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INFLUENCE OF LOCAL FACTORS ON THE IRON AND STEEL INDUSTRY IN LATIN AMERICA

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/CHAPTER III.

INFLUENCE OF LOCAL FACTORS ON THE IRON AND STEEL INDUSTRY IN LATIN AMERICA

INTRODUCTION

1. Scope and Purpose of the Study

Although the iron ore reserves of Latin America have not yet been prospected fully, it is known that the region is rich in high-grade ores. Reserves investigated so far, represent approximately 20 per cent of total known world reserves. Only a small amount of iron ore is at present mined in the region, representing in 1950 about 4 per cent of the world production.

The relatively slow development of iron ore mining is mainly due to the low iron and steel consumption of the region. This, in turn, is related to the low national income prevailing in most Latin-American countries. Another factor which limits iron and steel production is an almost general scarcity of good coking coals. Most of the steel plants would be compelled to transport their coal for long distances and many of them supplement local production by imports. Other possibilities which have scarcely been used so far, would be a resort to substitutes for coal, or to use other reduction methods than the blast furnace.

An additional obstacle to development of the industry in the region, is the general shortage of capital. Such shortage is of considerable consequence as the steel industry requires high investments.

The present study has two main objectives; first to determine the influence on the cost structure of the industry, of factors which originate in the location of the plants such as quality of raw materials and their distance from the plants, wage rates, etc.; and second to point out the technical problems which the industry would have to solve in order to make better use of available resources and to reduce costs.

Seven Latin-American countries have been selected for this comparative study. They are, Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela. They are either operating steel plants already, or are building them; others appear to have resources and possibilities for the operation of a steel plant. In each of these countries, one location for an imaginary steel plant was selected as an example. Pig iron, steel ingot and finished steel costs were then estimated for each one of these, in the imaginary plants. The selection of the site was preferably chosen for places where

/either a

either a steel industry exists or construction has been under consideration. Information regarding the factors which build up costs, was thus facilitated. The inclusion of a certain site in this study does not imply an opinion as to its comparative advantages in relation to other locations in the same country; nor does it imply that the selection of the raw materials cannot be improved by using different combinations.

Since steelmaking by the classical process of blast furnace, steel shop and rolling mills is the most widely used, and the one about which most information and cost figures have been published, the present analysis refers exclusively to this process. For each location at least two possibilities will be considered, namely, a) where the industry mines all or part of its raw materials, in which case it is called an integrated plant, and b) where the industry purchases its raw materials from other sources.1/

Scale of operation has important bearing on steel costs and, since it is determined by the size of the markets, it also becomes a locational factor in Latin America. To simplify, the total study has been divided into two parts, the first of which, contained in the present document, analyses the influence of the locational factors except size of the market, and document L.91, determines the influence of the scale of operation exclusively. The imaginary plants in the various countries are all of equal size, 250 thousand tons of finished steel per year. The most favourable selection of raw materials for each location has been determined, and production costs and the necessary investments have then been estimated. A considerable number of prices, and of various cost factors of minor importance, were not investigated in detail, but instead general assumptions were used. Many of these assumptions are based on conditions prevailing in the United States in 1948, and without too great a margin of error, they are still representative for general estimates. Because of the necessity to determine the overall results of these assumptions, and the desire to obtain a basis for comparison with costs of steel produced in one of the exporting countries, an identical imaginary plant was located on the Atlantic coast of the United States.

1/ Since the latter is the simpler case, the full set of calculations referring to it will be made first, and afterwards the necessary valuations for an integrated plant will be introduced.

/In regard to

In regard to the second objective, that of finding through analysis the main technical and economic problems facing the steel industries in Latin America, the procedure followed consisted in investigating the different cost items which appeared abnormally high in each location. The prospect for future research into such cost raising factors, were then analysed in the light of the documents presented at Bogotá. Comparisons were facilitated because the design of the imaginary plants is identical, except for differences which might arise due to variations in the composition of iron ore and fuel. Except for differences in raw materials costs, the main variations in costs are those caused by wage rates.

The usual procedure for cost analysis of a steel plant, is the separation of the different factors into two groups: a) assembly costs, and b) conversion costs. Assembly costs comprise the cost of mining and transportation of the essential raw materials to the plant. Conversion costs are those which arise from the transformation of these raw materials into pig iron, steel ingot and steel products.

The principal variations in pig iron costs produced in different plants are caused by differences in "assembly costs". In the present case conversion costs should be relatively constant except for the prevailing wage rates, as the plants are equally mechanized.

Since wage rates are one of the factors influenced by location, determination of costs in this paper departs from the usual procedure, separating labour from the remaining conversion costs. In this way the study is more flexible, as the addition of the wages to the other expenses yields the usual two groups of assembly costs and conversion costs.

2. Description of the Imaginary Plants

To summarize, this study refers to steel plants using coke blast furnaces, having an annual capacity of 250 thousand tons of finished steel, and as outlined in the first part of this study, purchase their iron ore, coal and limestone.

In addition to a number of general services, the productive sections of an industry of this type consist of: the blast furnaces and auxiliary equipment (handling of raw materials), coke ovens, by-products plant, transport facilities for liquid pig iron, pig casting machine, slag handling equipment,

/and mechanical

and mechanical facilities to treat, size and mix raw materials and fluxes.

The steel shop consists of a mixer (a refractory-lined tank to store liquid pig iron), steel furnaces, ingot moulds (cast iron moulds to receive the liquid steel and transform it into ingots), plus the necessary equipment to transport the raw materials and the hot metal in different stages, and that required to handle the scrap. Three types of steelmaking processes have been envisaged; their selection depends on analysis of the iron ore. They are the open hearth process, a combination of acid converters and open hearth, and the combination of basic converters and an electric steel furnace. The plant must melt and mix with the fresh material, two types of scrap: the scrap produced by the rolling mill itself, which will henceforth be referred to as "circulating scrap", and whatever scrap can be purchased outside to lower steel costs, and which will be called "purchased scrap".

