10 dollars per ton is obtained in operating costs;

Although it is difficult to calculate the reduction in the amount of space used in terms of costs, it is estimated that in a plant producing 1 million tons annually the area is reduced from 20,550 to 8,400

/square metres;

square metres;

The most important economic advantage of this process seems to be its yield. The sheet/ingot ratio in continuous casting is 95 per cent, compared with 85 per cent with the conventional process.

Continuous casting also has the following advantages as regards quality and operation:

Uniformity of the quality obtained;

Elimination of segregation and easy control of the size of the grain;

Good-quality surface, which reduces subsequent processing;

Being a simpler process, it requires less skilled personnel;

It can be easily automated;

Higher labour productivity.

It has the following disadvantages and limitations:

Need for synchronization of the steel production equipment with the continuous casting machine;

Low production speed;

Little flexibility as regards the shape of the sheets and blocks;

Insufficient control of boiling to permit the pouring of semi-killed steels.

For obvious reasons, notwithstanding the great strides made in continuous casting, the conventional processes are still those in normal use by the steel industries. Logically enough, the following improvements have been introduced in the conventional processes with a view to obtaining better-quality ingots:

Exothermic hot-top;

Protection by means of inert gases, mechanical improvements for more regular filling of the ingot mould, etc.

b) <u>Vacuum casting of steels or vacuum refining processes</u>

Under this heading are grouped the processes whereby the molten steel is subjected to a vacuum, even when this is done at the time of casting (since in this case, too, it is essentially a refining process rather than a special casting technique). The object of this treatment may be the elimination of hydrogen, and secondarily nitrogen; deoxidation; reduction of inclusions. Various processes have been suggested, it being possible to

/use a vacuum

use a vacuum in the melting and refining furnace, the pouring ladles and the ingot moulds.

The processes for degassing the ingot mould include:

Degassing the molten steel jet during its removal from a first ladle to an ingot mould, which is in a vacuum chamber;

Degassing the molten steel jet in the process of filling the ingot moulds, which have special covers (with an inlet for the molten steel and an aperture linking up with the vacuum system).

A number of steel companies are already using vacuum casting, although almost exclusively for special steels, in particular stainless steels. The advantage is that it is possible to obtain slabs of suitable sizes (up to about 10 metres long), with an excellent surface so that no processing is required before rolling.

7. World development of rolling techniques

The trend towards higher levels of efficiency in the production of primary iron and steel is also observable in rolling.

The following factors were mainly responsible for the rapid development of this part of the production cycle in a steel plant: increase in the size of the units; increase of the mechanization index; and automation.

In the markets of nearly every country in the world, flat products are noticeably increasing their share, year by year, for use not only in their final form but also in the form of non-flats, welded together or subsequently transformed by mechanical processes.

This resulted in greater use being made of continuous and semi-continuous mills. It was also noted that more use was made of these mills for the direct production of non-flat products, e.g., tubing, wire, etc. In both cases, the reason was better quality, higher productivity and, therefore, lower production costs.

Economies of scale, increased rolling speed and other factors encouraged the use of automation in some units, making it possible to obtain products of a more uniform quality at a lower cost.

Concurrently with the significant growth of demand for flat products, the requirements in regard to tolerance limits, surface and quality specifications for slabs became much more stringent.

/In view of this,

In view of this, nearly all the steel producing countries installed continuous and semi-continuous rolling mills. On the other hand, planetary rolling mills were also developed for more economical operation in the case of smaller production. At present, nearly all these mills are being used to obtain cold-rolled products. In 1966, there were 241 Sendzimir-type rolling mills in operation in the whole world, and some under construction. In the planetary rolling mills, further studies are being carried out with a view to replacing the hot-coils at the end of the continuous casting process by a small-cylinder Sendzimir, so as to be able, in one pass, to reduce hot-rolled strips and supply cold-rolled strips that will meet the closer tolerances.

The use of planetary mills to produce hot-rolled flats is not limited to combinations with continuous casting, which, in the last analysis, constitute another attempt to make the whole steelmaking operation a continuous process. These mills are being used to reduce, in one pass, slabs of 8 to 10 centimetres in thickness to a sheet of about 3 milimetres. It should be noted, however, that in practice this process still presents some problems, and the four units operating in the world today are still facing difficulties which are gradually being solved.

8. Automation of the steel industry

An analysis of modern steelmaking techniques is not complete without some consideration of the technical and economic prospects offered by the automation of this important basic industry.

From the administrative standpoint, automation in a steel company is directly intended to facilitate the plant's management. In this connexion it comprises two main objectives:

The first, in which the purpose is automatically to collect the manufacturing data required to manage stocks, calculate operating costs and prices for each product or semi-finished product, and order the quantity and quality of inputs required for the production of steel;

The second, in which the primary aim is optimum production planning, i.e., the establishment of weekly or monthly production programmes.

/On the basis

On the basis of data obtained in the plant and information supplied by commercial services, the computer automatically groups the orders, distributes production as economically as possible and provides guidance for the manufacturing services. It can also establish the daily programmes for each stage of production, in terms of orders and progress in manufacturing, and possibly even introduce changes in the programming.

The operation of many blast furnaces is already automated on the basis of metallurgical models. Automation consists basically in regulating the temperature in the lower part of the blast furnace, in order to stabilize the temperature and sulphur and silicon content of the pig iron produced. It is difficult to quantify the over-all economic advantages of automation in a blast furnace, since account must be taken not only of the improvement in performance of this reduction equipment (resulting, in principle, in a decrease in the coke rate or an increase in productivity), but also of the benefits accruing to the steel plant since it receives a more uniform pig iron of better quality as regards the sulphur and silicon content. Automation of the blast furnace is not easy, owing to the changes that take place in time in the physical and chemical properties of the burden. Therefore, attention should be given to an automatic control of the supply and regulation of the burden before any attempt is made to control the temperature in the blast furnace.

In the production of steel by the LD process, as in the blast furnace, steps should be taken first to regulate the supply of the burden, with due consideration for the effect of all the parameters involved, particularly the temperature of the pig iron, the nature of the scrap, ore and limestone, and the temperature in the converter. Moreover, account must be taken of the final analysis of the steel and the slag, and also of the temperature and weight of the molten metal obtained.

At the present time, many steel plants have a computer to regulate their operations on the basis of a mathematical model, furnishing the operator in the shortest possible time with accurate data regarding the proper weights of the materials to be charged into the furnace and the quantity of oxygen to be blown. This is called "static automation".

/If the idea

If the idea is to use "dynamic automation", as is used for example in the blast furnace, it is necessary to regulate the input variables of the system during the blowing operation, so as to establish the height of the lance, etc. The direct advantages of dynamic automation, taking into account the additional investment necessary, are not so apparent as in the case of static automation. It does, however, permit a reduction of a few degrees in the variations of the steel temperatures and ensures a more regular analysis of the metal and slag.

Automation of hot-rolling presents the great advantage over automation of pig iron and steel production that it is used in a less complex production process. Nevertheless, only some primary operations of the rolling cycle have been automated in the blooming mills, that is, the whole rolling sequence is not automated. For example, in the blooming mill, steps have been taken to ensure maximum efficiency in the movement of the pressure screws and the control of the feed cylinders and the outlet, the last two stages being duly synchronized.

The hot-strip mills are not fully automated either. Up to now, automation of this equipment has been intended to regulate the average thickness and width of the sheet at the outlet of the finishing mill, and the temperatures after completion of the rolling and coiling operations.

Some statistics show the following distribution of computers in the processes in use by the world steel industry in 1968: production of pig iron: 11.5 per cent; LD and electric steel plants: 25 per cent; rolling mills: 45.5 per cent; others: 18 per cent.

In conclusion, it should be added that automation in the steelmaking model does not mean a reduction in manpower, but merely the elimination of some of the operator's mental functions. It has certain direct advantages which are not always easily expressed in figures and some indirect advantages which cannot be measured in quantitative terms. There is, for example, the effect of the improvement in uniformity and quality of the products of one stage of production on the operating costs in the following stage and on the economic value of the final product.

/Chapter II

Chapter II

BRIEF DESCRIPTION OF THE BRAZILIAN STEEL INDUSTRY

The Brazilian steel industry has considerably increased its annual production over the past twenty years and now supplies practically the entire domestic market, as can be seen from the figures in table 1 for production, imports and exports of flat and non-flat products.

Table 1

BRAZIL: SUPPLY OF ROLLED STEEL PRODUCTS

(Thousands of tons)

Year	Non-flat products				Flat products			
	Production	Imports	Exports	Percentage of net imports a/	Production	Imports	Exports	Percentage of net imports a/
1951	433	237	-	35	249	150	-	37.5
1953	505	97	-	16.2	290	115	-	28.5
1955	519	212	12	28	413	133	-	24.5
1957	667	225	3	25	463	170	-	27
1959	877	339	-	28	615	168	-	21.5
1961	941	175	8	15	880	159	-	15.3
1963	1 176	188	-	13.8	1 041	288	-	21.7
1965	1 074	132	16	9.8	1 074	124	154 b/	(-3)
1967	1 403	178	20	10	1 428	161	234 b/	(-5.4)
1969c/	1 993	173	70 d/	5	1 977	231	255 b/	(-1.2)

Source: ECLA, on the basis of Brazil's foreign trade statistics and data published by the Latin American Iron and Steel Institute (ILAFA).
a/ Percentage of apparent consumption represented by net imports.
b/ Including semi-finished flat products exported mainly to Argentina.
c/ Figures provided by the Brazilian Steel Institute (IBS).
d/ Including semi-finished non-flat products.

/It should

It should be noted that imports consist partly of special steels of a size, shape and chemical composition which are not yet produced in Brazil. The rest comprise common steels for distant regions to which transport would be too expensive to supply them economically from the producing centres.

As regards non-flat products, it will be noted that net imports declined from 35 per cent of apparent consumption in 1951 to 10 or 11 per cent in recent years. On the other hand, production of flat products has more than covered consumer needs on the domestic market, since in 1965 and 1967 there was a net export balance, in contrast with the situation in 1951 when net imports amounted to 37.5 per cent of apparent consumption.

Table 2 presents a list of all the steel plants operating in Brazil in the years 1967-1969, except for two plants which had stopped working at that time (but have since been reorganized and are now in operation), and those plants whose blast furnaces produce only pig iron, although they may complete their cycle with the manufacture of centrifuged tubes.

In 1967, practically all Brazil's steel industry was at a great disadvantage as regards economies of scale, since, broadly speaking, an integrated plant using coke as reducing agent attains an economic scale of production when it produces approximately 2 to 2.3 million tons of ingots annually, and if it uses charcoal, approximately 1 million tons. The economic production of semi-integrated plants, except in very special cases, should be about 300 000 tons.

Most of the following analysis relates to the situation of the six integrated plants which were originally planned as integrated units (group I). These plants produced approximately 77 per cent of Brazil's total output of steel ingots in 1969. As regards technology, a few of the semi-integrated plants, which are responsible for 16 per cent of the steel produced, have remained at the same stage as when they started, with the same production methods and organization; but a large number have concentrated their efforts on diversifying their production, manufacturing special products as regards shape, size or the metallurgical composition of steel, which fetch better prices on the domestic market. Owing to the small output and wide scattering of this type of plant, only four of the eighteen included in table 2 were

/actually visited;

actually visited, these four plants, besides appearing in the table with a fairly appreciable output, all belonged to the group of enterprises which, technologically, must be classified as progressive. It should be noted that this small sample cannot be considered to be representative of the sector, since the plants were chosen precisely because of their reputation as innovators in Brazilian steelmaking.

Table 2

STEEL PLANTS OPERATING IN BRAZIL IN 1969

(Thousands of tons)

I. Integrated plants originally planned as such

Plant	Location	Structure	Production in 1969
V. Cia. Siderúrgica Nacional (Volta Redonda)	Rio de Janeiro	Sinter plant, coke plant, coke blast furnaces, Siemens Martin steel shop, blooming mill, semi-continuous strip mill, cold rolling mill, medium profiles mill, tinning line, galvanizing line	1,392
V. Usinas Siderúrgicas de Minas Gerais (USIMINAS)	Minas Gerais	Sinter plant, coke plant, coke blast furnaces, LD steel shop, blooming mill, hot rolling mills, cold rolling mills	791
V. Cia. Siderúrgica Belgo Mineira	Minas Gerais	Sinter plant, charcoal blast furnaces, LD and Siemens Martin steel shop, blooming mills, bar and wire rod mills, Steckel sheet mill	585
V. Cia. Siderúrgica Paulista (COSIPA)	São Paulo	Sinter plant, coke plant, coke blast furnace, LD steel shop, blooming mill, hot rolling mill, cold rolling mill	551
V. Cia. Siderúrgica Mannesmann	Minas Gerais	Coke blast furnace, electric reduction furnaces, LD and electric steel shop, blooming mill, merchant bar mill, tube mill	313
V. Cia. Aços Especiais Itabira (ACESITA)	Minas Gerais	Sinter plant, charcoal blast furnace, electric reduction furnace, Bessemer steel furnace, electric steel furnaces, blooming mill, hot rolling mill, cold rolling mill	154
		Total production group I	3,786

/II. Plants originally

II. Plants originally planned as semi-integrated units and subsequently integrated

Plant	Location	Structure	Production in 1969
Siderúrgica Barra Mansa S.A.	Rio de Janeiro	Charcoal blast furnaces, Siemens Martin steel shop, blooming mill, medium profiles mill, light profiles mill, stranding mill	111
Siderúrgica J.L. Alberti S.A.	São Paulo	Charcoal blast furnaces, Siemens Martin steel shop, blooming mill, medium profiles mill, round bar mill	112
Cia. Brasileira de Usinas Metalúrgicas	Minas Gerais	Charcoal blast furnaces, Siemens Martin steel shop, blooming mill, medium profiles mill, light profiles mill	27
Cia. Siderúrgica Pains	Minas Gerais	Charcoal blast furnaces, Siemens Martin steel shop, blooming mill, light profiles mill	35
Laminação de Ferro (LAFERSA)	Minas Gerais	Charcoal blast furnaces, Siemens Martin steel shop, blooming mill, light profiles mill	20
		Total production group II	305
		Total production integrated plants	4,091

III. Semi-integrated plants

V. Siderúrgica Riograndense S.A.	Rio Grande do Sul	Electric steel shop, continuous casting, blooming mill, medium profiles mill, light profiles mill, stranding mill	154
M. Dedini S.A.	São Paulo	Electric steel shop, Siemens Martin steel shop, blooming mill, light profiles mill	81
V. Aços Villares S.A.	São Paulo	Electric steel shop, blooming mill, bar rod mills, presses, vacuum casting	51
V. Aços Anhanguera S.A.	São Paulo	Electric steel shop, blooming mill, bar rod mills	70
Usina Siderúrgica São José	São Paulo	Electric steel shop, blooming mill, medium profiles mill, light profiles mill, fine profiles mill	77

/V. Ind. Metal

Plant	Location	Structure	Production in 1969
V. Ind. Metal N.S. da Aparecida S.A.	São Paulo	Electric steel shop, medium profiles mills, light profiles mills, forging shop	31
Usina Santa Olimpia de Ferro e Aço	São Paulo	Electric steel shop, blooming mill, profiles mill	41
Siderúrgica Açonorte	Pernambuco	Electric steel shop, blooming mill, wire rod mill	36
Cia. Siderúrgica da Amazônia (SIDERAMA)	Amazonas	Light profiles mill, wire rod mill	25
Siderúrgica Coferraz	São Paulo	Electric steel shop, blooming mill, light profiles mill	31
Lanari S.A. Ind. e Com.	Rio de Janeiro	Electric steel shop, blooming mill, medium profiles mills, light profiles mills	23
Cobrasma S.A. Ind. Com.	São Paulo	Electric steel shop, presses	18
Fábrica Fi-El Ltda.	São Paulo	Electric steel shop	22
Cia. Brasileira de Aço	São Paulo	Siemens Martin steel shop, blooming mill, light profiles mill	18
Cia. Metropolitana de Aços	Rio de Janeiro	Round bar mill	28
Eletro Aços Altona S.A.	Santa Catarina	Electric steel shop, blooming mill, light profiles mills	9
Electrometal Aços Finos S.A.	São Paulo	Electric steel shop, forging shop	3
Ind. Electro-Aços Plangg S.A.	Rio Grande do Sul	Electric steel shop, forging shop	1
		Total production semi-integrated plants	719
		OVER-ALL TOTAL	4,810

Source: Latin American Iron and Steel Institute (ILAFA), report of Latin American steel enterprises, 1969.

Note: The plants preceded by the letter V were visited during the field work for the study.

/Chapter III

Chapter III

PRESENT STATE OF TECHNOLOGY AND SPREAD OF NEW TECHNIQUES IN THE BRAZILIAN STEEL INDUSTRY

1. Introduction

Iron metallurgy in Brazil was initiated by Afonso Sardinha in the Serra de Cubatão area of São Paulo in 1587. It expanded slowly with the construction of several catalan hearths in the States of São Paulo and Minas Gerais in the late sixteenth and the whole of the seventeenth centuries.

In support of the idea of establishing large plants and using the ore found in the Rio Doce valley, the Intendente, Manõel Ferreira de C. Bethencourt, installed the first real blast furnace in the country at Morro do Pilar, and obtained liquid pig iron in December 1813. In São Paulo, steelmaking was reactivated with the establishment of an iron factory. In 1838, the Esperança plant was established near Itabira do Campo, with a blast furnace producing 6 tons a day. The builder of this blast furnace subsequently constructed a second, with a capacity of 15 tons a day, at Burnier.

In 1905, the position of the Brazilian steel industry was as follows: two blast furnaces, of which only one was in operation, producing 2,100 tons of pig iron, and about 100 furnaces producing 2,000 tons of iron bars annually.

The industry made a new spurt in the period 1917-1930. The engineers Amaro Lanari and Gil Guatimosim established the Companhia Siderúrgica Brasileira at Sabará, with a modern blast furnace, and in 1922, with the co-operation of ARBED, of Luxembourg, it became the Companhia Belgo-Mineira and installed a Siemens Martin furnace and rolling mills for small shapes and wire bars.

In 1930, Brazil produced only 36,000 tons of pig iron and 26,000 tons of rolled steel. The Monlevade plant belonging to the Companhia Siderúrgica Belgo-Mineira was brought into operation in 1937, with an initial capacity of 50,000 tons annually.

/In 1939,

In 1939, a group of Brazilian and United States experts studied the installation of the first coke steel plant in Brazil. This plant, which is situated at Volta Redonda and belongs to the Companhia Siderúrgica Nacional (CSN), started operating in 1942, and the first run of pig iron obtained in a Brazilian coke blast furnace was in June 1946. In that year, Brazil's pig iron production amounted to 371,000 tons and its steel production to 343,000 tons.

With the development of the Brazilian economy, the Volta Redonda plant was successively expanded until it reached its present capacity of 1.5 million tons annually. However, this quantity was not enough to cover the country's requirements. The following steel plants were then established in order to keep pace with Brazil's increasing rate of industrial development: COSIPA, Mannesmann, USIMINAS, etc.

Table 3 shows the development of Brazil's production of pig iron, by processes, during the period 1940-1969. It will be noted that it was not until 1964 that the output of coke blast furnaces exceeded that of charcoal blast furnaces.

The initial predominance of charcoal blast furnaces was mainly due to the strong attraction exercised by the existence of forest reserves close to iron ore deposits in the iron quadrilateral area. (Quadrilátero Ferrífero).

Table 3

BRAZIL: EVOLUTION OF PIG IRON PRODUCTION, BY PROCESS, 1940-1960

(Thousands of tons)

Process	1940	1950	1960	1962	1964	1966	1968	1969
Charcoal furnaces	186	315	966	1 132	1 070	1 011	1 212	1 471
Coke furnaces	-	193	793	808	1 353	1 783	2 019	2 108
Electric reduction furnaces	-	-	79	69	59	94	117	138
Total	186	508	1 838	2 009	2 487	2 883	3 343	3 717

Source: Brazilian Metal Association (ABM), ILAFA and IBS.

/The evolution

The evolution of Brazil's steel production was even more striking in the period between 1940 (141,000 tons) and 1969 (4,925,000 tons). The salient development was the sharp increase in oxygen steel production (see table 4). In 1960, the quantity of steel produced by this process was only 10 per cent of the total output, while in 1969 it was approximately 38 per cent.

Table 4

BRAZIL: EVOLUTION OF CRUDE STEEL PRODUCTION, BY PROCESS, 1960-1968 a/

(Thousands of tons)

Process	1960	1962	1964	1966	1968	1969
Siemens Martin	1 529	1 737	1 771	1 731	1 850	2 062
Electric	495	575	632	608	892	945
Oxygen converter	235	250	664	1 357	1 665	1 866
Total	2 260	2 562	3 067	3 696	4 407	4 873

Source: Brazilian Metal Association (ABM), ILAFA and IBS.

a/ In 1960, 400 tons of steel were produced in Bessemer furnaces, a figure which gradually increased to 51,000 tons in 1969. It is not inclued in the table since the steel was not melted in ingots but used as duplex for subsequent refining in other types of furnaces.

/Brazil's production

Brazil's production of both flat and non-flat products increased significantly over this period, the respective figures being 1,977,000 and 1,993,000 tons in 1969 compared with 834,000 and 974,000 tons in 1961.

The increasing production of pig iron, steel and rolled products in Brazil is due to the installation of new integrated and semi-integrated plants. With a view to obtaining a larger output, better quality and lower operational costs, many Brazilian steel enterprises have been endeavouring to absorb the latest foreign production techniques, and to develop and apply their own, as occurred in Japan in the second stage of its industrial development during the post-war period.

An example of the first case is the use of a prepared burden, combined with the injection of oil and oxygen-enriched air in the Belgo-Mineira blast furnaces at Monlevade, which pushed up production by about 23 per cent and resulted in a saving of approximately 6 per cent in the reducing agent. The process of producing steel in oxygen converters used by COSIPA, USIMINAS, Belgo-Mineira and Mannesmann, together with some improvements in the process, enabled these plants to raise their output in some cases by over 30 per cent. A large proportion of these technological innovations and of the techniques for manufacturing new products were obtained through technical assistance contracts with foreign firms, notably in the United States, Germany, France and Japan.

An example of the second case is the action taken by some Brazilian enterprises to improve the manufacture of products for both the domestic and the external market, taking into account the nature of the raw materials and the products and equipment available in Brazil, as well as the specific requirements of the consumer market.

USIMINAS, for example, for technical and economic reasons connected with the use of its raw materials, and on the basis of the results of studies and trials carried out entirely by its own engineers, is using magnesite refractories in its converters with excellent results. To achieve more effective results in a shorter time, enterprises such as CSN and USIMINAS have set up their own technological research centres, while others, such as COSIPA, are making use of research institutes such as IPT in Sao Paulo.

/2. Technology

2. Technology applied to raw materials

A great many iron ore deposits are known to exist throughout Brazil, but Minas Gerais is where the largest production of pig iron is concentrated and where the largest known iron ore reserves are located. A small proportion of the ore is made up of magnetites, and the rest of hematites and itabirites. The biggest concentration of these ores is found in the famous Quadrilátero Ferrífero, and the reserves, with an iron content of 60 per cent, amount to about 4,150 million metric tons. Therefore, Brazil's steel industry has nothing to worry about as regards the quantity or quality of its basic raw material.

Brazil's consumption of iron ore rose from 3 million tons in 1960 to over 5.3 million tons in 1968, and the effort to attain higher and higher productivity coefficients in the blast furnaces compelled steel producers not only to improve the raw material in relation to its natural form, but also to develop the use of agglomerates.

During the 1950s, there was a general move in the United States to classify the iron ore charged into the blast furnace within an ever-stricter granulometric range. This method, which was initiated in two plants that dit not obtain their ore from the famous Messabi Range,[1/] soon spread to the whole industry in the United States, and led to the agglomeration of fines. The Brazilian producers who were most alert to technological innovations started work almost immediately on these lines, one of the best examples being the Cia. Siderúrgica Belgo-Mineira. In June 1964 it made a number of modifications in its ore beneficiating installations in the Andrade mine, with a view to obtaining an ideal sizing for the iron ore of the burden in its blast furnaces. Thus, in mid-1968, it was producing ore classified between 6 and 20 milimetres, which they called natural pellets, as well as lumps of ore of 20 to 30 milimetres. Since the production of these pellets is limited, they are being used for only 50 to 60 per cent of the burden in the four blast furnaces. With the use of this type of ore in the above-mentioned proportion, the blast furnace output increased by 10 per cent and the coke rate dropped by 6 to 7 per cent.

1/ Kaiser, Fontana, and Birmingham, Alabama.

The concern for the use of a proper sizing for the blast furnace burden spread to the whole of Brazil's steel industry, which completely abandoned the old practice of crushing the lumps of ore to a specific size considered to be the acceptable maximum and charging the whole product, including the fines, into the blast furnace. At present few plants, or possibly none, have attained the level of efficiency at Monlevade. That there is still some way to go may be deduced from the fact that there are still plants in which the size of the ore used ranges from 12 to 65 milimetres.

Up to the present time, the Brazilian steel plants have used sintering as the only process of agglomerating iron ore. This form of agglomeration, which was just beginning to be used in the world steel industry in 1940, was initiated in Brazil in 1948, also by the Companhia Siderúrgica Belgo-Mineira, on the basis of studies carried out by the Technological Research Institute in São Paulo. The purpose of this innovation was two-fold: first, in anticipation of the widespread movement in favour of more stringent size limits, to eliminate the fines which were separated and use them as raw material for the sinter; and, secondly, to abandon the selective extraction at the mine intended to choose lumps of a specific size and use mass extraction processes because the fines could be utilized.

The production of sinter in Brazil rose from 827,000 tons in 1961 to approximately 2.5 million tons in 1969. At present, nine industries possess sintering machines with rated capacities ranging from 150 to 2,500 tons a day. Dwight-Lloyd machines account for the largest proportion of the installed capacity, while the first unit in Monlevade uses the Greenawalt process.

Mannesmann is the only modern integrated plant in Brazil which does not use sintering. It should be remembered that sinter enables the charge to be better prepared for the sequence of events which subsequently take place in the blast furnace, it gives the ore better granulometric characteristics, more resistance to pressure and abrasion and greater reductibility, and permits the utilization of the flue dust. But, according to the input costs and scale of operation, the production of sinter costs 3 to 6 dollars per ton, and in order to justify it these costs must be absorbed by the operational advantages obtained from their use.

/It is

It is possible that in the case of Mannesmann, such favourable results are not obtained. This company is supplied by its own iron mine, which produces a small quantity of fines which it exports. It is therefore in a position to select the ore within narrower size limits for use in its plant. The advantages of the use of sinter is considerably lessened if the ore consists of uniform size grains resisting the normal pressure of a hot and cold blast furnace burden.

Although the figures show that sintering is in widespread use in Brazil, a great deal of technological research is still required. In June 1969, USIMINAS carefully revised its sintering operations and obtained an appreciable increase in the output of its equipment, while maintaining the quality, through the more efficient preparation of the raw materials, particularly coke fines, by means of suitable modifications in the equipment, a higher operational index for the sintering machine, and more effective operational control. In September 1969, the productivity of the equipment had reached 39.8 tons of sinter per day per square metre of grate, which represents a 40 per cent increase over the initial June figure.

There has been no experience in the use of the other customary form of agglomeration, i.e., pellets, in the blast furnace burden of Brazilian steel plants, since they are not yet being produced. Steel companies will not be able to use them before April 1970, when the Companhia Vale do Rio Doce pelletizing plant, in the State of Espírito Santo, enters into operation.

The statements regarding the volume and quality of iron ore reserves are not applicable to Brazilian coal. According to the studies carried out to date, Brazilian coal reserves amount to about 3,000 million tons and the most important production centre is in the State of Santa Catarina, which in addition, is the only known region which supplies the metallurgical coal market.

Table 5 presents figures for the consumption of domestic and imported coal and the production of coke by integrated coke steel plants. The small share of Brazilian coal in the blends, which up to a short time ago was 40 per cent and is gradually declining, may be ascribed to the three following factors:

/Poor metallurgical

Poor metallurgical quality, since even after the washing and selection it has a high ash and sulphur content;

Difficult and costly extraction and beneficiation, owing to the unfavourable natural conditions of the mines;

A transport structure which substantially raises the c.i.f. cost placed at the steel plant.

Table 5

BRAZIL: CONSUMPTION OF DOMESTIC AND IMPORTED COAL AND COKE PRODUCTION BY THE STEEL INDUSTRY

(Thousands of metric tons)

	1960	1962	1964	1966	1967	1968 *	1969
Domestic coal	395	482	556	585	665	785	734
Imported coal	616	869	698	1 298	1 215	1 364	1 382
Coke production	705	764	909	1 233	1 317	1 464	1 507

Source: Luiz Fernando Sarcinelli Carcía, "Mercado de carvão brasileiro para fins metalúrgicos", a study presented to the Seminar on Coal and Coke organized by ILAFA in Santiago, Chile, in August 1969.

* CPCAN.

With a view to reducing the cost of the coke produced at the plant, USIMINAS carried out a number of studies to determine whether coke fines could be utilized as inert material in the coking blend. The conclusion was that approximately 7 per cent of this material could be used instead of United States high-volatile coal in the production of coke for smelting, and only 1.8 per cent for the production of blast furnace coke. This plant is currently studying the possibility of using about 5 per cent charcoal fines for the seme purpose.

/In view

In view of the difficulties that may be expected in regard to the supply of charcoal for the future expansion of the steel industry, and of the inadequacy of the existing coking facilities, the possibility is being explored of installing a large central coking plant at Belo Horizonte.

In the past, the existence of large forest reserves close to iron ore deposits led to the establishment of pig iron producers, some integrated and others not, which used charcoal as fuel and reducing agent. The foreseeable depletion of these forest reserves prompted some companies to plant large expanses of artificial forests, carefully selecting the quickest growing species, which resulted in the production of charcoal with excellent metallurgical qualities. These experiments were confined essentially to certain eucalyptus species imported from Australia and indigenous varieties of leguminous trees. As regards the charcoal-making process, after some attempts in centralized plants, with or without the recovery of by-products, it became general practice to produce the charcoal in the forests themselves and then to transport it to the steel plants. It should be noted that the prices of by-products of charcoal, as well as of coke, have dropped appreciably owing to competition from petrochemical products, thus making their recovery an unprofitable process. Other major technological problems are: first, the moisture absorbed by charcoal when exposed to rain, which has been solved by the accumulation of large stocks under roofing in order to reduce the moisture content to acceptable levels by natural evaporation; secondly, the degradation of the charcoal which produces large quantities of fines, for which a use is being sought. USIMINAS is experimenting with the inclusion of up to 5 per cent of this charcoal in the coking coal blend. Other studies relate to the possibility of manufacturing suitable briquettes. IPT of Sao Paulo and the ACESITA plant at Minas Gerais are working on this problem.

3. Technology applied to the reduction of ore

At present, 60 per cent of Brazil's pig iron is produced in coke blast furnaces, 36 per cent in charcoal blast furnaces and the rest in electric reduction furnaces.

/With a

With a view to raising the productivity of their blast furnaces and reducing the consumption of fuel, integrated steel enterprises are using different techniques in their reducing installations, in relation not only to the preparation of the metal burden, but also the injection of hydrocarbons and/or oxygen in the tuyeres, increase in the blast temperature, etc.

Thus USIMINAS, by using a larger proportion of sinter with a basicity of 1:3 and increasing the blast temperature from 737 to 940 degrees, raised its daily output of pig iron to about 1,000 tons in the period May-October 1969, that is, 43 per cent above the rated capacity of 700 tons for its blast furnace N° 1. At the same time, its coke rate dropped by 7 per cent, from 592 to 550 kilogrammes per ton.

In 1963 blast furnace N° 2 of the Companhia Siderúrgica Nacional became the first blast furnace in Brazil to use oil injection in the tuyeres. Because of a number of problems, as, for example, the difficulty of adapting the existing instruments, the first injection trials were conducted in six of the sixteen tuyeres. In 1964, the process was extended to the remaining tuyeres. Production in blast furnace N° 2 rose by an average of 12.1 per cent, the coke rate dropped by 10.6 per cent and each kilogramme of oil replaced 1.43 kilogrammes of coke. In blast furnace N° 1, where the same technique was applied immediately afterwards, the replacement rate was 1.85 per cent, and the production increase only 7.2 per cent. The relatively unfavourable results obtained in blast furnace N° 2 were due to the impossibility of using a higher blast temperature, the smaller proportion of sinter in the burden and defects in the internal profile of the furnace, in which the lining was at the end of its campaign. In addition to the CSN furnaces, this method is also being used by Belgo-Mineira and COSIPA. USIMINAS intends to introduce this technique in the expansion of its present installed capacity, mainly because its coke production capacity will be insufficient to cover the requirements contemplated by the expansion programme.

/The use

The use of high pressure at the top of the blast furnaces is becoming increasingly widespread in the more advanced countries. Through this method the reduction process can be speeded up, which results in a higher blast furnace productivity and a reduction in the coke rate. Applying this process would require reinforcement and modifications in the blast furnace structure. Previous ECLA studies 2/ indicate that it would be difficult to introduce such modifications in the facilities existing in Latin America. On the other hand, the COSIPA blast furnace, which is the last to be installed in Brazil by a large integrated plant, has the necessary facilities for the use of high top pressure. It is worth while to note that, five years after this blast furnace entered into operation, this advanced technique has still not been used. Probably the difficulty of starting the plant at the beginning and the irregular behaviour of the market prevented the company from utilizing this reserve capacity.

As regards charcoal blast furnaces, mention should be made of those at Monlevade, whose productivity and low specific consumption of carbon place them alongside some units in Sweden in the vanguard of this type of activity in the whole world. Oil injection in the tuyeres was initiated in blast furnace N° 2 at the beginning of 1967, with the use of 40 kilogrammes of oil per ton of pig iron. For this quantity, with a 50 per cent increase in sinter, the carbon rate ranged from 440 to 480 kilogrammes per ton and production rose by 6 per cent, each kilogramme of petroleum replacing about 1.6 kilogrammes of coal. Petroleum injection was initiated in the rest of the furnaces in June 1969.

With the expansion of the oxygen plant in the Monlevade steel plant it was possible to extend the practice of blowing oxygen-enriched air into the blast furnaces. The present system is to use air with an oxygen content of 26 per cent. Through this method, the productivity of the blast furnaces increased by 21 per cent, which compares favourably with the highest figures attained by Japan. Inevitably, owing to the more intensive operation of the

2/ ECLA, "La tecnología actual y los obstáculos para su incorporación en la industria siderúrgica latinoamericana", prepared by Armando P. Martijena, consultant, p.24.

/blast furnace,

blast furnace, the improvement in productivity was accompanied by a 5 per cent increase in specific charcoal consumption. In adopting this measure, Monlevade knew well the price it would have to pay for this production increase, but it was economically justified.

The fact that there was no surplus oxygen production capacity for some plants is one of the reasons why they are not using this method; another and perhaps more immediate reason is that the fuel represents the most costly input in the production of pig iron, and the use of oxygen increases the fuel rate.

Electric reduction furnaces are used to produce 4 per cent of all the pig iron manufactured in Brazil in the two plants ACESITA and Mannesmann. In addition to studies on the metal charge, the moisture content of charcoal and breaking of the electrodes, Mannesmann also carried out studies on the reducing agent. A comparison was made of Santa Catarina low-volatile coal, CSN coke and charcoal. The following conclusions were reached:

The consumption of energy increases when charcoal is replaced by coke, and also when coke is replaced by a blend of coke and coal;

Productivity declines when charcoal is replaced by a blend of coke and charcoal, and also when charcoal is replaced by coke.

As regards direct reduction processes, there are no facilities at present for the production of pre-reduced materials (sponge iron) in Brazil. However, two companies which are in process of formation propose to use these processes in the plants they intend to build: Aços Finos Piratini in the State of Rio Grande do Sul, and Usinas Siderúrgicas da Bahia in the State of Bahia. The two companies have chosen these processes, to a greater or lesser extent, because of the particular characteristics and specific conditions in the regions concerned, i.e., the physical or chemical composition of the raw materials, the nature or volume of the product required, the prices of some of the inputs and other economic considerations.

/The Piratini

The Piratini project contemplates the use of the SL/RN process, which will make it possible to use non-coking coal from Rio Grande so Sul with an ash content of 35 per cent, while the USIBA project consists in the construction of an integrated plant with an annual capacity of 140,000 tons in the north-east, based on the Mexico HyL process, using natural gas from the region.

4. Technology applied to the steel plant

Of the four basic processes used in the world steel industry, Brazil uses only the three most up-to-date methods: the open hearth (Siemens-Martin) process, the electric process and the pure oxygen surface-blown converter, which were responsible for 42, 20 and 38 per cent, respectively, of Brazil's total steel output in 1969. Of the older methods - natural air bottom-blown converters - only the Bessemer process is still in use; ACESITA produced 31,000 tons of this steel in 1968, not for the manufacture of final goods, but only as duplex in an intermediate pass for subsequent refining in the electric furnace. The basic (Thomas) converter of the same type has never been used in Brazil, because of the low phosphorus content of the ore. Moreover, in view of their many limitations and inflexible nature, it is very unlikely that new Bessemer converters will be built in the future. The converters of this type which existed in the Monlevade and Mannesmann plants were transformed into LD converters in 1957 and 1964, respectively.

As noted in chapter I, the main innovation in steelmaking in the last twenty years has been the large-scale application of industrially pure oxygen in the steel shop and, in particular, the development of the converter in which oxygen is blown on to the surface of the molten metal by means of lances. In Brazil, where steelmaking was in its early stages, this process was adopted when it was invented in 1953. Its share in total steel production increased from 10 per cent in 1962 to 38 per cent in 1969, at the expense partly of the electric steel shop, but mainly of the Siemens-Martin furnaces. As in the steel industry in the industrialized countries, more and more steel plants with oxygen converters are being established in Brazil.

/Belgo-Mineira

Belgo-Mineira was not only the first Latin American steel enterprise to introduce this process (its unit started operating in 1957), but it was also one of the first to accept it in the whole world. It was followed some years later by Mannesmann, which, as Belgo-Mineira had done, transformed its two 20-ton Bessemer converters into 25-ton LD converters. Two integrated plants - USIMINAS and COSIPA - were planned on the basis of this steelmaking process.

Although this is a new process, some Brazilian plants have already adopted a number of innovations in their oxygen converters with a view to improving the quality of the final product and raising productivity. For example, USIMINAS, under a technical assistance agreement with Yawata Iron and Steel of Japan, began in 1969 to use three blowing-channel lances in its converters. This has made for a more continuous blowing operation, higher productivity indexes, better-quality steel, etc. So far this method is being used exclusively by USIMINAS.

CSN is making full use of its eight open-hearth furnaces, two of which were constructed after the oxygen converter had been installed at Monlevade. With the object of raising the productivity of its installations, it is using all the oxygen it has available injecting 30,000 cubic feet per hour alternately in two of its Siemens-Martin furnaces. The fact that it has not installed an oxygen plant for its other furnaces is due mainly to problems which would arise in the handling of materials and the product obtained if all the Siemens-Martin furnaces were to increase their productivity beyond the present level through a wider use of oxygen. Furture expansion plans for this plant are based on the use of oxygen converters.

In some of the more industrialized countries - the United States, for example - the use of the electric steel shop has grown almost at the same pace as that of the oxygen converter, for different reasons, the most important being greater flexibility for melting scrap. Since there has not been an abundance of this material in Brazil, this situation does not apply. Although the output of steel produced in electric furnaces rose in absolute figures from 575,000 to 892,000 tons between 1962 and 1968, its share declined from 21.6 to 20.2 per cent. The expansion took place mainly in non-integrated plants, which are generally located in industrial centres where most of the scrap is produced. Another advantage is the greater flexibility of the electric furnace in the production of special steels, which is much more important for small and medium-scale semi-integrated plants than for the large integrated plants which essentially produce common steels.

It will be noted from the production structure of the semi-integrated industries listed in table 2 that there are still several steel plants operating with small or medium-sized Siemens-Martin furnaces, which are undoubtedly less efficient than the electric furnace. There may be different reasons for this technological backwardness: on the one hand, there may not be a cheap and sure supply of electric power available and, on the other hand, the company's financial position may not allow it to embark on substantial investment and modifications.

5. Technology in continuous casting

Pouring in Brazil is almost all done by the conventional process involving the production of ingots and subsequent blooming. Only two semi-integrated plants have introduced the latest techniques in this part of the steelmaking cycle: (a) in 1961 Siderúrgica Riograndense installed continuous casting equipment based on a machine constructed in Austria, and in 1968 it brought into operation a second machine, which was copied in Brazil from the imported model. It is interesting to note that the company keeps its old blooming mill in operation and only uses continuous casting for steels which fetch higher prices than the common steel bars for construction; (b) Aços Villares installed equipment in 1969 for vacuum casting; this treatment is reserved for only certain steels of the wide range of types produced by the plant.