The rolling mill consists of a blooming mill to roll the ingots pre-heated in pit furnaces into blooms, slabs or billets, according to size and shape of the final product. Next in order is the final rolling or finishing of the steel. Incidentally, the scale of operation has a greater bearing on this particular section, as it influences the degree of mechanization of the rolling mills.

Between the various blooming and rolling mills, there are re-heating furnaces to maintain the semi-finished steel at the necessary temperature, cranes and roller tables for its transportation, cold rolling, rectifiers, and shears for the finishing process, and finally, a special shop for the maintenance of the rollers.

The general services of the plant comprise administrative offices, transport within the plant, laboratories, warehouses, general repair shops, electric power facilities, lighting, steam, gas, sanitary services and so on.

3. Description of the Industrial Process

Iron ore, coke and fluxes, loaded into the upper part of the furnace, constitute the burden. The raw materials (mostly classified by size, within fairly narrow limits) are loaded into the furnace in strictly controlled doses, depending on their analysis. Hot air is injected at high pressure into the lower part of the furnace. It burns part of the coke raising the temperature sufficiently for the excess of fuel to react with the oxygen

/content of the

content of the ore, reducing it to liquid metal that accumulates in the lower part of the furnace. The hot gases leave the upper part of the blast furnace and, in passing through the layers of iron ore and coke, lose most of their excess temperature, pre-heating the material as they go down. The ore impurities, the ash of the coke and the fluxes make up the slag, which also drops to the bottom and floats on the top of the liquid iron owing to its lower specific gravity. The slag plays an important part in the process, protecting the metal from re-oxidation. The gases when leaving the blast furnace retain a relatively small amount of heating value. Part of them is used to pre-heat the air used in the blast furnace and the rest is generally mixed with the richer gas from the coke ovens to produce electric power, to be used for general heating purposes. Any excess of gas is sold. The liquid metal and the slag are extracted at regular intervals. The liquid pig iron is either carried directly to the converters, where these exist, to the mixer for storage, or to the pig-making machine. The slag is usually granulated with water and often used as a raw material for cement manufacture.

The liquid pig iron contains many impurities: carbon, silicon, manganese, phosphorus and sulphur. The reduction of their contents to certain established limits, usually very low, is called steelmaking. The processes used for such refining are based on the fact that these impurities have a greater affinity for air than for iron.1/

The oxidizing agents used for steelmaking are air, high grade iron ore, oxygen, and oxygen enriched air. The liquid steel thus obtained has often to be recarburized, or different alloys added, in the ladles coming from the steel furnaces. Once its chemical composition is satisfactory, it is poured into ingot moulds. Size and shape of the ingots varies in accordance with the products to be rolled and the size of the blooming mill. In order to reduce the section of the steel ingots or semi-manufactured products to final shape, they are placed between two moving steel cylinders which are often grooved in order to give the products a definite shape. This process is repeated using successively smaller sizes of final grooves, or increasing the pressure between the rolls, until the final section is obtained.

1/ With the exception of sulphur which is usually eliminated, in combination with lime, as sulphide of lime.

/4. Countries and

CHAPTER I - DATA ON SELECTED LOCATIONS

1. Countries and Locations Selected as Examples

One imaginary plant is assumed to be located in each of the following countries: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela, comprising about 80 per cent of the population of the region and accounting for 90 per cent of its steel consumption. 1/

a) Argentina

The most recent Argentine steel plant envisages the construction of three main plants: a) a large plant in San Nicolás on the Paraná River, using either imported or Sierra Grande ores, b) a small plant based on charcoal blast furnaces in the north, near the Zapla deposits, c) a medium size plant in the south, using Sierra Grande ores and possibly Rio Turbio coals supplemented by a binder.

For the purpose of the comparisons in this document, San Nicolás will be the only site considered; it is located between Buenos Aires and Rosario, the two most important steel consuming centres in the country. Cost estimates will be prepared using three different sources of iron ore: 1) Zapla ore of 48 per cent grade, transported by rail; 2) Sierra Grande ore of 57 per cent grade, brought by sea and river; and 3) Brazilian Itabira ore, 65 per cent grade, which will be shipped from Victoria. In each of these cases, the coking coal is assumed to be imported.

A fourth possibility, which has not been considered, consists of using iron ore from the Urucúm deposits, near Corumbá, Brazil, on the upper bank of the Paraná River, or alternatively from a Bolivia deposit on the opposite bank of the same river. Both these possible sources would require the upper Paraguay, and possibly part of the Paraná River, to be dredged.

b) Brazil

Among the many possibilities in this country, only the location at Volta Redonda will be considered, using iron ore from Lafaieta (65 per cent grade) and coke from a blend of 70 per cent imported and 30 per cent Brazilian coal.

1/ In this paper, steel consumption will include rolling mill products and also some easily manufactured steel products such as: wire, nails, tubes, etc. It does not include steel contained in manufactured goods, such as durable consumer goods, machinery, equipment, etc.