It seems unlikely that the existing blooming mills will be replaced by continuous casting equipment, basically for financial reasons. For this system to be more widely used it would be necessary to wait until the blooming mills become obsolete and have to be replaced in order to meet the growing domestic demand. According to present estimates, with the possible exception

/of some

of some small-scale industries, this does not appear to be the case in the near future. On the other hand, if a project for the construction of a large plant to produce non-flat products, were to materialize, it is quite likely that it would contemplate the use of continuous casting machines.

The main object of vacuum casting is to extract the tiny quantities of hydrogen and nitrogen which the steel may contain, with a view to improving the quality of the products, which is important in the manufacture of some types of fine steels. It is quite possible that some of the medium-sized plants producing this type of steel will follow the example of Aços Villares in the not too distant future. In the production of common steels in continuous casting machines vacuum pouring is justified only for the manufacture of flat products, since it permits the pouring of rimming steel, which produces the best surfaces on sheets. Once the maximum installed blooming capacity at Volta Redonda is fully utilized, any expansion of the plant would probably result in the installation of continuous casting machines for slabs, with prior vacuum casting of the molten steel.

6. Rolling techniques

The progress made in rolling techniques has been mainly in three directions: (a) stepping up the roll rotation speed in order to increase the mill capacity; (b) changing the process into an operation as continuous as possible to prevent counter movement of the goods in process; (c) partial automation of the work in order to control the roll rotation speed and pressure, with a view to obtaining a bigger output and ensuring the quality of the product, particularly its thickness and other dimensions.

There is no information to date that any Brazilian industry has increased the rotation speed of its rolling mills. On the other hand, Belgo-Mineira installed an almost completely continuous Morgan Mill for the production of wire in 1968. It is impossible for any Brazilian industry to replace its present rolling equipment by a more continuous mill, but very probably the mills acquired for the production of large quantities of products of sizes varying between narrow limits, and also those required for new projects, will follow that trend. Lastly, as regards electronic control of the cylinders, Volta Redonda has established a system for controlling the rolling pressure in its blooming mill for fuller utilization of its capacity, and USIMINAS has been using some automatic controls in its flat products rolling mills since 1966. There is no information of any other plants that may have projects in this particular field.

7. Quality control

In view of the steel consumers' increasing requirements, all the plants visited are introducing a greater measure of operational control during the different stages of production in order to improve and standardize the quality of their products. The composition of the raw materials for finished and semi-finished products is controlled. In this respect, the enterprises are not only suitably equipping their control laboratories, but they are also training their personnel, especially in other countries, to take care of this vital department.

8. Technology for the production of special steels

The growth and diversification of Brazil's metal-transforming industry in the past twenty years have given rise to a steadily increasing demand for the whole range of alloy steels and types of non-common steels existing in the manufacturing inventory of the industrialized countries. Brazil's steel industry has made a large effort to supply the many different types of steels required by the market, within the strictest quality standards.

Thus the large integrated plants are covering the country's demand for common structural steels, weldable structural steel, high-pressure steels, weldable high - corrosion - resistant steels, silicon steel plate, different alloy wire for the manufacture of cables, etc.

ACESITA, the special steels plant, and a large number of semi-integrated plants are manufacturing different types of tool steel, stainless steels for mechanical construction, steels with special surface, high-grade cast steel parts, steels for bearings, etc.

/The usual

The usual practice in starting a plant for the regular manufacture of these types of steel is to have recourse to foreign technical assistance, in the majority of cases from accredited manufacturers in this field and often against the payment of a royalty in the form of a percentage of the invoiced sales value of the type of steel concerned. In some cases, the technology required for these manufactures was developed locally, but, after reaching a certain stage by this means, a number of industries requested technical assistance from abroad, partly because the yields were unsatisfactory and partly because of the lack of uniformity in the quality of the steels.

9. Technological research for immediate application in the steel industry

Because of the difficulty of defining the activities generally classified as experimental research and development, manufacturers tend to adopt a negative attitude when questioned regarding the technological research in which their plants are engaged. They often think that their questioners are referring to some kind of pure research or a type with a limited application in the industry, and this is obviously not the case. On the other hand, research is being carried out for immediate application in many plants, generally by the personnel responsible for quality control, but in some cases by independent sections, separated from those exercising routine controls.

Several plants, convinced that foreign assistance is insufficient to transfer all the know-how required for their operation, particularly if there occur changes in the raw materials or in other operational factors, are reinforcing the sections capable of carrying out this research and adaptation, with a view to what some have called the creation of a national technology.

For example, in 1967 USIMINAS established its own research centre in which nearly thirty engineers are now working. CSN has a well-equipped laboratory for the same purpose, but staffing problems are preventing it from operating efficiently. ACESITA is working intensively, particularly in connexion with the fuller utilization of charcoal and resulting fines. Lastly, COSIPA signed an agreement on technological research and advisory assistance in this field with the Technological Research Institute of São Paulo, under the terms of which IPT carries out some work in its own laboratories, and performs other activities on an industrial scale in the COSIPA plant.

/Chapter IV

Chapter IV

CLASSIFICATION OF TYPES OF KNOW-HOW AND WAYS OF TRANSFERRING IT

1. Introduction

The construction of steel plants in developing countries entails the investment of an appreciable proportion of the scarce capital resources available and, if they are to attain the highest possible levels of technology and efficiency, considerable technical and financial assistance is required from abroad.

Moreover, the construction of a plant, concurrently with the development of infrastructure (mines, ore-beneficiating plant, railways, bridges, etc.), takes a long time. During this period, the market for steel products, which is generally in process of development, may fluctuate widely. Therefore, the industry should be planned on a long-term basis. Because of the complexity of the steel industry and its relationship with the sources of raw materials and services on the one hand, and the markets for products and by-products on the other, it is strongly advisable to incorporate these activities in a long-range "steelmaking plan".

Such planning is particularly important in large densely-populated countries such as Brazil, where consumer centres are far apart and there are plentiful sources of the main raw material - iron ore - while metallurgical coal is concentrated in one area. There was obviously no over-all planning when Brazil's steel industry was originally established; projects were studied individually under the auspices of different promoters, about which more will be said later. In any case, no very realistic results would have been obtained through over-all planning of the steel industry in the early 1940s, first, because of the impossibility at that time of foreseeing how the market for steel products would develop and, secondly, because of the technological innovations which have been introduced since, and are definitely oriented towards large-scale steel plants.

/The National

The National Steelmaking Plan, which was originally based on a study prepared by a United States firm of consultants, was approved in 1967. Since then it has been frequently modified in line with the structural changes that have taken place in Brazil and the availability of investment resources. Owing mainly to the lack of financial resources and of final broad policy-making decisions, priority was given to other economic sectors, but at the beginning of 1970 some government measures were adopted with the firm purpose of making good the three years' delay in the implementation of the plan.

The financial difficulties affecting the steel industry derive not from the lack of external financing, but from the shortage of domestic resources owing mainly to the deterioration in the price/cost relationship over the period 1966-1969, because of the persistently high tax and financial burden and the strict price control exercised by the Government.

Recently, by resolution No. 19 of the Inter-Ministerial Price Council (Conselho Interministerial de Preços - CIP), the government price control organ, an additional price adjustment was granted with a view to providing the steel sector with reinvestment resources. Legislative/Decree No. 569 of 7 May 1969, which is currently in force, provides the steel industry with the necessary conditions for financing its expansion without having to depend on authorized price adjustments. Under this Legislative Decree, imports of raw materials and other inputs, and equipment and parts which are essential for the operation, modernization and/or expansion of plants producing rolled steel products are exempt from customs duties for a period of thirty months.

The difficulty of obtaining supplementary resources still persists, first because of delays in the payment of direct government contributions, which, when they are received, fall short of the required amounts, and, secondly, because the private capital market in Brazil still lacks the necessary potential to finance the domestic investment in large and medium-sized steel plants, in those cases where external financing is available for the purchase of equipment which is not produced locally.[1/]

1/ Even in these cases, such financing must be guaranteed by the Government.

/In these

In these circumstances, the steel industry inevitably requires financial aid from the Government, which is generally granted through the Banco do Brasil and the Central Bank, or through the Banco Nacional do Desenvolvimento Economico (BNDE) and other bodies, such as the governments of Minas Gerais and São Paulo. In 1970, Mr. Marcos Vinicius Pratini, Minister of Industry and Trade, established the goals for the steel industry in the next four years and guaranteed the necessary resources to attain them.

These resources amount to 1,618.3 million dollars up to 1974, of which 933.5 million dollars are intended for the expansion plans of the three large State-owned steel plants, and 684.8 million dollars are for the rest of the plants including those operating with private capital. Of the total amount, 575.3 million dollars will be in foreign currency.

The resources in national currency would be provided by BNDE, which has a controlling share in three State-owned steel enterprises and has already advanced 90 and 98 million cruzeiros, respectively, to COSIPA and USIMINAS.

2. Brief description of the existing steel industry

There are six plants originally planned and operating as integrated units [2/] in Brazil, and seven integrated plants which resulted from the integration of plants originally planned as semi-integrated units which used scrap iron, or as non-integrated units which produced pig iron in charcoal blast furnaces.[3/] One of these plants - the Companhia Metalúrgica Barbará - does not produce steel, but uses its pig iron for the manufacture of cast iron tubes. With the exception of COSIPA and CSN, the integrated

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2/ Companhia Siderúrgica Nacional (CSN), Usinas Siderúrgicas de Minas Gerais (USIMINAS), Companhia Siderúrgica Paulista (COSIPA), Companhia Siderúrgica Belgo-Mineira, Companhia Siderúrgica Mannesmann and Companhia Aços Especiais Itabira (ACESITA).

3/ Companhia Brasileira de Usinas Metalúrgicas (CBUM), Companhia Ferro Brasileiro S.A., Companhia Metalúrgica Barbará, Companhia Siderúrgica Pains, Laminação de Ferro S.A. (LAFERSA), Siderúrgica Barra Mansa S.A. and Siderúrgica J.L. Aliperti S.A.

/plants in

plants in the first group were planned according to the location of their sources of raw materials. The Volta Redonda plant was established somewhere between the sources of raw material and the consumer markets; COSIPA, although it started as an integrated plant, developed in the same way as the plants which were originally semi-integrated units, i.e., its location was chosen near the market for finished products.[4/] Lastly, the blast furnaces which use charcoal for the production of pig iron, and the plants which started on those lines and later became integrated were obviously influenced by the facilities for acquiring the scarcest raw material, i.e. fuel.

The studies required to plan an integrated steel plant from the beginning are very complex and entail the services of dozens of highly-qualified experts, particularly in the technological and economic fields. Therefore, the six integrated plants in group I were planned with external technical assistance, while such aid was only used in the case of certain semi-integrated industries, and practically never in the non-integrated units. Probably only those semi-integrated plants which manufacture special products or use more advanced techniques had to request external technical assistance in their installation and starting up, including, if necessary, the know-how for the manufacture of special products.

To take only the most complex case, that is, the plants originally planned as integrated units, the general practice for projects which developed as a result of local initiative has been to use external technical assistance in carrying out the preliminary study. If the results and conclusions of the study were favourable, they were widely disseminated in an effort to obtain the necessary resources and support to finance the studies that would serve as the basis for preliminary planning. These studies were almost invariably entrusted to some foreign firm of consultants of international repute. Of course, in the case of plants financed directly with external resources, these studies were directed by the head office abroad.

4/ The semi-integrated plants using scrap iron were generally located in steel-consuming centres, which are a main source of this raw material.

/Brazil's steel

Brazil's steel industry has been financed by groups of different origin and composition, as may be noted from the following description:

(a) Foreign investment

The most typical unit in this group is the Companhia Siderúrgica Mannesmann, which started operating in 1956 and produced 313,000 tons of ingots in 1969. The original project was to produce seamless tubes by the Mannesmann process, and the manufacture of some types of special steels has recently been added. The Mannesmann office in Germany devised the project and was responsible for the whole of its execution.

The Companhia Siderúrgica Belgo-Mineira is the largest enterprise constructed with foreign capital; its plant at Monlevade began operating in 1938 and produced 585,000 tons of ingots in 1969.

This project was not financed exclusively with foreign capital, however, since it started with the purchase of a small integrated plant at Sabará, which had been constructed by a group of entrepreneurs in Minas Gerais. The company used foreign capital partly to develop the Sabará plant, which had been dismantled just a few years ago, and to plan the Monlevade plant, using its own technical resources. The Companhia Siderúrgica Belgo-Mineira was also established as a Brazilian limited company, in which today the head office (ARBED) has only a 3 per cent share.

(b) Government investment

In this group, the Companhia Siderúrgica Nacional started operating in 1946 and produced 1,392,000 tons of ingots in 1969.

The Volta Redonda plant is the result of action by the Federal Government. In 1939, it organized a committee of prominent Brazilian nationals and specialists which within a comparatively short period, secured the collaboration of individual high-level technical experts contributed by the United States Government and set up a joint group to carry out the preliminary studies. Once enough information had been gathered to ensure that the project could be financed, the services of the firm of consultants Arthur G. McKee were contracted to provide advisory assistance to the Brazilian group - in so far as was possible considering that the United States was at war - in the general planning of the over-all study, the feasibility study, the general and detailed projects, and the plant's construction and starting operation.

/Another plant

Another plant which was the result of government initiative is the Usina Siderúrgica de Minas Gerais S.A. (USIMINAS). The Government of the State of Minas Gerais, where the largest Brazilian iron ore deposits are located, not wishing to continue merely as an exporter of raw materials, assembled a group of private entrepreneurs, including some of the most important metallurgists in the state, with the same idea, to co-operate in the preparation of the preliminary studies. This group of entrepreneurs persuaded a consortium of steel industries and equipment manufacturers in Japan to participate in the project and furnish all the technical advisory assistance that might be required. Thus, the plant was constructed and started operating in 1963, and in 1969 it produced 791,000 tons of ingot steel. The Japanese firm contributed 40 per cent of the original financing and it still retains 18.82 per cent of the capital.

(c) Private enterprise

The oldest integrated plant, which owes its existence exclusively to the initiative of a group of private Brazilian entrepreneurs, is the Companhia de Aços Especiais Itabira (ACESITA). This plant began operating in 1951 and produced 154,000 tons of steel in 1969.

As its name indicates, it manufactures special steels, especially silicon steel sheets. It receives advisory assistance from certain foreign firms in the manufacture of some of its products. The promoters of this project obtained technical advisory assistance from the United States firm H.B. Brassert & Co. in the preparation of the preliminary project, but used the services of several other firms in the planning and execution of successive expansion programmes.

The largest plant, for which the idea and original project stemmed from a private group is the Companhia Siderúrgica Paulista (COSIPA) sponsored by São Paulo metallurgists in 1951-1953. This plant began operating in 1965 and produced 551,000 tons of ingot steel in 1969. The original group obtained the support of the Government of the State of São Paulo, and was able to contract the technical services of the United States firms Koppers and Kaiser for the preparation of the study and original project. It adopted the Kaiser layout and used the engineering services of the COBRAPI projects office of the Companhia Siderúrgica Nacional.

/3. Planning, feasibility

3. Planning, feasibility study, construction and entry into operation of a new steel plant 5/

For this type of action, highly-qualified specialists in different fields are required to carry out separate studies and projects with a common goal in view, i.e., to ensure the production of steel of adequate quality at the lowest possible cost. There would be no difficulty in contracting these specialists individually, but, in the interests of uniformity of objectives and team work, the industry uses the services of firms of consultants which have proven experience in this type of work and have teams of high-level specialists in the requisite fields.

The enterprise in process of formation should not merely contract a foreign firm of consultants to execute the project; it should include its own personnel in this stage of establishing the industry, otherwise it loses the chance of retaining part of the firm of consultants' know-how, since once the study is completed the international specialists return to their own countries to take up other work. Experience shows that it is vital for the personnel responsible for the industry's operation to know the reasons for selecting each technique, process or particular equipment from among the various alternative possibilities. Furthermore, it is impossible to expect a firm of foreign consultants to possess or to acquire, during the brief period of the contract, a good knowledge of local conditions, such as the available raw materials, supporting industrial infrastructure, administrative problems and economic and social conditions. It is therefore imperative that the new industry should set up its own technical department as soon as possible to perform its activities during the plant's regular operation. Its main function during the preparation and construction of the project should be to furnish the consultants with information and advice concerning local conditions. This technical department should participate in all phases of the project which are executed with foreign

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5/ See annex I for details of the distribution of responsibilities in the provision of external technical assistance between the local enterprise and foreign consultants, and of the risks deriving from the division of responsibilities.

advisory assistance: planning, construction, start of operations, personnel training and, later, other types of foreign technical assistance which the enterprise may obtain during its regular operation.

The technical department should, as far as possible, be made up of Brazilian professionals who have graduated from engineering and technical schools in Brazil or other countries, preferably with some experience in the areas of specialization covered by the project. If necessary, this group of local specialists could be supplemented by some foreign experts who would remain in the company's service after it starts operating and when a good proportion of their technical knowledge has been transferred to the local staff.

It is possible that the plants which were established in Brazil with foreign capital did not use firms of consultants but distributed the work among the specialists in the technical departments of the head office. If that is so, their line of action could not have been very different from that summarized below:

a) Planning, over-all studies and feasibility study

These activities should include a study of the market for steel products and its trends, since the plant will not enter into operation for at least four or five years, and in some cases seven to ten years. It is always advisable to evaluate the probable short-term market trends.

In the light of the market study, every possibility should be considered of expanding the production programme or of reducing the number of types of products, with a view to obtaining, in the first case, the advantages of economies of scale and, in the second a greater degree of specialization.

Concurrently with the market study, all the existing sources of raw materials should be investigated; this would entail, if necessary, geological and mining studies, and analyses of available resources and methods for their beneficiation. The main raw materials are:

(a) Iron ore;
(b) Fuel: charcoal (or coal) or electric energy;
(c) Fluxes: Limestone, dolomite, and others;
(d) Cooling water.

/Once these

Once these points have been determined, it is necessary to decide on best location for the plant, i.e., which of the possible locations offer the best over-all advantages from the combined standpoint of the cost of assembling the raw material and transporting the product to the consumer centres, and the type of economic and social infrastructure found in each. At the same time, some feasible production processes should be selected, since they may be affected by the choice of raw materials (iron ore, reducing agent and fuel), which, in their turn, may be closely linked with specific locations.

It is quite probable that, at this stage of the work, it will be necessary to prepare several projects on the basis of different processes, each for a specific location, before arriving at the basic estimates for the final choice of the plant's location. Once some conclusive results concerning these points are known, an over-all study should be prepared on very general lines, to serve as a basis for an economic feasibility study which would indicate the quantity and type of products that could be produced and the expected investment and operational costs.

b) Preparation of the general project. The over-all study should serve as a basis for planning the initial financing of the project. Once the financing is assured, the firm of consultants should prepare the general project. In addition to determining the questions which were not finally established in the over-all study, particularly in connexion with the raw materials and their beneficiation, the general project should cover the following points:

(a) Selection and detailed description of the processes to be used, choice of equipment and preparation of a flow chart for raw materials and finished and semi-finished products during the plant's operation;

(b) Location and size of the buildings and offices on the ground selected, layout of the equipment and division of work in the departments;

(c) Direct and indirect manpower requirements for the efficient operation of the plant, with a description of the duties of each staff member, a definition of the requisite level of professional experience and qualifications, with emphasis on the requirements of the posts which the consultant considers are vital for the plant's successful operation;

(d) Final estimate of the plant's investment and operational costs;

(e) Final appraisal of the project;

(f) Plan for executing the project.

c) Execution of the project

Once the general project and plan of execution have been approved, the next step is to establish the plant, test the equipment, start the plant and initiate operations and keep the plant running smoothly.

This phase of the project calls for considerable executive action at the local level, so the enterprise usually plays an important part in directing its execution.

Technical assistance from abroad continues to be of fundamental importance in this phase. It can be co-ordinated by a single enterprise which either assumes full responsibility or simply acts as adviser to several firms operating as a group or supplementing one another. There are various methods which can be used in these cases. The following are the most important:

(1) The firm which prepared the general project and plan of execution assumes the general management, establishing clearly which are the executive functions reserved for the enterprise;

(2) The firm which prepared the general project and plan of execution is replaced by another which assumes all the co-ordinating functions, along the same lines as in paragraph (i);

(3) The enterprise assumes the entire management, with technical advisory assistance which may be furnished by the firm which prepared the original studies and projects or another firm of consultants;

(4) The enterprise assumes the entire management and divides the work to be executed among construction firms, equipment suppliers and other firms which are contracted for the purpose.