/c) Chile

c) Chile

The site at the Bahía San Vicente, where the Huachipato plant is now located, was chosen as the example. Iron ore was assumed to be 60 per cent grade from "El Tofo" and coke from a blend of 85 per cent Chilean and 15 per cent imported coal.

d) Colombia

Calculations were made in accordance with the raw material supply and location of the Paz de Rio project (Belencito). High phosphorus content ore of 47 per cent grade, and coke made entirely from local coal, will be used. The main departure from the existing project consists in the size of the plant and that it is assumed flat products will also be produced.

e) Mexico

Among the many existing possibilities, the location and sources of raw material of the Monclova plant were chosen. Iron ore will be 60 per cent grade from Cerro de Mercado and coke produced entirely from Sabinas coal (State of Coahuila).

f) Peru

The selected plant has been located at Chimbote. It would use 60 per cent grade ore from Marcona, transported by sea to Chimbote. The fuel would consist of a variety of coke made of 15 per cent imported asphalt and 85 per cent anthracites from the Santa Valley region.

g) Venezuela

Owing to the proximity of the Naricual coal deposits, the imaginary plant was presumed to be at the Port of Barcelona, using "El Pao" ore (65 per cent grade). Two fuel possibilities were considered: a) the use of coke made from asphalt or petroleum residues, and b) coke produced from imported coal which could advantageously be transported as return freight on ships exporting iron ore.

h) United States

An identical plant to those assumed in the Latin-American locations was assumed to be at Sparrows Point, Maryland, where the Bethlehem Steel Corporation at present owns a plant using Chilean and Venezuelan ores. The hypothetical plant would use 65 per cent grade iron ore from "El Pao" and coke from West Virginia coals.

/2. General Basis

2. General Basis for Calculations

It has been assumed that, in all locations selected, the plant would be able to purchase scrap amounting to between 9 and 11 per cent of the requirements of the steel shop, at a price equivalent to 90 per cent of the pig iron cost.

As all the plants are assumed to have an annual capacity of 250 thousand tons of finished steel, the optimum capacity for the blast furnace would be about 800 tons of pig iron daily. An additional reason for accepting this capacity is that it does not appear to make excessive demands upon the quality of the coke. Except in those cases where the composition of the iron ore has influenced the steelmaking process, the design and degree of mechanization of all the plants has been assumed to be identical, and that they are equipped with the latest technical improvements justifiable on economic grounds. This assumption has permitted the use of identical figures for various consumptions expressed in physical units or of unit values.1/

Thus, uniform costs or prices have been adopted for the items detailed in Annex I. Among these general assumptions, the following important items should be mentioned: mining cost of iron ore and limestone (open pit operations in all plants), cost of transporting and pumping cooling water, cost of imported coal f.o.b.,prices of ferroalloys and other fluxes, cost of hydro-electric power, transport costs both for the raw materials and the finished products, equal need and costs for repairs and replacements per unit of steel produced, and lastly, capital charges.

With a view to simplifying calculations and eliminating the need to collect a variety of detailed data on the spot, and at the same time to maintain comparability, different assumptions of a technical nature were also made. Some of these appear in the text, together with the pertinent analysis, while others appear in the Annexes, and thirdly, the simplest are outlined below:

1/ It is evident that this generalization does not take the difference of wage rates from one country to the other into account. However, as the proportion of labour in many raw materials is small, the simplification of the calculations obtained by this method justifies the small margin of error which might arise.

/a) It was assumed

a) It was assumed that productivity of the workers in all these plants was the same as in the United States, although in countries where the steel industry would be new, efficiency could only be reached after several years' operation;

b) The assortment of finished products manufactured greatly influences the cost of labour and its efficiency. It is assumed that all the plants would produce the same assortment and equal quantities of the different products;

c) It was assumed that the daily output of the blast furnaces, identical in every case, is independent of the grade of ores considered in this study. This hypothesis is not actually true, but again the small margin of error to which it may give rise can be ignored.

The only raw material which has not been included in the above generalization is the coal of domestic production. Geological conditions, the thickness of the veins, and the scale of operation greatly influence its cost. On the other hand, since fuel influences the cost structure considerably, a wrong cost figure for it could greatly affect the results of this analysis. Hence fuel prices prevailing in 1948 were adopted for the existing deposits. In cases where the deposits must still be developed, as would apply for most of the integrated plants, an estimate was made based on expected productivity, taking into account geological conditions, size of the mine, prevailing wage rates and other data.

The basic assumption that most of the factors of secondary importance do not vary significantly from one plant to another, implies that differences in final cost will be due exclusively to a few important factors. They refer mainly to the quality of raw materials and their location, wage rates, etc. Accordingly, it becomes important to know: a) iron content of the ore and both carbon content and coking properties of the coal. With this information the quantity of raw materials required per ton of products can be determined; b) quantity and composition of certain impurities contained in ore and coal, to ascertain the steelmaking process, the amount of fluxes and ferroalloys to be employed; c) the distances and means of transport, in order to evaluate the cost of raw materials at plant; and d) the wage rates prevailing in similar activities. Calculations in this Paper have been organized as follows:

/a) Although costs

a) Although costs in an integrated plant1/ will be analysed after completing the study of a plant purchasing its raw materials, an analysis will first be made of the probable cost of mining the various raw materials. Next, it is assumed that the plants will purchase raw materials from other enterprises, at prices estimated in view of the preceding analysis.

b) The raw materials costs thus obtained, will be used to calculate probable pig iron costs;2/

c) The resultant cost of pig iron, will be used to estimate the cost of steel ingots;

d) The price of steel ingots so obtained will be used to estimate the cost of finished steel;

e) Combining the data thus obtained, the aggregate position of the conversion process will be analysed and certain conclusions concerning the cost structure of the industry determined;

f) The cost of the raw materials used in the blast furnace will be substituted by the necessary mining and transport costs to present the case of an integrated industry. Finally, an analysis of the variations of cost, if steel consumption increases in Latin America, will be prepared, and a comparison made with costs of imported steel.

CHAPTER II. PIG IRON COSTS

Pig iron costs will first be determined by the assumption that the steel plants have to purchase their iron ore, coal and limestone from other organizations.

1. Assembly Costs

Assembly costs have already been defined as mining of the main raw materials, and their transportation costs to the blast furnace. Since the

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1/ A plant which mines at least some part of its raw materials.

2/ All prices and value in this paper, unless otherwise indicated are at the 1948 value of the dollar.

/proportion of

proportion of such raw materials, necessary to produce one ton of pig iron, is high, ranging from 3 to 5 tons, assembly costs have an important bearing on the final cost of pig iron. In the following, the situation concerning the most important raw materials is discussed:

a) Iron ore

The influence on the cost of iron ore supplies is analysed in Annex 3. The iron content of the ore (grade), the amounts necessary per ton of pig iron, the distance and the means of transport are shown there. The data on which the estimates of Annex 3 are based, are the following: costs of iron ore and transport rates from Annex 1; total cost of iron ore in the plant, Annex 2. Regarding the amount of ferrous materials necessary for the production of one ton of pig iron, one thousand kilogrammes has been accepted. Thus, a small margin exists to cover unavoidable losses in the blast furnace.

Railway transportation has been the basis for overland transport costs. In some instances, the distances are very short and cost could be reduced by the use of road vehicles, in which case the figures shown in Annex 3 would perhaps be exaggerated. Sea transport was estimated on the basis of normal prevailing rates. It is thus excessive if the steel plant owns the ore ships. Consequently, the cost of ore per ton of pig iron, as shown in Annex 3, represents the probable maximum.

Attention should be drawn to the very high ore cost at the Argentine blast furnace of San Nicolás, if working with Zapla ore. The high price is due to the combination of relatively low grade iron ore, with a long railway haulage. This is the most unfavourable condition which can arise in practice. Therefore, calculations are also included based on Sierra Grande, or imported iron ore from Itabira, Brazil.

b) Coal costs

Annex 4 shows the statistics for the coal supply. The origin of the respective fuels are indicated and the proportions for blending in cases where more than one type of coal has been employed. Prices prevailing at the port of origin and transport cost to the plant are also presented, to obtain the cost of fuel at plant. Annex 5 determines the cost of the blend at each coke plant, the amount of coal necessary, and the resulting

/costs per

costs per ton of pig iron. The high price of Santa Catarina coking coal in Brazil is particularly notable, and is explained by difficulties in mining and washing. Through the latter process, two types of fuel are obtained: metallurgical coal for use in the coking plant and steam coal for which other applications must be found. Provision has been made to account for any increase in the price of coking coal, which might arise from losses in the sale of the other fraction.

From this annex, the advantage of the countries which mine their own coking coal becomes apparent. This is of course due to the relatively small price of coal compared with freight costs. The low value of imported coal in Venezuela, as compared with the high prices in Argentina, Brazil and Chile, is due to the assumption that coal could be transported as return freight in ships exporting iron ore.

c) Limestone costs

Annex 6 presents the figures for limestone costs, which are based on data contained in Annex 1. Except in Argentina, should Zapla ore be used, and in Chile, limestone is but a small item within total costs. The high figure for Argentina stems from the large amount required because of the low grade of the Zapla ore; in Chile the relatively high price is due to the long maritime transport involved. In Venezuela, if asphalt or petroleum residues are used, the amount of limestone would have to be increased to offset the high sulphur content of such fuels.

d) Total assembly costs of raw materials

Table 1 shows the assembly costs per ton of pig iron and the respective percentages corresponding to iron ore, coal and limestone. It permits a comparison of the influence of the different raw materials within the assembly costs of the various plants. Assembly costs at Sparrows Point are high in relation to those prevailing in other steel producing centres of the United States. In addition, as will be seen later, the final costs of steel depend essentially upon the size of the plant assembly costs and wage rates; a plant with low assembly costs has therefore one advantage in its favour.

/Table 1

Table 1. Assembly Costs and Raw Material Percentages

(dollars at 1948 value per ton of pig iron and percentages)

Plant	Total assembly costs (dollars)	Raw materials percentages		
		Iron ore	Coal	Limestone
San Nicolás c/	59.15	51.1	45.6	3.3
San Nicolás d/	42.74	48.0	50.0	2.0
San Nicolás e/	33.88	38.0	59.0	3.0
Volta Redonda	37.33	28.0	66.9	5.1
Huachipato	23.05	32.7	60.4	6.9
Belencito	17.62	44.0	49.6	6.4
Monclova	26.74	61.7	35.8	2.5
Chimbote	18.80	53.8	39.6	6.6
Barcelona a/	21.68	50.5	41.2	8.3
Barcelona b/	26.40	41.5	54.6	3.9
Sparrows Point	27.14	60.3	35.9	3.8

a/ Blast furnaces using asphalt or petroleum residue coke.
b/ Blast furnaces using coke made from imported coals.
c/ Using Zapla ore.
d/ Using Itabira coal.
e/ Using Sierra Grande ore.

A glance at this Table shows that assembly costs are very high at the San Nicolás plant in Argentina, especially if Zapla ores are used. Combinations of raw materials envisaged for San Nicolás, while still higher than most of the plants in the other countries, would be within reasonable range of the assembly costs of Volta Redonda.

The cost of coal is fairly high at San Nicolás, thus, in this study, imported fuel has been considered. Argentina has a substantial coal deposit at Rio Turbio, which is high volatile C grade, and therefore non-coking. Some of the papers presented to the Bogotá meeting describe methods used in other countries which have resulted in the utilization of up to 60 per cent of such coals for coke.

At Volta Redonda, the main problem is the cost of coal. Until a better solution is found for the washing problems of Barro Branco coal,

/relatively high

relatively high prices of coke will prevail in Brazil. In the present cost estimates, an increase of the percentage of imported coal has been contemplated. Other possibilities for reducing costs, which are being undertaken in the actual plant, are the improvement of transport and handling facilities for imported coal.

An excessive expansion of the coal in the ovens during the coking process, places Brazilian coal in a unique position in the region, since it requires that, only these highly volatile types of coal which exist plentifully in Latin America, be imported. The replacement of the United States coal used at present at Volta Redonda by high volatile Colombian coal, is a possibility which might result in a reduction of costs, in view of the shorter distance involved. Another possible solution, suggested by papers presented at Bogotá, could be the washing, through the new method called "phase separation" of the fraction which is at present discarded from metallurgical use. The problem of Brazilian coal is further complicated by its high sulphur content.