/Obviously, whatever

Obviously, whatever the form used, the enterprise can, whenever advisable, request additional technical assistance in the solution of specific problems, in order to settle doubts or differences of opinion.

The following main tasks should be carried out between the start of the construction work and the time when the plant is in regular operation:

i.) Review and approval of the design of the equipment;

ii) Preparation of specifications and evaluation of the suppliers' bids;

iii) Purchase services, inspection at manufacturers premises and transport;

iv) Preparation of detailed designs and plans for the construction of the plant;

v) Preparation of designs showing the system of distribution of power, piping, transport and other general services, and analyses of the flows within these systems;

vi) Preparation of periodical progress reports on the over-all project;

vii) Appraisal and approval of the work;

viii) Control of the cost of the project;

ix) Equipment trials and start of operations.

d) Personnel training. Clearly, the problems of personnel training are more serious in the period of establishing the first steel plants in a country, since in the installation of other plants advantage can be taken of the services of personnel which already have some experience in this field. This section deals mainly with the first case, since in the second it is generally possible to eliminate or reduce the number of measures to be adopted.

The training of manpower to operate the finished plant is one of the most important items to be provided for in the general project and plan of execution. If there is no skilled local labour available, it is imperative to recruit enough experienced personnel from other countries to solve the many problems involved in the management and advisory activities. It is also necessary to lose no time in selecting local personnel for training abroad.

Such training should be so scheduled that the workers are not absent during the stage of assembling the machines, equipment and facilities they will have to operate. It is useful for the enterprise to have external technical assistance in selecting personnel for training abroad and in supervising their progress.

At the beginning of this chapter it was suggested that a technical section or department should be set up in the initial phase of preparation of the final project so as to provide the management of the enterprise with advisory assistance in its discussions with the firm of consultants which is preparing the study. Once the construction is completed and the plant is in operation, it is of paramount importance that the enterprise should improve the technical capacity of this group of specialists, which must thereafter provide advisory services with a view to accelerating the plant's absorption of know-how. In this connexion, a small number of specialists should be carefully selected to ensure that, acting as a group, they will be able to keep well abreast of the operation and performance of all the factors involved in the industrial process. This personnel must absorb the modern concept of technology as quickly as possible and learn to adopt a co-ordinated procedure in the analysis of production factors and the provision of advisory assistance to the management of the enterprise in decision-making and the adoption of measures of all kinds.

There seems no reason why the manpower itself should not be trained by national specialists and, in fact, this appears to be psychologically the best solution.

4. Technical assistance in expansion and modernization programmes

The many activities under this head range in importance from substantial modifications involving large investments and covering all or several of the production departments to the installation of a single additional machine. In this case, fewer studies are required than in planning a new plant, and the alternative possibilities to be examined are strictly determined by the existing circumstances. In Latin America, owing to the small size of the market, the invariable practice is to construct plants by stages, establishing from the start the expansions to be effected

/later as

later as they become necessary. Even when this information is at hand, it is useful to carry out a detailed study of new investments, taking into account any changes that may have taken place in the market for steel products and the progress made in steelmaking techniques.

Whether or not foreign technical assistance is required depends on the importance and complexity of the project. In many cases, it may not be necessary to contract the services of a firm of consultants or even those of individual specialists. The projects can be executed by the technical department of the plant, which, in certain cases, can rely on the close co-operation of the suppliers once it has been decided which machines and equipment are to be purchased. If a company wishes to secure the services of a foreign firm, which is usually the case when external financing is required, this firm is expected to perform the same activities which have already been described in connexion with planning a new plant, so there is no need to list them again here.

5. Technical assistance in the introduction of technical innovations involving little or no investment

This type of technical assistance includes that required in the introduction of technical innovations consisting basically in the method of operating the equipment, which in some cases involves no investment at all and in others only a small one, such as that required to raise the blast temperature.

Most of the innovations of this kind can be adopted without any external technical assistance, since the work can be done by the plant's technical department. In some cases, however, it may be necessary to purchase patent rights, or to enlist the aid of a specialist in order to facilitate the requisite research.

Many enterprises which receive continuing technical advisory assistance from abroad, generally from the same firm which prepared the over-all plan of the plant, can solve their problems with this assistance. Others request the services of an independent specialist in addition to the collaboration of the equipment manufacturer.

6. Technical assistance in improving the plant's management and productivity

Generally speaking, the present management of Brazilian steel industries is far below the level found in steel companies in developed countries. Although there are a few enterprises which are fairly efficiently run by present international administrative standards, it is essential to establish such an organizational set-up as will keep abreast of the changes in production and administrative methods and institute proper control systems in order to attain the highest possible levels of efficiency for both manpower and equipment.

In view of the complex nature of such a study, it is advisable to contract the services of a specialized firm to undertake a thorough overhaul of the methods in use, and it is necessary to establish the best operational structure which will enable the enterprise progressively to assume more dynamic responsibilities within the industrial development process.

7. Technical assistance in the manufacture of new products

The development of the steel market and of steelmaking technology often encourages enterprises to include in their programmes the manufacture of new products which differ from the previous products in chemical composition, size, shape or the final treatment used, i.e., technical, mechanical, surface finish, plating, etc. Some of these products may be produced under a patent, in which case, besides purchasing the manufacturing rights, it is advisable to purchase the complete know-how. For those products whose manufacture involves changes in the production processes in use, it would be advisable to obtain technical assistance from abroad, say from some foreign firm which is manufacturing the product in its own plant, preferably to the kind of assistance which can be provided by a firm of consultants.

/8. Technical assistance

8. Technical assistance in improving quality control

Quality standards for steel products have become increasingly strict over the past twenty years. In countries like Brazil, where there are many steel companies, competition for the domestic market intensifies these requirements, and enterprises are redoubling their efforts to persuade the consumer to buy their products.

With a view to manufacturing a product which will meet the strict specifications laid down and retain its quality, it is indispensable to exercise an inflexible control over: (a) the chemical composition of all the raw material; (b) the operation of the equipment throughout the process. This requires a thorough inspection by a group of specialists and their assistants, after its functions have been defined, i.e. the type of inspection which should be effected, the frequency of the analyses and the degree of tolerance of undesirable materials or manufacturing defects which are acceptable.

With the object of establishing a quality control system or of improving that existing in the plant, two main types of procedures may be used for the transfer of the technical know-how that is required, preferably from an efficient industry which manufactures similar products:

(a) A group of specialists should be retained to study the procedure to be used and train the plant's personnel;

(b) A group of local specialists in complementary fields should be sent abroad to acquire knowledge for subsequent application in the plant.

It is also possible to combine these two methods.

The second method has the advantage that the personnel is better trained to deal with such problems as changes in the quality of raw materials or in the specifications laid down by the buyers.

/Chapter V

Chapter V

MEANS OF TRANSFERRING TECHNOLOGY AND THEIR RELATIVE EFFICIENCY

The previous chapter contained a description of the wide range of specialized knowledge which is required for the successful completion of activities from the stage of planning the plant to the start of operations. Foreign technical assistance is vital during this period and the future success of the enterprise largely depends on its quality and efficiency. Once the plant is operating normally, in the majority of cases it must continue to have technical assistance from abroad, but in a much smaller volume and measure of responsibility than in the initial phase. Each of the various stages of establishment and growth of a steel industry is described separately below:

1. External technical assistance in the establishment of new plants

Of the plants established before a start was made on planning Volta Redonda, probably the Belgo-Mineira plant brought the greatest technological contribution to Brazil. This company was set up in 1921 to expand and operate the steel plant at Sabará, which had been constructed by a group of metallurgists of Minas Gerais. Since the ground at Monlevade, purchased ten years before, was linked to the consumer markets and iron ore deposits by rail in 1934-1935, Belgo-Mineira decided to construct this plant, which began operating in 1937-1938. The whole process from the initial planning to the start of operations was conducted by ARBED, at that time the major shareholder in the company and the most experienced, but there is no information regarding the manner in which the head office in Luxembourg organized the work. Mention should be made, however, of the first appearance in Brazil, at that time, of the two following factors which were adopted by nearly all the plants established in the country:

(a) The construction of a model town equipped with all kinds of services and amenities for the accommodation of the plant personnel;

/(b) Initial

(b) Initial planning of the industry with provision for several expansion programmes, to be developed by stages once certain requirements had been fulfilled, particularly in connexion with the consumer market.

While the Monlevade project was established by a private foreign enterprise, the Volta Redonda plant was a Federal Government project. At the beginning of the 1930s, President Getúlio Vargas endeavoured to diversify Brazil's production and ascribed an important role in this task to industrial development. The construction of a steel plant capable of supplying the steel requirements of the existing manufacturing industries and railways was considered one of the basic features of this programme. Between the years 1930 and 1937, several groups of government officials and metallurgists were appointed to study the project and present their reports. In 1938 a more economic approach was adopted to the study and an official committee, headed by the well-known metallurgist Major Edmundo Macedo Sõares e Silva, was appointed.1/

At the beginning of 1939, the Brazilian Government obtained a promise of technical and financial assistance from the Government of the United States in the implementation of an industrial development programme in which the construction of a steel plant would be the most important individual project. The United States Government assigned high priority (A-6) to this project within the scheme for the distribution of resources drawn up by United States government officials, and in June 1939 it sent the Greenwood Technical Assistance Committee 2/ to Brazil. This Committee was integrated with the Brazilian Government Committee to form the Joint Committee.

1/ Most of the information on the period of organization of the Volta Redonda plant which appears in this study was taken from the thesis entitled "Brazil's Volta Redonda steel centre: Quarter century of progress, 1941-1966", prepared by Dr. Rady for his doctorate at the University of California, Berkeley. The authors are grateful to Dr. Rady for providing them with a copy of his thesis.

2/ This Committee consisted of a geologist, a railway engineer, an economist and a metallurgist.

/Since the

Since the Government had decided that the new steel industry would use the coke blast furnace process and as much Brazilian coal as possible, the Joint Committee focused its attention on a study of the steel market, raw materials and possible locations for the plant in the States of Minas Gerais, Espírito Santo, Rio de Janeiro and Santa Catarina. After several months of field work, the Joint Committee proposed the construction of a steel plant which would be managed by a Brazilian body set up exclusively for the purpose. On the basis of several experiments, the Committee suggested that the plant should use coke resulting from a blend of domestic and imported coal. It chose Santa Cruz as the best location for the plant because of its proximity to the port of Rio de Janeiro and the Brazilian Central Railway. The Plant's capital amounted to 40 million dollars, made up of 20 million dollars in shares and 20 million in bond issues. United States Steel Corporation had undertaken to subscribe shares to a value of 5 million dollars, but shortly after the project was prepared it withdrew its offer, partly because of the intensification of the war in Europe, and partly because of the Brazilian Government's objection to that company's large share in the management of the new plant, which was contrary to the intention of keeping it under Brazilian control.

As a result of the withdrawal of United States Steel, the Government announced that it was prepared to consider any reasonable tender from any country for the construction of a major steel plant. For this purpose it set up, in March 1940, an Executive Committee for the National Steel Plan, with the following functions: (i) to receive and evaluate all the tenders presented for the establishment of a steel industry in Brazil; (ii) to carry out the technical studies for the construction of a plant to produce rails, profiles and flat products; (iii) to organize a national company, with the participation of the State and private capital, to construct and operate a steel centre. It was stipulated in additional instructions, inter alia, that the plant should use as much domestic coal as possible.

The abandonment of the Santa Cruz project and the Government's announcement resulted in the presentation of a large number of tenders for the construction of the steel centre. They were received from Germany, Italy, Japan and the United Kingdom, but a drawback common to them all was inadequate financing. Krupp, one of the three German firms, presented

/two projects

two projects: one using the conventional technology, and the other consisting of a number of small reduction plants which would be located in Minas Gerais close to the iron mines and natural forests, with a view to using the Krupp-Ren direct reduction process. The primary iron obtained from these plants in the form of "Luppen" would be melted, bloomed and rolled in a central plant.

Besides receiving and evaluating the tenders for the construction of steel plants, the Executive Committee obtained a loan, signed a contract with a firm of consultants, organized an enterprise, selected the location for the new steel centre and carried out technological research.

A 20 million dollar credit was negotiated with the United States Export-Import Bank at the end of September 1940, and was granted on 22 May 1941. This credit was guaranteed by the Banco do Brasil and the National Treasury. The cost of the plant was estimated at 45 million dollars, and the Government undertook to contribute the balance of 25 million dollars through the issue of bonds and shares, both ordinary and preferential.

It was no easy task to select the firm of consultants. The Executive Committee finally reduced the list of candidates to two: Herman A. Brassert and Arthur G. McKee. Although Brassert had more experience in the construction of complete plants abroad, the Committee did not sign a contract with that firm for fear that the United States, which was actively involved in the war, might create difficulties in future negotiations, owing to the firm's previous connexions with Hitler, for whom it had planned and constructed the Herman Goering Werke. Early in the 1930s, McKee had played an important part in planning and constructing the large Magnitogorsk steel centre in the USSR, and in the construction of some plants in the United States and the United Kingdom. Nevertheless, it had little experience in the over-all planning of an integrated plant, having concentrated its attention on blast furnaces and other reduction sections. Consequently, the Executive Committee had to assume more responsibility than is usually the case in contracts with firms of consultants for this type of work.

Shortly after successfully concluding the negotiations with EXIMBANK, Dr. Guilherme Guinle, President of the Executive Committee, returned to Brazil to help organize the Companhia Siderúrgica Nacional, which was

/established on

established on 9 April 1941 as a semi-public enterprise. Its headquarters were in Rio de Janeiro, and its main office in the United States was in Cleveland, with subsidiaries in New York, Washington and Pittsburgh. The offices in the United States signed contracts for the financing of equipment with the following United States manufacturers: Koppers Company, McNally Manufacturing Company, Freyn Engineering Company, Rust Engineering Company, Morgan Engineering Company, Bethlehem Steel Company and Mesta Machine Company. Besides its daily participation in the preparation of the project, the CSN office in Cleveland co-ordinated the training of Brazilian engineers and personnel in the following fields of specialization: coal beneficiation, coking, gas system, blast furnace, steel shop, rolling mill, plant maintenance, water supply and transport.

Eight possible locations were considered: Tres Rios, Juiz de Fora, João Ribeiro, Lafaiete, Santa Cruz, Vitória, Antonina and Volta Redonda. Each location was examined in the light of the following criteria: (i) cost of assembling raw materials and transporting the finished products to the consumer markets; (ii) proximity to secondary industries and consumer markets; (iii) capacity of the ground to stand the weight of the installations; (iv) the earth-moving required to convert it into an industrial site; (v) water supply for industrial and domestic use; (vi) proximity of a sui suitable source of manpower; and (vii) safety from naval bombardment. Since none of the locations presented ideal conditions, McKee sent a study group, headed by William Haven to CSN. This group spent several weeks gathering information on raw materials, supply and cost of construction material, transport facilities and costs, the existence of skilled and unskilled manpower, etc. This information was used by the Executive Committee in selecting the location of the plant, which by process of elimination, was to be Volta Redonda. It then proceeded to purchase the coffee plantation Santa Cecilia for the construction of the plant and its satellite town. This was an excellent choice for many reasons: the ground was situated between the sources of coal and iron ore, between the steel markets and the processing industries in Rio de Janeiro and São Paulo, and in a politically strategic position in the State of Rio de Janeiro, close to the States of São Paulo and Minas Gerais, each of which has for some time aspired to be the centre of Brazil's major steel industries.

/The technological

The technological research carried out by the Executive Committee was centred on studies of the raw materials to be used at Volta Redonda, the types of equipment and processes to be installed, and the number of types of final products to be manufactured. Fifty tons of coal, extracted from each of the principal coal mines in Brazil, were sent first to McNally-Rheolaveur Company at Pittsburgh for a study of its washing properties, and then to Koppers at Kearney and other laboratories for coking. The results showed that it was economically feasible to produce metallurgical coke using two-thirds Brazilian coal and one-third imported coal. The production programme originally established envisaged the manufacture of 295,000 tons of finished steel and 50,000 tons of pig iron annually. A little over one-third of the rolled steel should consist of rails, owing to the high priority which the Government had assigned to the reconstruction of the railways; approximately half the production should consist of flat products of all types, and the rest of medium and light profiles.

The Executive Committee established that the plant should be partially in operation two and a half years after a start was made on its construction, and it should be operating normally after three years. The United States' active involvement in the war made it impossible to comply with this programme, owing to difficulties in the manufacture, delivery and transport of the equipment requested from that country.

The Volta Redonda project as originally planned by the Executive Committee, known as Plan A, consisted of a blast furnace with a daily production capacity of 1,000 tons of pig iron, four 150-ton open-hearth furnaces, a coke battery with fifty-five retorts and by-products recovery, rails and medium profiles rolling mill, a sheet and flat product rolling mill, a tin plating line, and other auxiliary equipment. The designs were started in January 1941, under the auspices of the CSN office in Cleveland, and detailed lists were also prepared of the materials required, together with the specifications. More than 30,000 copies of plans, 168,000 tons of construction material and 7,000 tons of equipment and machinery were inspected by this office between 1941 and 1946. Apart from the technical assistance it provided, the Cleveland office deserves credit for the efficient way in which it co-ordinated all these operations of CSN in the United States.

/Since McKee

Since McKee was not in a position to provide all the services, and still less all the equipment required, the CSN office in Cleveland spent several months at the beginning of 1941 seeking and selecting United States firms with sufficient experience and skill in the manufacture of materials and heavy machinery. McKee and EXIMBANK co-operated with CSN in this task and, once the manufacturers had been selected, the contracts were signed in August 1941.

Lieutenant Colonel Edmundo Macedo Sõares, with the assistance of a group of Brazilian specialists and some United States consultants, personally directed the construction of the Volta Redonda plant and supervised the work being carried out simultaneously in Minas Gerais and Santa Catarina. The combined labour force consisted of 17,000 persons, 14,000 working at Volta Redonda and the rest evenly distributed between the various sources of raw material. From 1942 to 1946 McKee kept a permanent strength of twelve engineers at Volta Redonda, who were responsible for the construction of the blast furnace and the provision of assistance in dealing with other construction problems. The equipment manufacturers also assigned technical personnel to the plant to take care of their part of the project. In all, CSN contracted the services of fifty-five engineers and technicians in the United States to work at Volta Redonda during the construction of the plant. This number proved insufficient, but it was not possible to increase it because priority had to be given to the United States war effort. Consequently, this manpower shortage was made good by Brazilian specialists.

With the rise in prices of raw materials, services and manufactured products in both the United States and Brazil at the beginning of 1943, it became imperative to increase the EXIMBANK loans to 45 million dollars and the share capital of CSN to the equivalent of 50 million dollars.

The difficulty of obtaining regular supplies of equipment and of contracting additional technical personnel in the United States slightly delayed the plant's construction and start of operations. The industry began operating late in 1946 and was not running smoothly until 1948. The first expansion was effected over the years 1950-1954, doubling the previous capacity; the second in 1956-1960, to attain the production of 1 million tons of ingots; the third in 1965-1967, bringing production up to 1.5 million tons, and work has been proceeding on the fourth since 1969, consisting in the elimination of some bottlenecks and increasing the installed capacity to approximately 1.7 million tons of ingots. Volta Redonda once again concluded technical assistance contracts with McKee for the planning and execution of all these expansion programmes.3/ The former technical department of the Volta Redonda plant, which played a vital role during the construction of the first stage, gave valuable co-operation in the execution of these projects, but under better conditions as a semi-autonomous body and subsidiary of the plant: Cía. Brasileira de Projetos Industriais (COBRAPI).

When the first stage was being planned, CSN had to choose between the two following processes for use in the plant: open-hearth furnaces which were finally adopted, or the acid Bessemer steelmaking process. The investment in the steel shop would have been less than half if the latter process had been chosen, although, in spite of its feasibility, it had two disadvantages: (a) it required the extraction of low-phosphorus ore, leaving the extraction of high-phosphorus ore for a later stage; (b) it offered no means of making use in the plant of an estimated 100,000 tons annually of circulating scrap, which meant transporting it for sale to the semi-integrated steel plants in Rio de Janeiro and São Paulo at considerable loss to CSN. For this reason, in spite of the greater investment required, it was decided to construct four open-hearth furnaces, each with a capacity of 150 tons. In view of the fact the first

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3/ Recently, CSN signed a technical assistance contract with United States Steel Corporation to carry out a survey and evaluation of the types and characteristics of the equipment, processes and products from the technological stanpoint, followed by an appraisal of their use and technical and economic suitability compared with the practices in use in more up-to-date and efficient plants. The contract provides for an analysis of the principal technological options open to modern steel plants and an indication of the most significant trends in the development of steel manufacturing techniques, covering all the processes from the ore to the final steel products, taking into account the problems connected with reduction, steel manufacture, casting and rolling, in an examination of the technological possibilities and trends with respect to the type, characteristics and uses of the products manufactured by the plant.