In the case of Chile, it is essential to reduce prices and increase domestic production of coal. The Huachipato plant has conducted considerable research in this direction. Document L.27 refers to savings in blast furnace operations through the elimination of some injurious petrographic compounds and the coal fraction above 1.35 specific gravity.

In the case of Monclova, Mexico, the factor which principally raises assembly costs are those for iron ore owing to the long haulage distance. Prospecting has been conducted recently to locate more favourable ore deposits. This search has met with some success and at present several new deposits are being studied.

Assembly costs at Chimbote are quite satisfactory. It should be noted that the use of anthracite-asphalt coke has been envisaged, although the necessary process is still being investigated. A group of Peruvian industrialists has sponsored the research, described in document L.14. A pilot coking plant is being installed to learn the characteristics of the coke, before outlining details of the full-scale blast furnace. In the present estimate, a larger percentage of imported asphalt, as a binder, than the indication given in document L.14, has been considered, thus giving a safety margin should the new process not entirely fulfil

/expectations.

expectations.

Table 1 shows that the principal economic problem related to assembly costs in the steel industry of Venezuela, is the cost of coal. Various solutions are being considered, of which the possibility of using gas reduction as an alternative to the blast furnace will not be considered here, as it falls without the scope of this Paper. Among other possibilities, which are examined, the following may be mentioned: production of coke from natural asphalt or petroleum residues; improvement of non-coking coals through addition of asphalt or petroleum products or, lastly, employing coke from imported coal. This fuel might advantageously be imported as a return load of ships exporting iron ore.

For a plant located at Barcelona the cost of iron ore is relatively high. This is because the ore will have to be submitted to a complicated system of transport with several handlings. It might well be that Barcelona is not the location with the most favourable assembly costs; in this particular case it has tentatively been chosen on account of its vicinity to the Naricual coal deposits.

Lastly, the abnormally high cost of iron ore at Sparrows Point shown in Table 1, is due to the great distance from Latin America. In the case of plants operating on the Atlantic seaboard of the United States, this handicap is finally offset by advantages in transportation of the finished products to the coastal regions.

2. Conversion Costs

Two main factors, influenced by location, have a bearing upon conversion costs of iron and steel. These are: a) wages, and b) price of the by-products of the coke plant, gas, etc.

a) Labour costs

Table 2 shows the hourly rates of wages considered as an average of the wages which the respective industries would have paid in 1948. To obtain these data, actual averages of steel plants operating that year in several countries were used. Where no steel plant exists, the wage rates of a similar activity, preferably petroleum refineries, were used.

/Table 2

Table 2. Wage Costs
(dollars at 1948 value)

Plant	Hourly rates	Wages per ton of pig iron
San Nicolás	0.57	0.45
Volta Redonda	0.53	0.41
Huachipato	0.44	0.35
Belencito	0.60	0.47
Monclova	0.49	0.38
Chimbote	0.41	0.32
Barcelona	2.00	1.56
Sparrows Point	1.57	1.22

Throughout, efficiency of labour has been assumed to be equal to that prevailing in 1948 in the United States. In the case of blast furnaces the wage rates have been multiplied by 0.78, the number of man-hours required for the production of one ton of pig iron in an 800 tons daily blast furnace. Some additional labour is used for maintenance and repairs.

b) Costs and credits in the coke plant

Excluding amortization and the interest on capital, operations in the coke plant involve certain costs and bring some returns from the sale of by-products. The balance of this position is shown in Annex 7. The differences shown in the coke yield for several plants accrue from variations in the chemical composition of the coal, and it becomes necessary, therefore, to include them among locational factors. The basis which was used for these calculations is shown in Annex 8.

It should be noted that in two plants, (Chimbote and Barcelona) assumed to be using totally or partially asphalt or petroleum binders, no account has been taken of the value of by-products. In fact, the quality and value of the latter depends on the nature of the petroleum products used and their behaviour at high temperatures. It might well be that their value corresponds exclusively to their residual heating power. However, it might also be that aromatic hydro-carbons, of higher value as chemical compounds, are formed due to cracking in the coke ovens under special conditions.

/3. Costs not Related

3. Costs not Related to the Location of Plant

In the general assumptions shown in Annex 1, the cost estimates for certain items, supposed to be identical in all these plants, were given. Among them are the following:

Item	Dollars per Ton of Pig Iron
Cooling water	0.42
Repairs and maintenance	0.50
General and miscellaneous costs	2.65 a/
Returns from sale of blast furnace gas	- 1.90

a/ These have been slightly increased in the case of Colombia and Venezuela, in order to make up for the higher wage levels.

A blast furnace of the characteristics contemplated would have required in 1948 in the United States, an investment of 80 dollars per ton of pig iron produced annually. This investment comprises coke oven, raw material stockyards and their equipment, pig-casting machine, cranes, etc.[1] It has been estimated that in the United States an 8 per cent provision annually is sufficient to cover amortization of these investments and interest on loans.

In Latin America, due to the smaller availability of engineering resources and to the longer transport distances involved, in addition to the necessity to keep a larger assortment of spare parts, this investment and provision for its service seemed insufficient. The investment figure was increased by 20 per cent to 96 dollars per ton and the provision for their amortization and interest on loans, to 9 per cent annually.

4. Cost of Pig Iron

With the data obtained thus far, Annex 9 was prepared, comprising all the items which make up the cost of pig iron. In order to facilitate analysis, these figures were re-grouped in Table 3 under various major accounting headings, which will be used throughout to analyse the cost structure in the various phases of the industry. These items differentiate between assembly costs, direct and indirect labour costs, and other conversion costs.