/LD oxygen-blown

LD oxygen-blown furnace in the world entered into operation only in 1952-1953, in Austria, the Siemens-Martin process selected was the most up-to-date technique at the time when the first and second stages were being planned. It was different in the case of the expansion projects for the third and fourth phases, whose execution was initiated in 1956 and 1965, respectively. It is quite possible that this delay in accepting the new process was due, on the one hand, to a normal reluctance to accept the process as being capable of producing good-quality steel - as occurred in the large-scale application of the process in the United States - and, on the other hand, to reluctance on the part of Brazilian technicians to substitute a new process for one which had already produced good results and the fact that some items of the expansion of the Siemens-Martin steel shop, such as buildings, overhead and other cranes, etc., were already completed.

In the case of COSIPA there was a long delay, owing mainly to the financing difficulties encountered right from the start (1951-1953), when the project was devised by the metallurgists Plinio de Queiroz and Martinho Prado Uchoa, of São Paulo, who received advisory assistance first of all from Koppers Company, Pittsburgh. In 1959, as soon as the financial obstacles were overcome, the project was initiated and COSIPA contracted the services of the firm of consultants Kaiser Engineers, of California. Once the agreement was signed, a COSIPA commission went to California to co-operate with the firm of consultants in planning the layout of the plant prepare the over-all plan and draw up the list of equipment. Thus, everything points to the fact that Kaiser played little or no part in selecting the raw materials, types of products to be manufactured, and location of the plant, which had already been chosen.

Once the basic list of equipment had been completed by Kaiser, the commission, with the help of the consultants, selected the suppliers, and studied the technical specifications in the tenders and the terms of payment, which, in view of the financial position of the project, were of the greatest importance.

/Contracts were

Contracts were then concluded for the delivery of machines and equipment with, inter alia, the following firms: Gutehoffnungshütte (Germany), VOEST (Austria), Westinghouse Electric (United States), CECI, Schneider, Stein Roubet, Delattre Fois and Enterprise Générale (France) and Innocenti and ILVA (Italy).

Besides Kaiser, COSIPA obtained assistance from CSN in the construction of the plant and some technical details. Thus, CSN participated in planning the plant, with co-operation from McKee under a contract for the provision of general advisory assistance. However, the most important co-operation which COSIPA received from CSN was in the form of services provided by COBRAPI, which was responsible for all the engineering part of the construction. Throughout the construction (1961-1964), Kaiser maintained a strength of five engineers with permanent residence in São Paulo.

On the basis of Kaiser's general plans, COBRAPI prepared all the detail plans for the project, the layout of the equipment on the site and the civil construction plans, with the exception of the calculations of reinforced concrete, which were subcontracted to a Brazilian firm. COBRAPI was also responsible for preparing the specifications for all the construction materials, the tube systems, building calculations, electrical system, rolling bridges, transport, etc. It analysed approximately 6,000 designs received from both Kaiser and the equipment suppliers, and prepared 5,000 additional detail plans. During the period of construction of the COSIPA plant, COBRAPI maintained a strength of 60 to 70 engineers, technicians and planners working on this project.

In 1965, the COSIPA rolling mills were in operation, using semi-finished products obtained from Volta Redonda, and at the end of that year the blast furnace was started. In view of the fact that COSIPA was originally constructed as an unbalanced plant, as were Monlevade, Volta Redonda and USIMINAS, the company has steadily expanded, ever since its first units started operating normally. It has obtained technical assistance mainly from McKee for this purpose.

USIMINAS owes its origin to the establishment of an ad-hoc company which was organized in April 1956 by a group of entrepreneurs in the State of Minas Gerais, with an initial capital of about 50,000 dollars. This enterprise carried out preliminary studies to determine whether it would be feasible to construct a steel plant in Minas Gerais with an initial production of 500,000 tons annually. On the basis of the results of this study, the company obtained co-operation from the state and from some of the large Brazilian steel enterprises. In April 1957 the Horikoshi-Lanari agreement, which was the basis of the project, was signed after approximately six months of negotiations with several Japanese missions in Brazil. The agreement stipulated the construction of a plant in the State of Minas Gerais with an annual production capacity, in the first stage, of 500,000 tons of steel.

The agreement sets forth a general description of both the project and the proposed social and financial structure of the enterprise, and contains guiding principles governing the relations between the enterprise under study and the participants therein. The participation of Brazil and Japan, with 60 and 40 per cent of the capital respectively, was confined merely to financing and guaranteeing the project. The plant's location at Ipatinga, in the vicinity of ACESITA, was chosen by common consent by the Japanese group and the technicians of the original ad-hoc enterprise. The financing requirements, which were established immediately after the basic agreement was signed, were estimated at 250 million dollars, of which Japan provided 99 million dollars' worth of credit for equipment, in addition to 40 per cent of the capital, or 72 million dollars, i.e., its share altogether amounted to 127,800,000 dollars, or a little over half the total.

Japan provided nearly half the technical assistance and manufactured 80 per cent of all the equipment, while Brazil's technical services were limited to the task of adapting the Japanese procedures to the conditions prevailing in Brazil and to training activities. The installation of the plant was initiated in August 1959 and the blast furnace started operating in October 1962, the LD steel shop and blooming mill in June 1963, the plate rolling mill in July 1963, the hot-rolling mill in May 1965 and the

/cold-rolling mill

cold-rolling mill in October 1965. The plant was not operating normally until 1967, when it produced about 600,000 tons of ingots, or slightly more than the initial rated capacity. Most of the Japanese technical personnel which had collaborated in the initial operational phase returned to Japan at that stage, leaving the operational functions virtually in the hands of Brazilian technicians.

As soon as the rated capacity had been reached, the enterprise embarked on an expansion programme intended to increase the capacity to 1.4 million tons of ingot steel, which is the present goal of USIMINAS. This expansion is being effected partly through the installation of new equipment and partly by increasing the productivity of existing facilities.

In view of the large number of Japanese engineers and technicians who took part in the initial construction phase up to the start of the plant's operation, and the fact that many decisions were adopted in Japan, it is difficult to determine to what extent the members of the original Brazilian enterprise participated in the adoption of decisions during this period. Undoubtedly, they contributed their knowledge of local conditions to the study, and very successfully too, judging from the operational results obtained by the enterprise. Nevertheless, in view of the number of Japanese technicians who took part in the construction and installation, and the predominance of Japanese equipment in the plant, USIMINAS must be considered as a project which was technologically planned and executed by foreign enterprise for purposes of this study.

To complete the description of the planning and construction of integrated plants which were originally planned as integrated units,4/ there only remains to analyse the way in which external assistance was used in the ACESITA and Mannesmann plants. Unfortunately, the construction of ACESITA took so long and the plans underwent so many changes that any far-reaching research into the question must lie outside the scope of this study. In any case, it is only a small plant producing special steels,

4/ As distinct from plants which began operating with blast furnaces or as semi-integrated units by melting scrap, and were subsequently integrated.

/so that

so that this omission is not very important. Mannesmann represents a foreign investment project which was planned entirely by the head office in Germany, and there is no information available as to whether this firm used its own or other consultants. There is no doubt that in co-ordinating the planning and operation of this industry the existing local conditions were not properly considered. The high moisture content of the charcoal sold in Minas Gerais was not duly taken into account; this caused initial difficulties in the operation of the electric reduction furnaces which use this raw material.

Thus, the two plants for which there is most information available on the activities and operations prior to the start of operations are Volta Redonda and COSIPA. Fortunately, they are also the two plants which used the largest proportion of Brazilian technical assistance. Therefore, a comparison of the procedures adopted by each, and their efficiency, is of considerable interest to this study. Table 6 indicates the persons and units that exercised most influence in determining the technology to be used, adopted decisions and executed the principal phases from the time the original project was devised up to the plants' entry into operation.

Except for the different names and persons involved, the way in which the conceptual part of the work, from the original idea of the project to the preparation of a preliminary estimate and investment plan is very similar in the two enterprises. The difference lies in the fact that when COSIPA submitted the project to Kaiser Engineers it had advanced further in developing the plan and did not request advisory assistance in selecting the location, which had already been done by the group of entrepreneurs which promoted the project on the basis of studies carried out by a local firm of consultants. Since the selection of the iron ore depended on the plant's location, neither was this question raised with the United States consultants. On the other hand, as stated above, CSN studied eight possible locations and did not adopt the final decision until it had received a cost study and recommendation from McKee. The choice of Volta Redonda as the location for the CSN plant determined, to a great extent, the supply of iron ore.

/Table 6

Table 6

AGENCIES WHICH SUPPLIED THE TECHNICAL CO-OPERATION AND ADOPTED DECISIONS CONCERNING PLANNING CONSTRUCTION AND START OF OPERATIONS IN SOME BRAZILIAN STEEL PLANTS

Item	Volta Redonda (CSN)	COSIPA
Preliminary idea of the project	Federal Government	Paulista Group
Production programme	Federal Government and CSN	Paulista Group
Raw materials		
Iron ore	CSN and McKee a/	Paulista Group
Coking coal	Federal law	Federal law
Location	McKee and CSN	Paulista Group
Processes		
Reduction	Federal law	Federal law
Steel shop	McKee and CSN	Kaiser and Paulista Group
Rolling mill	McKee and CSN	Kaiser and Paulista Group
Auxiliary equipment	McKee and CSN	Kaiser and Paulista Group
Budget and investment plan	McKee and CSN	Kaiser and Paulista Group
Layout of the plant	McKee and CSN	Kaiser
Sizing of equipment	McKee and CSN	Kaiser
Purchasing contracts (equipment)	CSN and McKee	Paulista Group and Kaiser
Construction and detail plans	CSN and McKee	COBRAPI and Kaiser
Equipment erection	CSN and manufacturers' technicians	COBRAPI and manufacturers' technicians
Tests of equipment	CSN, manufacturers' technicians and McKee	COBRAPI, manufacturers' technicians, COSIPA and Kaiser
Start of operations	CSN, manufacturers' technicians and McKee	COBRAPI, manufacturers' technicians, COSIPA and Kaiser

a/ The selection of the iron ore depended on the location of the plant and the steel making process selected.

/In retrospect

In retrospect, it might be asked whether foreign technical assistance in the selection of the location for the COSIPA plant might not have avoided some of the problems encountered, e.g., the low resistance of the soil for some of the structures. This specific case brings into focus a point which may be very important for the success of a steel industry project. All too often, and this may quite well have happened in the case of COSIPA, the choice of location and possibly of manufacturing programme is influenced by political issues, over and above that dictated by technical and economic considerations. In these cases, the effect of adequate technical assistance from abroad, acting as a catalyst on local political pressures, can be of inestimable value.

As regards the layout of the plant, COSIPA's action in contracting the services of Kaiser Engineers seems to be the best procedure. As noted above, CSN could not adopt this procedure because McKee, the only firm of consultants available, was unable to provide all the services, owing to innumerable problems deriving from the war. The same observation is applicable to the sizing of equipment.

In the two cases under consideration, Brazil participated fairly intensively in the negotiation of contracts for the equipment. The selection of possible suppliers, with the help of the firm of consultants, is generally followed by the negotiation of terms of payment, and obviously the plant representatives who finally assume responsibility for debt servicing are in the best position to discuss them with the suppliers. It should be noted that, in this aspect of the establishment of the industry, Volta Redonda also obtained significant help from EXIMBANK, which was very interested in seeing CSN operate successfully.

The construction of Volta Redonda, including the town and the Lafaiete mines and coal mines, was basically the responsibility of a group of Brazilian technical experts headed by Lieutenant-Colonel Macedo Sõares, which had McKee's assistance in the adoption of vital decisions, and assigned a total of eleven engineers and technicians to undertake this task. After the construction phase had been completed, part of the Brazilian technical team assumed operational functions and the rest then formed COBRAPI, which assumed the same functions in COSIPA, aided by five

/Kaiser engineers

Kaiser engineers and technicians. In both these cases, the Brazilians did highly important work, since, partly because of the war and partly for financial reasons, the contracts with the consultants did not provide for the preparation of a large proportion of the detail plans, layout of services, etc.

As is customary in these cases, the installation and testing of the machines and equipment were essentially the responsibility of the manufacturers' technicians. The reason for this is that, although the company directors recognize that their own personnel is capable of undertaking this work, they wish the equipment manufacturers to assume full responsibility, as this eliminates or simplifies any subsequent disagreements or discussions of a technical or financial nature.

These considerations are also applicable to the start of operations and the entry into regular operation; but during these phases the company staff in charge of the operation of the different units takes an active part in the work. To sum up, it may be concluded that, with COBRAPI's co-operation, reinforced as far as possible by one or two technicians requested on a temporary basis from some of the steel industries currently in operation - that is to say, through the combined efforts of several enterprises - that is to say, through the combined efforts of several enterprises - it would be perfectly feasible to plan a whole new industry of this type in Brazil. Even in this case, external technical assistance would be most useful, particularly for the following purposes: (a) to help establish a technical and economic criterion for the selection of the plant's location; (b) to assist in the selection and sizing of equipment, since the staff of firms of consultants with more experience and standing should possess more up-to-date information about the prices charged by the different manufacturers and the investment required for each of the alternative possibilities offered.

Nothing has been said here about the problem of personnel training. It is considered that, if the planning of a new industry in Brazil is organized on the basis of Brazilian institutions, there should be no major difficulties, and in any case it is always possible to obtain help from equipment manufacturers if a process or machine is being installed for the first time in Brazil.

2. Foreign aid in the expansion of existing capacity and the introduction of important modifications in the equipment

The growth of steel consumption in Brazil over the past few decades shows that the market doubled in periods which ranged from six to fifteen years, and everything indicates that this state of affairs will continue. If if was decided to construct a complete balanced steel plant to meet a specific demand, in a few years it would be necessary to build and put into operation a second unit with the same capacity, and so on. Under those conditions, at first there would be a balanced plant with all its production departments operating with the same load factor, thus guaranteeing the satisfactory utilization of the capital invested. In this initial stage of industrial development, however, the markets are too small for the plant to obtain all the benefits deriving from economies of scale. Therefore, the general practice initiated by Belgo-Mineira in 1934-1935 is to over-size part of the equipment, buildings, etc., in order to facilitate expanding the plant as required, thereby reducing the investment for expansion programmes. In these circumstances, the plants are planned by stages, one covering the immediate construction and others covering expansion the programmes envisaged from the start.

However, great strides have been made in world steelmaking technology during the last few decades and, when the time comes to expand the plant's capacity in line with the original project, it may so happen that this is not the most appropriate solution. Therefore, the expansion programmes should be duly reviewed before putting them into practice. In most cases, it may be found that it is enough to purchase one or two new pieces of equipment and expand the capacity or increase the productivity of the existing equipment by means of some of the technical innovations that have been tried out by world industry.

This part of the study on foreign technical assistance is devoted to an examination of these situations, but it is confined to the changes introduced in the processes with a view to increasing the productivity of the operating units through the investment of significant sums. In

/the light

the light of the existing experience and knowledge in Brazil, which varies from one department or process to another, the analysis is divided into five sections:

(i) Coking and agglomeration
(ii) Reduction
(iii) Steel shop
(iv) Pouring and casting
(v) Rolling

Table 7 shows the degree in which Brazilian steel industry depends on foreign technical assistance in each of these departments for different functions connected with planning, construction and the start of operations, presented as an average for the industry on the basis of visits paid to six integrated and four semi-integrated plants and of interviews with a considerable number of metallurgists. The degree of dependence shown in the table is represented by the following percentages:

Dependence on foreign technical assistance (Percentages)	Situation
100	Complete dependence
70-90	High dependence
40-70	Limited dependence
20-40	Little dependence
Less than 20	Very little dependence
0	Complete autonomy

Foreign technical assistance is generally transferred by the following means:

Suppliers of technical assistance	Key
Firms of consultants	Consultants
Individual specialists	Specialists
Equipment manufacturers	Manufacturers
Licensers of the equipment process	Licensers

/Table 7

Table 7

DEGREE IN WHICH THE BRAZILIAN STEEL INDUSTRY DEPENDS ON FOREIGN TECHNICAL ASSISTANCE FOR EXPANSION OF EXISTING CAPACITY AND IMPORTANT CHANGES IN THE EQUIPMENT

Production department	Selection of process	Sizing of equipment	Civil construction	Installation of equipment	Tests and running in
Coking and agglomeration	Complete autonomy	Complete autonomy	Complete autonomy	Complete dependence on manufacturers a/	Complete dependence on manufacturers a/
Reduction	Complete autonomy	Complete autonomy	Complete autonomy	Complete dependence on manufacturers a/	Complete dependence on manufacturers a/
Steel shop	High dependence: consultants and licencers b/	Complete autonomy	Complete autonomy	Complete dependence: manufacturers, consultants, licencers a/ b/	Complete dependence: manufacturers, consultants, licencers a/ b/
Casting	High dependence: consultants, and licencers c/	High dependence: consultants and licencers c/	Complete autonomy	Complete dependence: manufacturers, consultants, experts, licencers c/ a/	Complete dependence: manufacturers, consultants, experts, licencers c/ a/
Rolling	High dependence: consultants, experts, manufacturers d/	High dependence on manufacturers d/	Complete autonomy	Complete dependence on manufacturers d/	Complete dependence on manufacturers d/

a/ The general rule is that the plants request the manufacturers to assume full responsibility for the installation, testing and running in of the equipment, even if these tasks could be fulfilled by plant staff in most cases.

b/ In the expansion of steel shops of the classic type, there is a marked autonomy. The foreign contribution concerns the use of oxygen, be it for the transformation of existing furnaces or the construction of new ones and, in the latter case, it is considerable.

c/ There is plenty of autonomy in the handling and expansion of pouring and casting of ingots of the classic type. External aid is necessary to design and put into operation continuous casting strands or vacuum casting.

d/ Most of the rolling problems can be solved locally. External aid is necessary for electronic control of the process (automation).

/Clearly, table

Clearly, table 7 is too general to cover every situation. The intention was to provide a broad picture of the general possibilities open to steel enterprises, which means that some may act differently, or in a certain enterprise a different procedure may be adopted, in practice, according to competition or in line with the confidence which the management places in its technical experts. Moreover, it must be remembered that nearly all the steel enterprises have general advisory contracts in force with firms of consultants, in the majority of cases, but not always, with the same firms which prepared the original plan. In these circumstances, even though a department of the plant may have complete technological autonomy, the enterprises - for policy reasons and sometimes out of courtesy - submit their projects for consideration by their general consultants. The following comments are intended to clarify part of the contents of the table:

Coking and agglomeration. As regards coking, so long as the plants continue to use a blend of varying proportions of domestic coal and United States fuels, there would not appear to be any need for technical assistance in the selection of the process and type of equipment or in the sizing of equipment. This assumption is strengthened by the fact that the margin for obtaining and utilizing coke by-products - which offer a great many alternative possibilities - is reduced to simple and well-defined lines, imposed by the competition from petrochemical products. It will probably be more convenient in the future to use coal from other sources, such as Colombian coal, and there may then be some advantage in modifying the system of charging the retorts; in that case, it may be decided to introduce new systems in the expansion programmes and, if convenient, to modify the existing retorts. As is more evident than in the case of coke, there is complete technological autonomy in the preparation of charcoal, which is used by several Brazilian plants.

The same technological autonomy is found in the agglomeration of ore particularly sinter. Incidentally, the first sinter facilities in Brazil were constructed at Monlevade in 1943, at a time when Belgo-Mineira had lost contact with its head office in Luxembourg since 1939 as a result

/of the

of the Second World War. The technological research for the use of sinter at Monlevade was carried out entirely in the Technological Research Institute at São Paulo by the engineer Tarcísio de Souza Santos, and the start of operations was the responsibility of the engineer Francisco de Souza Pinto.

The normal procedure for undertaking expansion programmes which require investment in this department is to select the process and the size of the plant, choose the manufacturer and, once the contract for the purchase of equipment is signed, obtain the basic plans so as to prepare the construction, foundation and installation projects and execute this part of the work in Brazil.

The plant staff is almost invariably responsible for the assembly, installation and testing of the equipment and the start of operations, under the supervision of engineers and technicians from the firm of suppliers. This is not so much because the Brazilian personnel is not capable of doing this work properly, but mainly because the plant management quite rightly prefers the manufacturers to assume full responsibility for the satisfactory operation of the equipment they supply. This observation is applicable to all the expansion programmes carried out in the plant.

Reduction. The degree of technological dependence of the reduction department is much the same as that of the coking and agglomeration section, as regards both the coke and charcoal blast furnace. This is obviously not the case where direct reduction processes are concerned, but so far none have been installed in Brazil and very few exist in the world. An expansion programme based on the installation of such process would involve complete dependence on its licencers and the equipment manufacturers. It is unlikely that any new electric reduction furnaces will be installed in Brazil; but if such a plant were established, despite the small number installed in the country, the technology involved is relatively simple, as borne out by Mannesmann, which, with technical assistance from the firm Nationale Coque (Italy) and the efforts of its own staff, succeeded in increasing the plant's pig iron production capacity from the original 80 tons to 140 tons daily. Lastly, beginning 1955, Volta Redonda increased the diameter of its furnaces from 7.60 to 8.36 metres and

/from 7.90

from 7.90 to 8.51 metres, respectively, in order to increase production. The first expansion was effected with the technical assistance of McKee, who had prepared the original design for these furnaces, and the second exclusively with Brazilian technology.

Steel shop. It is highly improbable that any plant today might decide to construct an open-hearth steel plant without the use of oxygen, a process in which Brazil already enjoys complete technological autonomy. Almost the same might be said of the construction of an electric steel plant. In the case of an electric furnace, it will probably be necessary to obtain external assistance in sizing, if the furnaces were much larger than those now operating in Brazil. Therefore, the high dependence shown in table 7 for the selection of the process and sizing of equipment is for oxygen steelmaking. In addition to the fact that the processes are still used under patents, and licenses are required to operate them, enterprises have preferred to request external aid in dealing with a number of problems such as the behaviour of the refractory, personnel training, etc., even though both Monlevade and Mannesmann have used their own staff exclusively to transform old Bessemer furnaces into LD furnaces.

Pouring and casting. It is considered that Brazil has enough knowledge and experience to dispense with any foreign technical assistance in the expansion and modernization of pouring and casting facilities of the conventional type. However, if a plant sees fit to install continuous or vacuum casting machines, the need to purchase licences and patents, and technical problems which Brazil has little experience in solving, arise once again, since only one semi-integrated plant for special steels uses vacuum casting and one plant producing common steels has installed continuous casting machines - one of which was purchased abroad and the second was constructed in Brazil modelled on the first - apart from the conventional blooming mills which continue in operation.

Rolling. Technological dependence of the ordinary type of rolling mills is very small and is limited to equipment of unusual design. In contrast, if the new equipment has electronic size control systems or modernization programme involves the installation of such controls in the existing equipment, the plant will be heavily dependent on foreign technical assistance. So far, only two plants have branched out into this field: Volta Redonda, which installed an electronic control system in the blooming mill with a view to making full use of its capacity; and USIMINAS, which did the same in its cold-rolling mill to control the thickness of the product.

The description of the external technical requirements in expansion and modernization programmes shows the high level of technology that Brazil has attained in the planning and preparation of steel plant projects. Foreign technical aid is required only to introduce the latest processes applied in world steelmaking. Even in this case, as may be inferred from some examples of exclusively Brazilian achievements, the adoption of a system of technological exchange whereby a specialist in one plant may work in another industry for a certain length of time, while retaining his original post, would appreciably reduce the number of problems in which the transfer of foreign know-how by means of consultants and specialists is indispensable. Of course, this does not apply to patented processes or equipment, since in this case it is preferable to request the licencer's assistance, which could probably be obtained at a very small additional cost.

The depth in which the problems deriving from the expansion or modernization of each department have been analysed reveals the most critical details and questions involved in planning a completely new industry. Logically enough, a Brazilian enterprise wishing to use the processes which table 7 shows as requiring considerable external assistance would be compelled to obtain the relevant information from abroad, even if the planning and over-all study could be carried out entirely in Brazil.

/3. Foreign technical

3. Foreign technical assistance in the improvement of production processes not requiring much investment, the manufacture of new products and technological research

The technical staff of steel plants keep abreast of world progress in technology through meetings, interviews, books and visits - both of Brazilian technical personnel to another plant in the country or abroad, and of foreign specialists to the plant concerned - which constitutes a mental challenge and spur in the application of this knowledge. In Brazil, moreover, there is competition for the market and rivalry as regards technological progress in the steel industry, which motivates a desire and need to improve the quality of the products and reduce operating costs. This dual motivation, one acting mainly on the technical staff and the other on the management, have driven and are currently driving the whole steel industry to introduce every possible improvement in its operation. The previous section dealt, apart from the expansion programmes, with the improvements which entail the modification or replacement of part of the equipment. This section relates to all the improvements which can be introduced without the need for costly purchases.

To facilitate the analysis, two types of problems are dealt with separately: (i) those in which the change is essentially in one process or production department, although if, for example, the quality of the steel is altered it would then be necessary to study its behaviour in the rolling mills, etc.; (ii) the improvements which must be planned and introduced on an interdepartmental basis.

a) Innovations and research in only one production department

Table 8 was prepared with the same distribution as table 7 and represents the views of the technical experts consulted in Brazil regarding the degree of dependence on foreign technical assistance in the following respects: technological research for immediate application; improvements in production processes and use of equipment entailing little investment; and the technology required to manufacture new steel products. The situation by department is analyzed below.

/Table 8

Table 8

BRAZIL: FOREIGN TECHNICAL ASSISTANCE IN THE IMPROVEMENT OF THE OPERATION OF VARIOUS PRODUCTION DEPARTMENTS, THE MANUFACTURE OF NEW PRODUCTS AND TECHNOLOGICAL RESEARCH, NOT REQUIRING APPRECIABLE INVESTMENT

Production department	Improvement in processes in use	Technological research for immediate application	Manufacture of new products
Coking and agglomeration	Complete autonomy	Little dependence: consultants and specialists	Limited dependence: consultants and specialists
Reduction	Complete autonomy	Complete autonomy	Complete autonomy
Steel shop	Limited dependence:[b/] consultants, licencers and specialists	Limited dependence:[b/] consultants, licencers and specialists	High dependence:[b/] consultants, licencers and specialists
Casting	High dependence: licencers, manufacturers and specialists[a/]	High dependence: licencers, manufacturers and specialists[a/]	Complete dependence: manufacturers and licencers
Rolling	High dependence: licencers and specialists[c/]	Limited dependence: specialists[c/]	Complete dependence: manufacturers and licencers[c/]

a/ There is almost complete autonomy in the classic casting process. Foreign assistance is required in connexion with continuous casting and vacuum casting.

b/ Dependence on foreign assistance is limited to some problems connected with the use of oxygen in the steel shop.

c/ The need for foreign technical assistance is considered to be limited to the use of electronic controls in all or some of the rolling mills.

/Coking and agglomeration

Coking and agglomeration. As in the case of the expansion of plants, there may be said to be a fairly satisfactory degree of technological autonomy in these departments. This will remain true of coking so long as the present practice continues of using domestic coal mixed with certain coals imported from the United States. To illustrate this point, USIMINAS is adding a small proportion of charcoal fines to the coking blend with excellent results, and this innovation was adopted without any foreign technical assistance. Moreover, ACESITA is attempting, without external aid, to manufacture briquettes of charcoal bound by molasses. Technology of this kind should obviously be developed in a technological research institute rather than in an industrial plant, and it is mentioned here as an example of the many cases in which there are no proper links between the steel industry and Brazil's technological institutes, since IPT is engaged in similar research.

Reduction. Of all the production departments of the steel industry, the reduction department has undoubtedly reached the highest degree of technological independence. The following are some of the achievements of the technical staff of steel plants: in the ACESITA plant, the charcoal blast furnace which was originally planned to produce 350 tons daily, is now producing 450 tons, while the electric reduction furnace, with a rated capacity of 145 tons daily, is producing 212 tons. The USIMINAS blast furnace, originally planned to produce 700 tons daily, is producing 1,100 tons, and the Monlevade charcoal blast furnaces have raised their joint production from a rated capacity of 360 tons to 1,600 tons daily. COSIPA, without external aid, increased its blast furnace capacity from 1,560 tons to 2,100 tons daily, and expects to reach 2,400 tons as soon as it starts to use oxygen in the tuyeres, for which it has to wait until the expansion programme is implemented.

As regards technological research, ACESITA is studying the injection of a blend of oil with charcoal fines in the tuyeres, the main problem being the high concentration of potassium in the charcoal fines, and the difficulty of determining the quantity of charcoal in the blend. These problems, as in the previous case, could perfectly well be studied in a

/laboratory - or

laboratory - or possibly a pilot plant - by some technological research institute, before the system is introduced on an industrial scale. At the same time, ACESITA is studying the possibility of producing a chromiferous pig iron, which would be a new product of the reduction department.

Steel shop. This department may be said to have complete technological autonomy in the production of steel without the use of oxygen, and it uses external aid on a limited scale only in the introduction or improvement of oxygen steelmaking. In this field too, however, there have been important achievements: in the USIMINAS plant, the two oxygen LD converters which were originally planned to produce 50,000 tons a month are producing 70,000 tons and this figure is expected to increase still further. In ACESITA, the three electric furnaces which had a total rated capacity of 86,000 tons annually are producing 110,000 tons. Technical assistance was obtained from SOFRESID, in France, in introducing these improvements, but only for the electrical part. Lastly, at Monlevade, the LD converter planned by VOEST (Austria) to produce 36 tons daily is now producing 44 tons.

Monlevade even developed a technique which was widely disseminated in steel publications at the time. In addition to the scrap which is added to the LD furnace charge in order to cool it, up to 2½ per cent of lump ore is also added, depending on the silicon content of the molten pig iron. The results of this process were observed by the engineer from Linz who took part in the start of operations of the LD furnace and developed and adopted it.

To give some idea of the importance of new products in the steel industry, it is worth mentioning that USIMINAS, in addition to common steels, is producing welding steels, high-resistant and corrosion-resistant steels, and deep-drawing steels. The plant received technical assistance from Yawata, Japan, in the start of operations of all the necessary manufacturing cycles. ACESITA produced stainless steel sheet and chromium-nickel tool steel without external aid, but it is now seeking technical assistance from Germany, the United States or Japan in improving the

/quality of

quality of these products. This plant is also manufacturing non-oriented grain silicon sheet, with Japanese advisory assistance. Lastly, Monlevade is producing steel cables of different composition, and has just started manufacturing high-resistant steel strips of the Firestone type, Inland Steel patent, modified by ARBED, for which it pays a royalty.

Casting. In this department, the dependence on foreign assistance is practically negligible, except in the case of continuous casting or vacuum casting, new patented techniques which so far have not been used by any of the large integrated steel enterprises in Brazil and are not likely to be used for many years. The use of continuous casting would not be justified so long as the existing blooming mills continue operating, or only if the results of experiments in using the process for pouring rimmed steel were satisfactory.

Rolling. Brazil's steel industry relies heavily on foreign technical assistance in these departments in connexion with the installation of electronic controls (automation). On the other hand, it enjoys complete autonomy in the introduction of ordinary innovations in the production of common steels, which consist primarily of designs of the cylinder grooves with a view to the production of new forms of profiles, and in stepping up the speed of the existing mills so as to increase production capacity, which is the common objective of a world-wide movement. Lastly, in the case of new products, i.e. steels whose chemical composition and physical characteristics (except size) differ from the ordinary types, the usual practice is to invoke assistance in rolling these steels from the foreign specialists who are responsible for their preparation in the steel shop, in those cases where the necessary operations are different from the norm.

b) Operational improvements introduced on an interdepartmental basis

The most important control operations under this heading include: (a) quality control; (b) administrative structure and control; and (c) control of operations and flow of materials to ensure the highest possible productivity for both equipment and labour. Clearly, these three forms of control are interrelated, with greater interdependence between (b) and (c).

While quality control begins, to a certain extent, when the plant is operating normally after the start of operations, the improvement and co-ordination of administrative functions and productivity control begin in the following phase, after the initial stage in which the main objective is to attain the established production goals. Once they have been achieved, the enterprise turns its attention to the three problems mentioned above, spurred by competition in terms of quality and by the need to consolidate its economic and financial position by adopting measures to reduce costs.

Quality control. As stated above, quality control is necessary right from the time the plant starts operating. The general rule in the introduction of this control is to send qualified personnel abroad to acquire technical and practical knowledge of the subject, and to supplement this group by the temporary recruitment of some foreign specialists who are usually suggested by the consultants themselves, and by auxiliary staff members who have received no training abroad but have specialized within the plant.

So that the products manufactured will meet the required specifications, it is essential to carry out a continual inspection of all the raw materials and semi-finished products obtained in the production process, and to exercise a systematic control of the execution of operations throughout the production cycle. In the plants visited, the number of persons in charge of quality control ranges from fifty to ninety - including specialists, technicians and auxiliary staff - according to the degree of diversification of production. This group must work in a co-ordinated manner during the plant's operation and establish operational standards for the equipment, so as to ensure that the specifications can be met.

In theory, it might be considered that at the end of the phase covering the start of operations the plant possesses a perfect quality control organization and that this problem will not arise again, at least until new products requiring special treatment in certain parts of the long production cycle are included in the manufacturing programme, but this has not been the case in Brazil. In practice, however, at some time after their entry into operation, all plants must obtain additional

/equipment and

equipment and send a group of specialists to acquire the necessary knowledge in some foreign plant. Clearly, the problem cannot be solved by contracting a team of six or seven specialists to train a group of Brazilians for a limited time and then return to their own country. In order to ensure the success of such a mission, it would be indispensable that before arriving in Brazil the experts should already be accustomed to working as a team. Such a condition considerably impedes this form of transferring know-how and the industry has always had to use the system of sending a group of its personnel to work on the problem together with the specialists in some foreign plant which provides this kind of advisory assistance.

At present, the Brazilian steel industry in general has excellent quality control departments directed entirely by Brazilian specialists. Therefore, the plant staff itself could serve to train new groups of this type, except in the control of new products, which may not be included yet in the production programme of any of the plants.

4. Administrative organization and increase in productivity in developed countries

In recent years, the science of administration has reached a high level in the management of industrial enterprises in developed countries. The method is to establish an organic and functional structure which can keep pace with production and administrative processes and establish the necessary provisions and controls to attain the highest level of efficiency in both labour and equipment. In view of the complex nature of such a study, it is advisable to contract the services of a foreign firm which has specialized in steelmaking and has the required experience to undertake a thorough overhaul of the methods in use and establish the best operational structure for the purpose.

It was noted that few of the plants visited had used this type of advisory assistance successfully, although they had all received a certain amount of aid in administrative matters from their consultants at some stage of their operation. Only two enterprises - COSIPA and VILLARES - said they were thinking of obtaining some external assistance in connexion with administration, efficiency and marketing; but it seems that the

/firms contracted

firms contracted to provide this assistance will also be expected to fulfil essentially technical advisory functions.

5. Evaluation of the methods of obtaining foreign technical assistance for the steel industry

It is impossible within the scope of this study to undertake a comparative evaluation of the methods used by the steel industry to obtain foreign technical assistance. For such a study, it would be necessary, in practice, to determine what would have been the technical and economic results of the plant's operation if a different system had been used to obtain this assistance. At most, some of the errors and/or omissions committed during the planning and construction of the plants may be pointed out, but in fact not many errors have been observed and some have already been commented on in the relevant sections of this chapter.

It is therefore considered of greater interest to present some of the comments made by the managers and staff of the steel industries consulted regarding their method of obtaining foreign "know-how".

Planning, construction and start of operations. On the whole, the steel industries expressed satisfaction at the work done by the consultants under these three headings. In only one plant the manager stated that there had been errors in the original project; but it is a small plant which had great difficulty in securing financing and the project was initiated after a long delay. During that period it is quite likely that there were technical innovations which were not taken into consideration, and if so it would have been advisable to review the whole project once the necessary resources were available for its execution.

Another plant limited the services of the firm of consultants which it had contracted to prepare the original project to the preparation of the layout of the plant, and signed a contract with another firm of consultants in connexion with the management, training, etc. While one of the firm's directors was of the opinion that the latter contract had been usefully and satisfactorily fulfilled, another director felt it would have been better to divide the second contract into several parts and use firms which had specialized in each field, in line with a highly selective criterion.

/Advisory assistance

<u>Advisory assistance in expansion programmes or details of plant processes</u>. As regards efficiency in the transfer of know-how in connexion with expansion programmes and/or details of the processes used in plants, there is consensus that if the contract merely provides that the firm of consultants should send a specialist for a limited period to solve the problem, the industry obtains little more than a "prescription", which becomes useless as soon as any change occurs in the working conditions. The best system is for the Brazilian enterprise to send its technicians abroad to study the problems and seek adequate solutions. Another entrepreneur, whose firm has concluded one of the best contracts with a foreign firm for general advisory assistance known to exist in Brazilian steelmaking, stated that the form in which this aid is received can never be applied directly in the plant and has to be adapted by his technicians.

Although in the manufacture of seamless tubes Mannesmann uses know-how transferred from its head office in Germany, whose new technological achievements are immediately communicated to the Belo Horizonte plant - either through visits of its technicians or publications - it endeavours to keep abreast of the development of technology in the manufacture of tubes all over the world, and sends its technicians to the United States, Europe and Japan in order to keep informed. It is currently preparing a modernization programme in which the knowledge acquired during those missions is incorporated.

The system of technological co-operation between Brazilian enterprises is illustrated by the initial phase of operations of the COSIPA LD furnaces. The licence was obtained from VOEST, in Linz, which sent an engineer and four foremen for the phase covering the start of operations, who remained at the plant for five months. The plant staff was trained entirely in Brazil. The foremen and staff engaged in casting, sampling, etc. at Volta Redonda, and the heads of shifts and blowers at Monlevade. The Monelvade plant also co-operated with COSIPA in the manufacture of the special refractories for the LD furnace.

/<u>Manufacture of</u>

<u>Manufacture of new steel products</u>. One of the entrepreneurs, whose plant's production was fairly diversified, expressed the view that the absorption of foreign know-how for the manufacture of special steel products should be accompanied by the knowledge required to obtain a reasonable rate of return. At first sight, it seems very simple to obtain know-how when it is transferred through a foreign enterprise, but any change in the other operations often gives rise to problems which are difficult to solve and external aid must once again be sought. For this reason, the enterprise is concentrating its efforts on training its staff abroad.

The directors of one of the special steel plants which produces the widest range of types of steel said that the cost of training his technical personnel to a level where the plant can develop its own technology would be so enormous that they had decided to import the know-how on payment of royalties. In 1952, they signed a contract for general advisory assistance with Böhler, which manufactured several types of steel products: cast iron parts, tools and parts for mechanical construction. This contract was renewed in 1962, but Böhler had given up some lines which the Brazilian company could not abandon. Moreover, there was new demand, mainly from the motor-vehicle industry, which compelled the industry concerned to seek additional technical advisory assistance.

They consider that in order to take advantage of these contracts they must have a high level of knowledge, since if a local problem arises unexpectedly or it becomes necessary to manufacture some new product it is difficult to make the situation clear by the existing means of communication. Therefore, they have adopted the policy of sending their more highly qualified staff abroad for a period of two months, and plan beforehand the questions they should study.

The cost of the advisory assistance is correspondingly lower in the case of recipient firms with a higher level of technology, since the owner of the know-how always considers the possibility that the technique could be developed locally, without any benefit to the consultants.

/Technological research

Technological research. The manager of one of the State plants said that he considered that technological research should be divided into two areas: one for improving the routine work in the plant, with a view to establishing normal operating conditions, which would be developed in the plant itself; and the other for innovations, which should be developed in research institutes rather than at the plant, where the staff should concentrate on seeking solutions for the many routine problems. He considered that such institutes were indispensable in order to ensure that the Brazilian steel industry could keep pace with innovations in the more advanced countries and adapt them to local conditions.

The present plan for the establishment and reinforcement of a team to carry out technological research for immediate application in one of the Brazilian State plants was primarily the result of some failures in the attempt to tranfer foreign know-how. Nevertheless, in spite of the firm's efforts to develop its own technology, there will always be some need for international technical aid, particularly in the manufacture of new products. With the object of setting up its own technological research centre in the plant, this enterprise contracted the services of a foreign firm to plan the organization of its research department, and requested research centres such as Battelle, Bisra and IRSID to provide training for carefully selected technicians so that they can execute the project proposed by this firm.