The same figures are shown in Table 4, where they are expressed as percentages of total cost.

1/ It does not include investments in mines and transport facilities.

/Table 3

Table 3. Pig Iron Production Costs

(1948 dollars per ton)

Plant	Assembly costs a/	Salaries and wages	Other conversion costs	Capital charges	Total
San Nicolás d/	57.25	1.02	1.72	8.64	68.63
San Nicolás e/	40.84	1.02	1.93	8.64	52.43
San Nicolás f/	36.98	1.02	1.88	8.64	48.52
Volta Redonda	35.43	0.94	1.84	8.64	46.85
Huachipato	21.15	0.79	1.67	8.64	32.25
Belencito	15.72	1.07	2.53	8.64	27.96
Monclova	24.84	0.87	1.77	8.64	36.12
Chimbote	16.92	0.73	4.83	8.64	31.12
Barcelona b/	19.78	3.56	5.97	8.64	37.95
Barcelona c/	24.50	3.56	1.87	8.64	38.57
Sparrows Point	25.24	2.79	1.46	6.40	35.89

a/ After deducting blast furnace gas credit.
b/ Using asphalt or petroleum residue coke.
c/ Using coke from imported coal.
d/ Using Zapla ore.
e/ Using Itabira ore.
f/ Using Sierra Grande ore.

/Table 4

Table 4. Pig Iron Production Costs

(dollars of 1948 and percentages)

Plant	Assembly costs a/	Salaries and wages	Other conversion costs	Capital charges	Total
San Nicolás d/	83.4	1.5	2.5	12.6	68.63
San Nicolás e/	78.0	1.9	3.7	16.4	52.43
San Nicolás f/	76.2	2.1	3.9	17.8	48.52
Volta Redonda	75.6	2.0	3.9	18.5	46.85
Huachipato	65.3	2.5	5.2	27.0	32.25
Belencito	56.3	3.8	9.0	30.9	27.96
Monclova	68.7	2.4	4.9	24.0	36.12
Chimbote	54.5	2.3	15.4	27.8	31.12
Barcelona b/	51.7	9.7	15.8	22.8	37.95
Barcelona c/	63.4	9.5	4.8	22.3	38.57
Sparrows Point	70.4	7.8	4.0	17.8	35.89

a/ After deducting blast furnace gas credit.

b/ Using asphalt or petroleum residue coke.

c/ Using coke from imported coal.

d/ Using Zapla ore.

e/ Using Itabira ore.

f/ Using Sierra Grande ore.

In Table 4 some striking differences appear between the various plants, to some of which references have already been made. For instance, the high proportion of conversion costs in relation to the total cost of pig iron in the Chimbote plant, are caused by the lack of any credit for the sale of by-products from the coke plant. Venezuela shows a very high proportion of expenses for wages; as indicated in Table 2, the highest wage rates, for all the plants considered, exist there. This strongly underlines the advantages to be gained by a development similar to that of the United States industry: higher mechanization and capacity of the plants.

As regards the relationship between capital charges and labour costs, it will be found that the latter are considerably lower. The ratio between wages and capital charges varies between 1 to 6 and 1 to 12. This emphasizes

/the importance

the importance of reaching full capacity, even if more men than necessary have to be employed. The wage rates used in this analysis for the different countries have been made sufficiently high to provide for a margin to be used as an incentive for workers to attain high efficiency. Until this is attained a certain training period will be necessary.

Considering the problem from another angle, this relationship fully justifie the policy adopted by some managements of the recently established Latin-American industries, which are as follows:

1) All efforts are directed towards raising production to full capacity;
2) Once that goal has been attained, to ensure that the standards of quality are obtained;
3) Subsequently improve labour efficiency by encouraging good workers and dismissing the others, if excessive manpower has been necessary at the start to accomplish the first condition.

But several Latin-American steel industries have been unable to maintain permanent production up to capacity, in spite of operating for some time. Shortages in transport, in adequate raw material supply, in adjustment between capacity of the various sections of the plant and the market, or finally, in efficient management, all of them, if they prevent full capacity from being reached, cause a substantial increase of costs, especially in regard to capital charges per unit of production.

CHAPTER III. STEEL INGOT PRODUCTION COSTS

As briefly mentioned in Chapter I, liquid pig iron tapped from the blast furnace contains various metalloids in solution: carbon, silicon, phosphorus and sulphur, etc. In the different types of steel, small quantities of these substances remain. The process of reducing the amounts of these substances to specification limits takes place in the steel shop.

With the exception of sulphur, these impurities are extracted by taking advantage of their greater affinity for oxygen. The steelmaking processes may be divided into two principal types; a) converters, in which oxidation of the impurities is effected by air pressed through the liquid metal, and

/b) furnaces, in

b) furnaces, in which oxidation takes place, partly on the surface and partly by adding oxidizing agents, such as iron ore. The latter type of furnace can be heated with gas or petroleum (open hearth furnaces) or electric current. The sulphur is usually extracted through its reaction to lime, by addition of limestone; the resulting sulphide of lime passes into the slag. The other impurities once they are removed from the metal by oxidation, also increase the volume of slag. When controlling the progress of steelmaking for each load of metal, attention to the transformation which the slag is undergoing is therefore essential.

Both the impurities contained in the pig iron and the fluxes which have to be used for their elimination determine whether the reaction is acid or basic. According to this, the preferential extraction of one or the other of the metalloids is encouraged.

In addition to the quality of the available ores, which determines the amount and type of the impurities, the requirements of the market are also influential in the steelmaking process and reaction. This is because steel produced by different processes may have limited ranges of application. Lastly, the necessity of re-using the scrap produced in the rolling mills, plus the scrap which can be purchased, also influences the type of process.

The abundance of scrap on the market, through discarding used iron materials, is one of the advantages highly industrialized countries have for producing cheaper steel than in Latin America, where scrap is usually scarce. Incidentally, it has been assumed that all the plants would be able to buy enough purchased scrap to cover 10 per cent of their steel ingot production.

On account of its flexibility for the fulfilment of most of the necessary conditions, it was assumed that the process used in the steelmaking departments, in these plants, would principally, be the basic open hearth. In the countries where there is an adequate supply of iron ore, it has also been considered that 20 per cent of the liquid pig iron would be refined by the acid converter (Bessemer) process. The nature of its ore, which makes basic converter (Thomas) indispensable, causes Colombia to be an exception. Here the scrap from the rolling mill plus the purchased scrap would be smelted and refined in a basic electric furnace.

/In short,

In short, it has been assumed that basic open hearth furnaces will be installed for refining the total output at San Nicolás and Monclova. A combination of 80 per cent basic open hearth steel and 20 per cent Bessemer is assumed at Volta Redonda, Huachipato, Chimbote, Barcelona and Sparrows Point. Lastly, Belencito is based on a Thomas installation, supplemented by an electric furnace for re-melting the scrap.

1. Pig Iron Used in the Steelmaking Departments

Table 5 shows the amount of pig iron which would be required by the aforementioned three combinations, respectively, in order to produce one metric ton of steel ingot. It can be observed that the basic open hearth furnace would require 759 kilogrammes, the combination of Bessemer and acid open hearth 768 and lastly, the Thomas converter 857 kilogrammes of pig iron per ton of ingot.

Table 5 Pig Iron Required to Produce one Ton of Steel Ingot

(kilogrammes)

	100% open hearth	20% Bessemer, 80% open hearth		100% of pig in Thomas converter; scrap in electric furnaces	
	Open hearth	Open hearth	Bessemer	Thomas	Electric furnace
Liquid pig iron	759	615	153	857	-
Circulating scrap	203	171	-	51	153
Purchased scrap	101	102	-	-	101
Bessemer scrap	-	28	-	-	
Total liquid metal	1.063	915	153	908	254
minus losses in furnaces	63	55	13	148	14
Total steel ingots	1.000	860	140	760	240
minus losses in furnaces	48	43	7	38	12
minus circulating scrap	203	171	28	151	49
Rolled steel products	749	646	105	571	179
Pig iron per ton of finished steel	1,013.4	1,023.6		1,143.7	

2. Steelmaking Costs

Again a series of general assumptions are made in order to facilitate calculations of steelmaking costs and to increase comparability. Some of these assumptions correspond to physical units, while others constitute the aggregate of the values of certain items of heterogeneous nature. The

/former are

former are shown as a footnote to the Table in Annex 10, while the latter are expressed in dollars per ton in the same Annex.

Among the more important assumptions, attention should be focussed on the following: a unit value of 90 per cent of the cost of pig iron has been assigned to all scrap whether purchased or circulating. Capital charges follow the same criteria in the case of the blast furnaces.

In the open hearth, Bessemer and Thomas processes, which use a minimum of electric power, it has been assumed that power was supplied by the general power plant of the mill, and its costs were included under the heading "general and miscellaneous costs". At Belencito, the additional power require for the electric resmelting furnace has been included as a separate item, prices being approximately equivalent to the rates prevailing in the United States.

Table 6 has been prepared with data taken from Annex 10 and shows costs of steel ingots in the various plants. In Table 7 they are shown as percentages of total costs; the structure of these tables follows the same lines adopted for pig iron. The items thus listed are: a) raw materials; b) salaries and wages; c) other conversion costs, and d) capital charges.

/Table 6

Table 6 Production Cost of Steel Ingots

(dollars of 1948 per ton)

Plant	Raw materials f/	Salaries and wages	Miscellaneous conversion cost	Capital charges	Total costs
San Nicolas a/ g/	73.05	2.35	3.37	6.40	85.17
a/ h/	56.32	2.35	3.37	6.40	68.44
a/ i/	52.28	2.35	3.37	6.40	64.40
Volta Redonda b/	50.97	1.95	3.23	5.94	62.09
Huachipato b/	35.42	1.62	3.23	5.94	46.21
Belencito c/	26.53	1.50	4.22	6.22	38.47
Monclova a/	39.50	2.02	3.37	6.40	51.29
Chimbote a/	34.23	1.51	3.23	5.94	44.91
Barcelona b/ d/	41.33	7.37	2.94	5.94	57.58
Barcelona b/ e/	41.98	7.37	2.94	5.94	58.23
Sparrows Point b/	39.21	5.79	3.23	4.40	52.63

a/ 100% open hearth.

b/ 80% open hearth, 20% Bessemer.

c/ 100% Thomas, electric resmelting of scrap.

d/ Using asphalt or petroleum residue coke.

e/ Coke manufactured for imported coke.

f/ Discounting product of sales of slag from Belencito.

g/ Using Zapla ore.

h/ Using Itabira ore.

i/ Using Sierra Grande ore.

/Table 7

Table 7 Production Costs of Pig Iron

(dollars of 1948 and percentages)

Plant	Raw materials (per cent)	Salaries and wages (per cent)	Miscel-llaneous conversion costs (per cent)	Capital charges (per cent)	Total costs (Dollars)
San Nicolás a/ g/	85.7	2.8	4.0	7.5	85.17
a/ h/	82.3	3.4	4.7	9.4	68.44
a/ i/	81.2	3.6	5.3	9.9	64.40
Volta Redonda b/	82.0	3.2	5.2	9.6	62.09
Huachipato b/	76.7	3.5	7.0	12.8	46.21
Belencito c/	69.0	3.9	11.0	16.1	38.47
Monclova a/	76.9	3.9	6.7	12.5	51.29
Chimbote b/	76.2	3.4	7.2	13.2	44.91
Barcelona b/ d/	71.7	12.8	5.1	10.4	57.58
Barcelona b/ e/	72.2	12.5	5.1	10.2	58.23
Sparrows Point b/	74.5	11.0	6.1	8.4	52.63

a/ 100% open hearth .

b/ 80% open hearth, 20% Bessemer.

c/ 100% Thomas, electric resmelting of scrap.

d/ Using asphalt or petroleum residue coke.

e/ Coke manufacture from imported coke.

f/ Discounting product of sales of slag from Belencito.

g/ Using Zapla ore.

h/ Using Itabira ore.

i/ Using Sierra Grande ore.