Lastly, in the interests of greater technological exchange between the Brazilian steel industries, a firm which produces special steels suggested the establishment of a service for co-ordinating Brazilian enterprises, which would be responsible for providing technical assistance to all plants.

/Chapter VI

Chapter VI

OTHER PROBLEMS

1. Transfer of foreign know-how versus the local creation of know-how

There do not seem to be any restrictions on the transfer of foreign know-how to steel industries in Brazil. To be able to convert local currency into foreign exchange for the necessary payments, the enterprise must register its contracts at the Central Bank of Brazil. This institution does not examine the cost-profit ratio of the operation concerned, nor the possibility of substituting local knowledge for the foreign technical assistance contracted. Therefore, the Brazilian firms are exclusively responsible for the decisions in this respect.

The stage of development reached by the Brazilian steel industry, which already has twelve integrated plants and more than nineteen semi-integrated plants which in 1969 produced over 4.5 million tons of steel ingots, may be ascribed to the appreciable fund of experience and technological knowledge that it has accumulated.

If necessary, much of the foreign technical assistance which is currently requested could be dispensed with at no great loss.

This only applies, however, to the classic processes that have been in use for some time in the industrialized countries. The newer processes which may be of interest to Brazilian industry are not widely known and are often still under licence. Obviously, in these cases, it is best to purchase the know-how and avoid wasting efforts and resources on discovering what is already known. Moreover, in the opinion of several metallurgists, the new technology transferred by the patent owners is seldom ready for use; it must be adapted to the particular conditions at the plant and in the country. The adaption of new techniques to local conditions is a complex technical and scientific task which offers considerable scope to Brazilian specialists who must have the highest possible training. This is being undertaken by several Brazilian industries.

/It should be noted,

It should be noted, however, that the technological knowledge existing at present in Brazil, such as that acquired through the intensive training and specialization of many professionals, is not centralized in institutions but spread among the technical experts employed by a large number of steel enterprises.

To a certain extent, COBRAPI constitutes an exception to this rule, since this enterprise is made up of part of the technical staff of Volta Redonda, thus possessing a team of technicians capable of assuming the responsibilities involved in studying every detail of the construction of a new steel plant on the basis of a layout. If a new enterprise is to be successfully planned, a group must be set up to take care of the preliminary studies, the general planning and the technical and economic feasibility studies of the project. This same group, or another, should be responsible for purchasing the equipment. Brazil's experience shows the advisability of obtaining some technical support from abroad in order: (a) to ensure that the production programme - in both volume and range - is in line with economic criteria rather than the preconceived ideas of the group of promoters of the project; (b) as far as possible to counteract political pressures in connexion with the plant's location; (c) to co-operate in the selection of the equipment suppliers, since a firm of consultants with experience has a better knowledge at a given moment of the supply position in the world market.

As regards the introduction of recent innovations in the Brazilian steel industry, a complete lack of organization is noted with respect to research, and a lamentable inactivity on the part of the Technological Research Institute of São Paulo in the last years, following the period of tremendous initiative and important studies two decades ago. IPT conducted studies and experiments which resulted in the adoption of the sintering process at Monlevade in 1948; and these were followed by many studies on the manufacture of pellets, on the basis of which the Companhia Vale do Rio Doce is shortly to initiate production. There are a number of problems of this kind which should be dealt with by well-equipped steel research institutes with skilled specialists and a

/technical staff

technical staff capable of meeting the minimum requirements for the satisfactory performance of a technical research institute. It is necessary to promote discussion of the main problem among specialists in the different areas of activity.

In the case of Brazil, the problems relate, inter alia, to blast furnace fuel and the possible manufacture and use of pre-reduced pellets. Other sections of this study deal with the efforts made by some metallurgists to solve the fuel problem by means of studies and research carried out in the plant itself.

This is not the place to examine the problems of institutions such as IiT, or the difficulty they have in playing a more dynamic role in industrial development, but at first sight one of the main obstacles they encounter as State institutions is their inability to compete with the wages offered by industry. Metallurgists and other steel research specialists are in such demand by the steadily expanding steel industries that it is almost impossible for the institutes to retain their services.

This is partly why the plants themselves carry out many studies and detailed experiments of the processes in use in order to improve their operation, although it would be more productive if the research were centralized in a technological institute. However, since such institutes are practically non-existent, the enterprises and their technical staff have been carrying out this research, probably with some duplication of effort and at a high cost, but on the whole with excellent results. Most of these problems can be solved by the plant staff itself, without external aid, except in some cases which are mentioned below. The ready exchange between enterprises is frequently noted in this type of work. This exchange generally takes place at the initiative of the technical operating staff and is subsequently authorized by the departments concerned. As regards progress in operational technology, know-how is transferred from one enterprise to another through periodical meetings of specialists, such as the ABM congresses, and possibly through visits to other plants. It may be affirmed that any initiative to promote the holding of meetings, discussing problems and promoting discussions in the operational field brings significant benefits to the industry in general.

/For the introduction

For the introduction of the latest technological advances in the operation of the equipment, Brazil needs external technical aid only in solving those problems concerning which it has little experience, and those relating to processes covered by licences or patents, as for example the LD steel shop, although in this field a great many improvements in the details of the operation have been introduced by the plant specialists. In those cases where the experience of foreign firms is indispensable in introducing changes, enterprises which have general technical assistance contracts in force make the necessary consultations before starting the research and experiments in their plant.

Lastly, as regards the manufacture of new products, as a rule these are developed by the large steel-producing enterprises, either in laboratories expressly devoted to this purpose or in their own plants. The reason for this is the small market existing for new products and the researchers' desire to obtain the maximum benefit for the longest possible time. Consequently, the organization of joint research for the development of new products is impracticable both in Brazil and in the more advanced countries, so that this field does not offer much scope for a technological steel institute in Brazil.

Some successful results have been obtained by the Brazilian steel industry in the autonomous development of techniques for the manufacture of special products, but when this work is completed, either because of low returns obtained or unsatisfactory quality, or both, the enterprise often requests technical assistance from an experienced foreign producer.

Since Monlevade entered into operation in 1937, however, Brazil has steadily accumulated a fund of technical knowledge and experience, particularly in respect of planning a steel plant, subsequent innovations, followed by quality control and the control of the processes, and, more recently, the manufacture of special products. This knowledge acquired by the technical and administrative staff of steel enterprises is being increased through ever more intensive training and specialization as more and more Brazilian professionals are granted fellowships for training in industries and/or technological research institutes in developed countries.

/The specialization

The specialization of Brazilian professionals is probably the best means of transferring foreign know-how, and should be used increasingly, as certain enterprises are now doing. Other instruments for the transfer of know-how - the retaining of consultants and individual specialists, the purchase of licences and patents, and advisory assistance in the installation and operation of equipment - will continue to be used by the steel industry for many years, probably on a larger scale than is really necessary, because of the directors' understandable desire to have additional technological support in the adoption of decisions, which either represent new investment or may result in losses of time and materials. There is therefore a gap in some types of technological research of interest to a number of plants which could be carried out jointly. These are the types of research to be conducted by research institutes, and it should be remembered in promoting this research that the professional staff of such an institute should maintain a higher technological level than the technicians working in industries which will be its clients. In view of the drive noted in most steel industries to raise the technological level of their specialists, it will be a complex and increasingly difficult task to organize an institute which can lead the way to developing an autonomous technology in Brazil's steel industry, as IPT did in the past.

2. Factors determining the propensity to innovate

During the field work undertaken with a view to preparing this chapter, on the basis of ten plants chosen out of the many visited it was possible to judge the companies' sensitivity to the recent technological innovations in world steelmaking. Owing to the characteristics of Brazil's steel industry, these ten plants do not represent a homogeneous sample, since they include plants constructed thirty-five years ago and others which have been operating for less than two years. The sample comprises six integrated plants and four semi-integrated plants; three of the ten basically produce rolled flat products, some only produce special steels, and the rest bars and profiles of common steels, and some special steels.

/Because of the

Because of the heterogeneous nature of the sample, or rather the small number of plants in each category, it was not possible to investigate the factors determining the propensity to innovate by the method which would have yielded the most positive results, i.e., taking the main technological innovations one by one and examining the position in each plant. It would be necessary, for example, to seek answers to questions such as: how did an improvement in sizing the blast furnace burden come to be introduced in the industry? What was the attitude of the owners and technical staff of the plant? Has this improvement been perfected or is it still in a preliminary or intermediate stage? The same would have to be done to investigate the position with regard to more complex improvements which require substantial investment, such as the use of sinter, oxygen, etc.

It was therefore decided to make a general subjective appraisal of the companies' attitudes to technological progress. This appraisal cannot be considered to be very precise. There are plants where the operation of some production departments has reached the peak of efficiency in line with the latest world methods, while other departments are relatively backward. In these cases, an attempt was made to evaluate the average position and, according to their attitude to technological progress, the firms were classified in the three following categories: (a) plants which continually study the innovations introduced in the world steel industry and apply them as soon as possible (these plants were considered to be technologically "very aggressive"); (b) plants which keep abreast of progress in steelmaking but apply the innovations with a certain time-lag, although they are well ahead in some respects (these plants are described as "progressive"); (c) plants which maintain a conservative attitude to innovations and wait for the results obtained by the enterprises using them in order to avoid possible difficulties or failures (these are described as "conservative". See table 9).

/Table 9

Table 9

BRAZIL: CLASSIFICATION OF THE TEN PLANTS CONTAINED IN THE SAMPLE IN REGARD TO THEIR PROPENSITY TO INNOVATE

Type of enterprise and plant	Very aggressive[a/]	Progressive[b/]	Conservative[c/]
Enterprises with foreign capital producing:			
Common steels	2	--	--
Special steels	2	--	--
Enterprises with Brazilian capital producing:			
Common steels	--	3	1
Special steels	2	--	--

a/ Plants which continually study the innovations introduced in the world steel industry and apply them as soon as possible.

b/ Plants which study the innovations introduced in the steel industry of the most advanced countries but apply them with a certain time-lag.

c/ Plants which maintain a conservative attitude to innovations and wait until they have been generalized to a certain extent, in order to avoid possible difficulties or failures.

Several factors influence the companies' propensity to innovate, as may be seen from the sample. The most important are: the behaviour of plants operating with foreign capital compared with that of Brazilian-owned plants; the type of competition for the market, whether free or monopolistic; the attitude of the technical staff of the plant and, lastly, the directors' attitude.

The following comments on the influence of these factors on the companies' propensity to innovate are based on information obtained and the operations observed during the visits to the plants covered by the sample.

/3. Influence of

3. Influence of foreign investment

Table 9 presents the enterprises included in the sample, grouped according to their basic production line (with those producing common steels shown separately from those mainly or exclusively producing special steels) and the origin of their capital. In all the plants operating with foreign capital, except for one in which foreign investment accounts for 70 per cent of the shares, a very minor proportion is actually foreign investment, and in one it represents only 3 per cent of the shares.

In spite of the undoubted failings of this method of analysis, it reveals the advantage enjoyed by enterprises constructed by foreign enterprise and/or in which foreign firms still have a share in the capital with regard to technological innovations. In fact, the four companies in this category are shown in table 9 as being very aggressive, while only two of the six plants established with Brazilian capital (33 per cent) are so described. Most of the latter fall into the category of enterprises which apply innovations with a certain time-lag.

After examining the question, it was concluded that there were two possible reasons for this difference: (i) speedier transmission of the latest technological advances by the head offices concerned; (ii) it is easier to convince the local directors of the feasibility and benefits of an innovation if the suggestion is based on an evaluation by the foreign head office. In fact, three of the four Brazilian plants which operate with foreign capital have a system for the automatic transmission of information about the results of research and progress achieved by their principals abroad. This point was not discussed at the fourth plant, but presumably it has the same system. It is interesting to note that, with few exceptions, technological advances in world steelmaking are being made in the plants themselves rather than in technological research institutes. It occasionally happens that some of the innovations are devised in the research laboratories maintained by the more progressive industries, but obviously the work of putting them into practice (development work) is done, if necessary, in pilot plants. Even in this case the final stage is always their application on a limited industrial

/scale. The

scale. The whole process of development from the initial experiment until the innovation is fully accepted by the industry takes place at a rate which varies according to the cost-profit ratio of the operation, the complexity of the process, and the ease with which the quality standards established for the final product can be safely met. It should be noted that the criterion for determining the propensity to innovate of the plants included in the sample was to classify as aggressive those plants where a new technique had been adopted shortly after it had become known. In other words, the plants classified as aggressive were those which, as far as their resources permitted, kept pace with developments in world technology.

All foreign enterprises which have subsidiary plants in Brazil operate on highly competitive markets, and it is a question of survival for them to keep abreast of all the processes and innovations which are being developed by their competitors on the world markets. If this information is immediately transmitted to the Brazilian plant, if possible duly adapted to local conditions, this plant has an advantage in terms of time over its competitors, which have to rely on their own efforts to obtain information about what is happening in a specific plant in a distant country, or must wait for the firms with which they have general advisory assistance contracts to provide it. This is only valid so long as:
(i) under the terms of the general technical assistance contract the consultants firm is required to report the appearance of any innovation to its client immediately, but this is the case in only a few contracts;
(ii) the firm of consultants has the organization to provide this type of service, which, as will be seen later, seems highly doubtful.

The method most frequently used to disseminate new practices which the plant that devised them does not specifically wish to keep secret, is through periodical technical publications and meetings of all kinds, where the specialists who took part in the new development describe the results of their work. As is easily understandable, it usually takes at least a year from the development of the innovation to its dissemination. Even so, the information is always received with a certain amount of caution. Consultants engaged in planning steel industries or their expansion must be able to assure their clients that they have recommended the best installations, and they probably only suggest processes which have been used successfully by several plants for a number of years.

The degree of aggressiveness in regard to technology no doubt varies from one firm of consultants to another, and in each firm between one production department or process and another.

It may therefore be concluded that the plants classified as lagging behind in technological progress should revise their contracts with general consultants and include clauses covering the provision of the above service, if the firm is in a position to furnish it. A second possible explanation for the more efficient transfer of technology to plants with foreign capital is more apparent and can be summarized as follows: the technicians at the company's head office learn of some new development in a foreign steel industry. After studying it for possible use in their own plant, they send the information to the Brazilian subsidiary. The management makes a rapid evaluation and transmits the study to the technical staff. If it is of interest, the possibility is explored of adapting the innovation to the processes in use and the results are sent to the head office for approval. If the Brazilian specialists' ideas are favourably received, they are returned to the management of the local plant with the head office's agreement.

It is more difficult to ignore a suggestion from the head office than a proposal made by a consultant or a local specialist, particularly if the suggestion is accompanied by specific instructions to put the innovation into practice as soon as possible.

4. Effect of competition for markets

The Brazilian steel market has been highly competitive in recent years. Table 10 shows the evolution of the supply of flat and non-flat rolled products in Brazil, by origin. It will be noted that net imports of non-flat rolled products dropped from 35 per cent of apparent consumption in 1951 to somewhere between 10 and 11 per cent in the last few years. It must be borne in mind that a proportion of the imported products are

/special steels

special steels which are not yet being produced in Brazil in those sizes, forms or chemical composition, and the rest are common steels for areas far from producing centres which cannot be supplied economically by local plants because of the high freight costs involved. The table also shows that small quantities of non-flats have been exported. Since 1964 the position with regard to the supplies of flat products deteriorated. In 1965 and 1967 exports of flats exceeded total imports; thus from 37.5 per cent of apparent consumption which was imported in 1951, Brazil reached a net export figure of nearly 5 per cent.

Table 10

BRAZIL: SUPPLY OF ROLLED STEEL PRODUCTS

	Non-flat rolled products				Flat rolled products			
Year	Production	Imports	Exports	Net imports as a percentage of apparent consumption	Production	Imports	Exports	Net imports as a percentage of apparent consumption
1951	433	237	---	35	249	150	---	37.5
1953	505	97	---	16.2	290	115	---	28.5
1955	519	212	12	28	413	133	---	24.5
1957	667	225	3	25	463	170	---	27
1959	877	339	---	23	615	168	---	21.5
1961	941	175	8	15	880	159	---	15.3
1963	1176	188	---	13.8	1041	288	---	21.7
1965	1074	132	16	9.8	1074	124	154 a/	(-3.0)
1967	1403	178	20	10	1423	161	234 a/	(-5.4)
1969 b/	1993 c/	173	70	5	1977 c/	231	255	(-1.2)

Source: ECLA, on the basis of Brazil's foreign trade statistics and information published by ILAFA.

a/ Including semi-finished flat products exported mainly to Argentina.

b/ Brazilian Steel Institute.

c/ Including semi-finished products for export.

/The prices of

The prices of products have been fixed by the Brazilian Government and, in the case of steel, the authorized adjustments have not kept pace with the cost increases in the principal inputs of the steel industry; but even so, in many cases, the steel companies have had to sell their products at less than the official prices in order to keep their plants in operation.

The market depression in 1967 prompted steel industries to export, and sales of flat products on the external market represented about 16 per cent of production, but they were effected at considerable sacrifice in price. Since 1969 the Brazilian Government has established tax incentives for exports of manufactured products, and the sales prices of steel became also remunerative.

Many enterprises have a diversified range of production and some of their products have no local competition; but these monopolistic conditions are not very significant within the companies' total volume of sales, except in two cases where the products concerned account for approximately half the total sales. The first of these enterprises works with foreign capital and is one of the most active industries in Brazil in introducing technical innovations, and the second was the only enterprise to be classified as conservative in table 9. It is not possible to generalize regarding the situation in the steel sector in the light of these examples; in order to complete the picture, however, it might be added that the conservative enterprise has been affected only since 1964-1965 by competition from other steel enterprises in the production of types of steel which represent 50 per cent of its output, and it has already taken the first steps to introduce the necessary innovations as soon as possible so as to make its products more competitive.

Nearly all the steel industries are evidently anxious to improve quality control. In most of them, this is the direct result of the keen competition in both common and special steels on the domestic market. To perfect this control, the plants have installed laboratories and provided the technical staff with highly specialized training, and have devoted their attention to improving the quality of their products and enhancing the plant's prestige.

/The staff

The staff responsible for quality control plays an important part in the whole system of modernizing steelmaking processes, since, in addition to the necessary analyses and inspections, it must establish norms for the operation of the equipment with a view to meeting the established quality standards. Hence its importance in the task of assessing the feasibility of introducing any change in the operation of the plant.

Lastly, four of the plants producing special steels were classified in table 9 among those which are most alert to technological innovations, while only 33 per cent of those producing common steels were included in this group. The reasons for this difference may be the keen competition existing in special steels, or the fact that the manufacture of special steels requires more highly trained personnel, largely of the same level as that responsible for quality control, and more flexibility and expeditiousness in the adoption of decisions by the administrative staff of the plant, whose production must be adapted to the development of industries using special steels.

5. Influence of the technical staff of steel plants

As a rule, the technical staff members of Brazilian steel plants are well up to date in the technological innovations relating to their particular areas of activity and are anxious to apply them in their plants. Any arrangement of an institutional nature which could help to reduce the time between the first successful application of a technological innovation in world steelmaking that could feasibly be put into practice in an existing plant and the moment when it comes to the knowledge of the operational staff of the Brazilian steel industries would be of great value. The main systems for spreading new technologies include: access to specialized periodicals and publications, participation in specialized meetings, visits to plants, etc. It would probably be highly useful to strengthen the existing system of periodical technical meetings and congresses at the operational level, and promote meetings on a limited number of subjects which, in the course of time, would cover the different areas of activity within the context of the Brazilian steel industry.

/The majority

The majority of the technical staff take pride in the efficiency of the processes they are in charge of, and they often bring pressure to bear on the directors to obtain authorization to introduce innovations. The measures referred to in the previous paragraph would help to intensify this pressure.

There are cases, however, where the operating staff may know of possible improvements but do not insist on their being adopted. These cases of indolence are evidently few, and the best solution would be to replace the unsatisfactory technicians. In other cases a certain resistance is observable because the staff member is fully aware that even if he knows what action to take this does not automatically mean that he is capable of taking it. In these cases, the best course would be to obtain the services of a Brazilian or foreign specialist, and it is important that the entrepreneurs should not think less of a technician who has been frank enough to confess his fears; on the contrary, the best attitude is to value him more than the technician who simply ignores the innovation, with economic loss to the firm.

6. <u>The directors' influence</u>

Few Brazilian steel enterprises have been operating at an economic rate of return over the past few years, owing to debt servicing and the need to finance indispensable expansion programmes. The small profit margins attributable mainly to the imbalance that exists between the different production departments until such time as the plant is expanded, and the low prices authorized by the Government and resulting from the keen local competition, have caused many directors of steel plants to adopt a permanently cautious attitude to expenditure and the adoption of innovations.

It is essential to convince the directors of the technical and economic advantages of adopting the proposed innovations so that they will authorize the changes, even if they entail no investment and all the more so if they do. The higher the technical level of the administrative staff, the easier this task becomes. Unfortunately, for obvious reasons, the directors' posts are occupied not always by persons with previous experience in steelmaking, but by outstanding figures in the business, finance and political world, or simply in society. If consideration is given to the awkward financial situation of most steel industries and the necessarily defensive position assumed by some directors, it is not surprising that the latter act, as a rule, as a moderating element in the introduction of technological innovations in the steel industry. In practice, with rare exceptions, only a strong and competent personality, or several acting together among the directors, management or senior technical staff would be capable of overcoming this kind of obstacle and gearing the plant's general policy to the greatest possible technological aggressiveness. Very probably a cursory investigation would serve to identify those responsible for encouraging and maintaining a progressive attitude in the plants that hav been classified as aggressive. During the visits to ten enterprises it was noted that not a few persons of this category were following that course of action in different plants. It is out of place to mention them in this study, but in order to make quite clear the purposes underlying these statements, it is important to recall as an example Louis Ensch's great influence in the progress of the Brazilian steel industry.

Annex I

THE DIVISION AND DISPERSION OF TECHNOLOGICAL RESPONSIBILITY IN THE CONSTRUCTION OF A STEEL INDUSTRY[1/]

1. Planning, construction and start of operations of new plants

In order to analyze the particular case of the steel industry, consideration should be given to the salient characteristics of the assimilation of foreign technical progress throughout the process of investing capital and obtaining the highest possible productivity. It is important to bear in mind that investment does not always involve the assimilation of technical progress. Capital has existed for a long time and has served many purposes, but this very fact shows that if the investment does not help to increase manpower productivity in a given activity, it cannot be assumed that the technological level has been raised.

The fundamental economic objective which should be pursued by the steel industry is to produce steel ingots at the lowest possible cost. A long-term approach must be adopted to development. This entails considering all the factors and their respective trends which can and do affect projects and achievements over the long term. Of course, it is not always possible to forecast what the situation will be in the case of several factors, especially those most affected by unstable economic conditions; but this does not prevent others, particularly those controlled by the firm receiving technical know-how, from being analyzed, evaluated and put into practice.

The following comments relate to the characteristics of the technical assistance available to a new steel industry, highlighting the problems involved in this transfer and the action that may be taken to attenuate any adverse economic effects.

1/ Based largely on the document entitled La tecnología actual y los obstáculos a su incorporación en la industria siderúrgica latinoamericana (ST/ECLA/Conf.23/L.34), August 1965, prepared by the consultant Armando P. Martijena for the ECLA secretariat.

/External technical

External technical aid is an onerous service and one of the many items included in investment. Responsibility for the efficiency of this service in every case rests equally on the contracting parties. The transfer of assistance is subject to a number of requirements and conditions which must be harmonious and not produce a contrary effect. Since these requirements stem from the wishes of the two parties, it must be assumed that, in order to obtain the best possible results, their contributions should be based on the respective qualifications. The value of each transfer depends on its scope and depth, both of which should be predetermined; but it is the buyer who must define clearly what he wants, accept a fair price for the offer and demand that he receives what he was promised.

The economic consequences of the transfer of technical know-how must be borne primarily by the recipient. This is yet another reason why he should proceed cautiously and do everything in his power to achieve maximum efficiency during his negotiations. But apart from the imbalance with which the results of the transfer of technical know-how are usually projected, it would be neither logical nor fair to distribute the responsibility for the practical results before carefully analyzing the development of the whole process.

The transfer covers a sequence of activities: over-all and feasibility studies, general project, plan, execution, detail projects, construction and installation, tests, start of operations, etc. The various methods used to obtain technical assistance show different degrees of decentralization of responsibility. In few, if any, cases do the contracts cover all the areas in which external assistance is necessary in including operational training. In some cases the local enterprise requests a firm to undertake the over-all study, feasibility study and general project and then, with or without technical guidance, concludes contracts with specialized firms for the supply of equipment, including the execution of detail projects and the installation and start of operations of the equipment they supply.

In other cases, the over-all and feasibility studies are carried out by a firm whose contract ends with the relevant report. A second

/firm provides

firm provides the advisory assistance and technical management to execute the project up to the start of operations of the complete plant; then, under its supervision or with its advisory assistance, contracts are concluded with specialized firms for the supply of equipment, execution of detail projects, installation, start of operations and smooth running in of the plant. In all these cases, the decisions regarding the work and equipment are adopted by the local enterprise.

Another procedure is to make one specialized firm responsible for the project, and to entrust the top-level technical management of its execution from the construction stage to the start of operations to other firms which co-operate with one another.

Everything seems to indicate that the best procedures are those where the responsibility throughout the process is centralized in the hands of one firm with complete technical authority from the preliminary studies to the start of operations of the whole project.

Continuity of operation results in benefits, particularly if the price of the service provided is proportional to the expected operational results. Moreover, it is thus possible to obtain a more suitable over-all quotation than by any other procedure. Naturally, this method compels the local enterprise to ensure continuity and control, for which purpose it can also obtain foreign technical assistance on a permanent or temporary basis. But the main advantage is that in the case of complete contracts there will be no division of responsibility.

When technical assistance is obtained from several firms, even over different periods, it is impossible to prevent a division of responsibility which results in dangerous gaps. However, it is difficult to centralize all the responsibility, even when the technical management is in the hands of one firm, since the local firm's intervention will always partially and to a varying extent, depending on each case, diminish the responsibility contracted in theory. For this reason it is particularly important that the technical management contracted should unreservedly take part in and approve all detail projects prepared by firms of specialists, approve all purchases, equipment tests, etc. Notwithstanding the above, local factors may impose special conditions for the methods of obtaining foreign know-how, as occurred at Volta Redonda. The main point is that certain basic criteria for the planning and execution of new developments should be respected.

2. Basic criteria for the project, construction and start of operations

A new project will be better planned and executed if greater attention is paid to the technical and economic criteria for the manufacture of steel products.

The freedom of action, within certain limits, of firms which undertake to transmit technical know-how is hampered in many projects. In some cases, the local enterprise has already established the sources of supply, and in others, either wholly or in part, the type and/or volume of production, objectives, successive stages of development, location of the plants, processes to be used in each stage, etc.

Obviously, limitations of this kind established beforehand are completely arbitrary from an economic point of view, since they involve factors whose importance can be gauged only as a result of planning. Such conditions seriously obstruct the firm that is providing the technical assistance in the fulfilment of its responsibilities.

The initial investment capacity for the first stage of a development project is a limiting factor which the local enterprise usually establishes beforehand. But this capacity depends, of course, on how the investment is actually spread over the period covered by the project, the terms obtainable for purchases abroad, the plant's operational return, etc. Therefore, it should be clearly understood by both parties that to predetermine this factor is somewhat risky. The only factor which should be established beforehand in planning a plant is the social capital which may be needed during the period covered by the project, construction and start of operations, and it should be left to those providing the technical assistance to suggest the most suitable structure of the total capital, the amount of foreign credit that may be obtained and the capital which may feasibly be invested in the first stage and, possibly, in subsequent stages. This procedure is not normally followed.

/It commonly happens

It commonly happens that the technical and economic criteria for the production of steel are not duly complied with, because the obligations and responsibilities of those providing the technical assistance and those receiving it have not been properly established. This is a crucial problem. To ensure that the technical assistance will yield the best possible results, it is imperative to lay down exactly what type and quality of equipment should be bought and what means should be used to check the quality of the assistance, and the proper safeguards should be established to ensure correct delivery. In order to fulfil these requirements, the purchaser must undoubtedly be highly qualified and experienced.

Perhaps the basic reason for the deficiencies observed is the failure to give due weight to the economic projections of the use of technical know-how, in all the phases of development in a given project. Any deficiency in the action adopted by one party will naturally prompt the other party to take steps to protect itself from any eventuality.

Once the extent to which the rate of return will be affected by the raw materials, processes and machines to be purchased has been accurately determined by those providing the technical assistance, there should be no difficulty in measuring their economic significance in the project. Moreover, the solutions suggested should be compared with other possible solutions.

A long-term approach should be adopted to development projects. The long-term objectives cannot be fully attained unless attention is paid to the financial implicatons which the factors involved will have in the industry's economic and financial development. It may be noted that in several projects no such long-term view has been adopted. In other cases it is thought that they have been satisfied, once the final stages of the future expansions have been broadly outlined, but a cursory analysis suffices to show that the factors on w ich this outline is based are neither consistent nor sound.

It is sometimes contended that analyses based on hypotheses which may change radically in the course of time are not really practical; but it is always better to adjust the projections when necessary than to adopt a short-term approach to the projects and activities.

It should be kept well in mind that the steel industry operates within the context of general industry and that, in particular, it is economically affected by sectors which provide it with raw materials, other materials, and services of different kinds. The situation of those sectors should be carefully analyzed, not only in the planning stage but also in the subsequent phases of construction and entry into operations.

There is not much doubt that from the preliminary planning derive the main forces which hamper technological development in the steel industry. In some cases, the studies are incomplete or have not been prepared in sufficient depth. The much needed external aid is requested from time to time, mostly to deal with partial problems without the indispensable over-all view. In some projects there was no preliminary planning, since a collection of superficial and piecemeal information sometimes provided by unqualified persons cannot be described as such.

With incomplete preliminary studies or without them, decisions are adopted regarding the supply of raw materials, the location of plants and, in some cases, the processes and the volume and diversification of the final production.

In most cases, however, more external aid was received in the preparation of projects; but, as noted above, often the know-how was transferred on previously, and sometimes arbitrarily, established bases. In these cases, the foreign firm can hardly be held responsible for mistakes and differences, unless it had signed a contract giving it the responsibility and complete freedom of action to revise all the decisions adopted thus far. Therefore it is understandable that, as a general rule, the firms responsible for preparing a project should base their studies on the information received from the local enterprise, and should make it quite clear that in the event of any changes in that information the projects and proposals should be revised accordingly.

The local enterprise would always be able to obtain the necessary data to accept or reject a given proposal; in case of doubt, the best course would be to seek advice from third parties of recognised ability and repute.

/It is common

It is common knowledge that technical assistance is provided in line with certain fixed rules established jointly by the firms engaged in this activity to protect their interests. But although they contain limitations of different kinds, these rules are in no way a threat to the essential rights of the buyer.

3. Basic criteria for planning and the general project

Planning should not jeopardize the basic economic objective pursued, i.e., the concentration of resources in the most advantageous production lines. Be that as it may, several *de facto* situations exist which show that this requirement has not been observed as strictly as it should, mainly because economic considerations have been relegated to second place and other criteria have prevailed, such as: import substitution, regional development, and consolidation of positions in expectation of a big enough market and to satisfy national defence needs.

Some of these weak points are dealt with below:

(i) Size of the market and economies of scale. Economies of scale have a marked effect on investment and operational costs in the steel industry. Although there is a well-known relationship between the volume and the efficiency of investment, with few exceptions the development of Brazil's steel industry has been planned and executed without considering this factor. Many plants were constructed when the market was barely sufficient for a fraction of the final planned capacity. In order to alleviate somewhat the adverse effects of the inadequate market, these plants were constructed by stages with very uneven capacities between one production department and another, which added to the unfavourable effect of the idle capacity of the units which were initially too large and were intended to be fully utilized in the final stages of the proposed capacity. Since there are several plants in this position competing for a small market, the situation described above is being excessively prolonged. Even today, no Brazilian plant has the capacity to satisfy the conditions normally required for favourable economies of scale in their respective groups, although these deficiencies will gradually diminish if the new National Steel Plan is implemented.

/(ii) Location

(ii) Location of the plant. Several plants in Brazil were constructed in unsuitable locations from an economic standpoint. Still more serious is the case of a number of projects for new plants which are under study or being negotiated, whose planning to a great extent ignores all economic considerations and is mainly guided by political criteria, such as the desire of nearly every Federal state to construct its own steel plant. The ideal location for all plants making common steel is an area where the assembly cost of raw materials and transporting the finished products to the respective markets is lowest. In selecting the location of a plant, the fact is often overlooked that the quality, price and additional costs involved in the handling, transport and preparation of the raw materials affect the cost of building up stocks. Another frequent mistake is that, probably as a matter of simple convenience, the plants are located in the vicinity of population centres.

(iii) Study of raw materials. In some cases the study of local raw materials has not been sufficiently thorough, since the manufacturing processes were chosen on the basis of piecemeal studies. A study of this kind should be comprehensive, i.e., it should cover iron ore, manganese, limestone, dolomites, fuels, electric power, refractories, water, etc. In several cases the study of raw materials was not carried far enough to determine alternative supply possibilities, and these were not assessed in relation to their influence on the cost of production. The more negative the influence of certain production factors is, especially if they escape the firm's control, the greater should be the attention to their price and procurement. Examples of this are the limitations deriving from the small market and the high prices of fuels in Brazil in general.

(iv) Economic relationship between raw materials and the processes used. The only possible way of establishing this relationship is to make a careful examination of the possible manufacturing processes applicable to the available raw materials, and their effects on costs. The study cannot relate exclusively to foreseeable conditions for the start of operations; it must cover projections for different supply values over a sufficient period of time, since if there are any changes in the annual

/volume of

volume of production, the economic relations between the processes and the inputs will also vary. This aspect of the analysis, which would enable the effect of economies of scale to be assessed in each case, has not been considered in the proper scope and depth. If a different procedure had been adopted, no doubt different processes would also have been chosen, or at least the initial volume of production of some units would have been modified.

In planning the first large integrated steel plant, the prevailing objective was to use local coal, even though its weighted price was much higher than that of imported coal, and its quality inferior. The firm purpose of replacing imports prevailed over technical and economic criteria. A different course might have been followed if the real economic significance of this import substitution had been fully analyzed and account taken of the indirect effects of higher steel prices on the engineering and durable products industries and on potential exports of manufactured goods.

(v) Saving in fuels. A complete analysis of this question covers the following key points which have not always been considered in planning a steel plant: (a) the thermal efficiency of the furnaces and electric power plants; (b) the use of all waste heat; (c) conservation of heat. The saving in energy which can be obtained in the production furnaces is undoubtedly the most important item within this context. Sometimes, however, the advantage gained by saving of fuel in the reduction of ore is offset by the low yield obtained from the steel ingots in the rolling mills. Therefore it is important to consider the saving that can be effected throughout the process. It would thus be possible to measure the effects on such saving of the technological advances used in modern steelmaking (preparation of raw materials, use of oxygen in the reduction of ore and fines, utilization of heat from the steel ingots, production of high-pressure steam, etc.).

(vi) Choice of range of products. The enormous economic advantage obtainable through specialization in the rolling mills does not seem to have been properly assessed. As rolling equipment becomes increasingly specialized, the number of types of rolled products it can produce diminishes. This is the result of the efforts to obtain a greater saving

/in labour, fuels,

in labour, fuels, etc., since they led to the manufacture of larger and heavier ingots, blooms, etc. A pronounced tendency to diversify the production of rolled products will make it necessary to operate the mills at a much slower pace than their full production capacity. It should be remembered that the size of all mills is determined by the maximum size of the product it is wished to obtain, and that optimal production is attained when rolling those products.

(vii) General project and projections for its execution. Once the over-all study is completed and, consequently, the project's economic feasibility has been established, a start is made on the general project. One aspect of the general project which is of particular interest and is often not studied in sufficient detail is what may be termed the plan of execution of the project. This plan covers all the necessary provisions for systematically carrying out the construction and installation work and for training the labour force so as to ensure the highest possible return on the investment.

When the stage of execution of the project is reached, there is usually a decentralization of responsibility since the local enterprise assumes part of the management of the work from the foreign technical assistance. Responsibility is usually divided and the results of this division depend largely on the amplitude to which the local enterprise carries its part and on the procedures adopted. One of the commonest effects is the lack of complete forecasts at the level of execution of the project.

Examples of palpable defects in the plans of execution may be observed in the errors made in estimating pre-production expenditure, in relation to the amount of local investment required, and in the shortcomings of the organic structure of the enterprises.

There are cases in which execution has taken over seven years from the time when the general project for the construction and installation was completed until the stage-by-stage operation of the producing units was about to begin.

(viii) Study of the economic and financial development of an enterprise. The study and consideration of all factors contributing to a company's operational costs is usually incomplete. Neither is a

/sufficiently long-term

sufficiently long-term approach adopted in these studies, which makes it difficult to obtain a clear view of the firm's probable economic and financial development. The level of technology of the science of administration applied in the steel industry should be high, and thus provide sound guidance in channelling action through efficient instruments for achieving specific objectives. Nevertheless, the projects do not go far enough into a calculation of total operating costs, for which purpose it would be necessary to study and determine the organic structure of the whole enterprise, analyze the characteristics and organization of the markets, etc.

Only occasionally are thorough detailed calculations made of pre-production expenditure and administrative and sales costs and structure. Nor has special attention been paid to determining the policy that should govern the amortization, the integration of share capital, establishing of reserves and fixing sales prices; estimating the effects which amortizations, long-term credit and interest will have over time; or ascertaining what credit is required for the plant's operation, etc. The working capital requirements are sometimes established by means of rough approximations instead of a detailed study, according to local conditions, of the amount which the different items of the assets and liabilities may reach. The lack of a real study of the economic and financial development of enterprises over a long enough period of observation to be able to evaluate the problems they will have to face, at least until they are operating with a normal degree of efficiency, is a serious omission.

(ix) Some technological problems affecting the execution of projects. Certain shortcomings in the projects interfere with their execution. The construction and installation work imposes severe requirements on the management of local enterprises, even when they are backed by the technical management of a specialized foreign firm. Real technical management is not always exercised in practice. If functions and responsibilities are not clearly defined beforehand, it commonly happens that the foreign firm merely fulfils the functions of providing advisory assistance, while the local enterprise must fill the gaps in management, with the resulting transfer of responsibility.

/Sometimes the

Sometimes the desire of certain executives to introduce reserves - - particularly in regard to relations with local staff organizations and also in administrative activities - is responsible for a decentralization in the execution of technical management, which contributes to the division of responsibilities. If foreign technical assistance is confined to advisory services, because the local enterprise reserves the executive powers for itself, it is all the more necessary to determine what areas are covered by such assistance.

Several firms of suppliers of equipment normally take part in the work of construction and installation. It is vitally important to obtain foreign technical assistance in inspecting the manufacture of equipment, its acceptance and operating tests. The detail project for the foundations for fixed machines and installations, buildings, etc. involves activities which should be carefully distributed and co-ordinated so as to avoid overlapping and loss of time and resources.

The suppliers normally assume responsibility for installing and starting the machines. Nearly all the difficulties which arise in connexion with these activities are due to omissions in the specifications and/or the conditions under which the acceptance tests must be carried out. It is therefore essential to receive responsible foreign technical aid right from the start.

(x) Some technical problems at the start of operations. In order to prevent these problems from accumulating and thus exceeding the operational capacity of the labour force or producing costly idle capacity, the usual procedure is to plan the completion of the installation work in such a way that the production departments enter gradually into operation. A reasonable dephasing of some two months or more makes it easier to overcome any defects discovered in the tests and start of operations.

The key importance of maintenance staff and resources, particularly in plants which are a long distance from sufficiently industrialized centres, has sometimes been under-estimated. The training of this staff and the adequate provision of resources have often been neglected during the preparation and execution of projects, precisely for want of sufficient attention to local conditions in the provision of foreign technical

/assistance. Generally

assistance. Generally, the maintenance staff must take an active part in the start of operations until the machines are running smoothly. Any shortcomings of this staff during the start of operations and any shortage of maintenance machines and equipment necessitate emergency measures which are always costly and detrimental.

A factor which helps to aggravate this situation is the failure to provide an adequate stock of spare parts. Because of this, one plant was forced to stop a whole production department for some time. The foreign firm providing technical assistance usually finds it difficult to establish adequate reserves. Ignorance of local conditions and its knowledge of what might be the results of any lack of foresight induce it to establish maximum figures. The local enterprise usually reacts to this by reducing the quantities as it sees fit, with the resulting shift of responsibility. The fact that attention is usually centred on the performance of the machines, equipment and installations, measured by the physical units produced, has sometimes caused other aspects, which combine to make the plant efficient, to be overlooked. Foreign technical aid is generally used to expand this performance, regardless of the needs in relation to other operational factors.