Since a fundamental assumption was that all these plants were built along similar lines, the differences shown in Table 6 are mainly determined by: a) fluctuations in costs of raw materials, and b) fluctuations in wages. The influence of the latter is greater than in the case of pig iron, since more labour per ton is used in this department than in the blast furnace.

/Variations in

Variations in other conversion costs and in capital charges are very small and stem from differences in the processes imposed by the composition of the iron ore. In this connexion, at Belencito, where costs are slightly higher for these two items, the column "raw materials" was credited with 6.50 dollars per ton obtained from the sale of phosphate slag. Document L.54 refers to the possibility of adding phosphate rock to the burden of the blast furnace in order to obtain basic converter pig iron. Such a procedure could be probably applied to advantage in Argentina, Brazil, Chile and Mexico, in which case a credit for phosphate slag would also appear in the corresponding estimate. Incidentally, some of these countries require phosphorus fertilizers urgently. The fact that there is hardly any trade in steel ingots, makes any further analysis of these costs unnecessary.

CHAPTER IV. ROLLING MILL COSTS

1. Types of Finished Products

In a country where there is only one iron and steel industry, the plant usually has to supply the necessities of pig iron for foundries and tubes and often those of liquid steel for steel castings. These three outlets for the industry's products represent only a small proportion of the market. Most of the pig iron, the scrap and the steel ingots are rolled into finished products. Usually the rolling mill consists of a blooming mill which trasnforms the ingots into blooms, slabs or billets followed by various finishing mills, in which, in the course of the immediate or subsequent process, the semi-finished material is rolled into steel products.

The design investments and output costs of the rolling mill depend fundamentally on the types and quantities of products to be produced. The possible variations affect the types and size of blooms and slabs, the design and the degree of mechanization of the finishing mills. In this Study, it has been assumed that all the plants will produce an equal assortment of products, selected in such a way as to correspond to the situation which often arises if the plant is the only source of domestic steel in a small market. The limitations on the assortment are imposed

/by the basic

by the basic assumption that each section of the plant should have a relatively high utilization factor. Under these circumstances special products for which there is only a limited demand, would continue to be imported.

Table 8 Breakdown of the Programme for the Rolling Mills

(tons and percentages)

Product	Percentage of total	Tons per year
Bars and rails		
Heavy rails and shapes	6.5	16,250
Light Bars of less than 38 mm. square, with an average weight equivalent to 16 mm. diameter (5/8")	42.5	106,250
Wire bars and heavy wire	17.0	42,500
Flat products		
Plate over 12.7mm.thickness (1/2")	1.0	2,500
Plate and sheet, and strip for welded tubes up to 100 mm.	18.0	45,000
Sheet for tinplate and galvanization a/	15.0	37,500
	100.0	250,000

a/ Despite the inclusion of sheet in the programme, and contrary to usual practice in Latin America, investments and costs for tinning and galvanization have not been considered in these papers.

As noted, the tonnages indicated in this Table correspond approximately to consumption in a small market, but, in addition to the size limitation, no highly developed steel transforming industry should exist there. It was further assumed that the manufacturing orders for merchant bars would average 200 tons per order, and that the operating factor is about 70 per cent.

2. Rolling costs

As for efficiency, wages, capital charges, raw materials and miscellaneous, general assumptions were made which can be met in a new plant after a reasonable period of experience. With these data and based on steel ingot prices, as obtained in the preceding section, Annex 11 was prepared.

/The resulting

The resulting figures have, in turn, been grouped together in Tables 9 and 10 along the same lines used in the preceding sections. The first of these tables shows the figures in dollars (at 1948 value) per ton, and the second as percentage of total cost. The latter has been broken up into: a) raw materials; b) wages and salaries; c) other conversion costs, and d) capital charges.

Table 9 Costs per Ton of Finished Steel

(dollars of 1948 per ton)

Plants		Raw materials	Salaries and wages	Miscel-laneous conversion costs	Capital charges	Total costs
San Nicolás	d/	97.72	6.96	4.65	18.81	128.14
	e/	79.36	6.96	4.65	18.81	109.78
	f/	74.92	6.96	4.65	18.81	105.34
Volta Redonda		72.14	6.48	4.65	18.81	102.08
Huachipato	a/	54.78	5.38	4.65	18.81	83.62
Belencito		45.33	7.33	4.65	18.81	76.12
Monclova		60.45	6.00	4.65	18.81	89.91
Chimbote		53.33	5.00	4.65	18.81	81.79
Barcelona	b/	68.58	24.43	4.65	18.81	116.47
Barcelona	c/	69.31	24.43	4.65	18.81	117.20
Sparrows Point		62.48	19.18	4.65	13.94	100.25

a/ Using asphalt or petroleum residue coke.

b/ Using coke from imported coal.

c/ Using Zapla ore.

d/ Using Itabira ore.

e/ Using Sierra Grande ore.

/Table 10

Table 10

Costs per Ton of Finished Steel

(dollars of 1948 and percentages)

Plants		Raw materials (per cent)	Salaries and wages (per cent)	Miscel-laneous conversion costs (per cent)	Capital charges (per cent)	Total costs (dollars)
San Nicolás	c/	76.3	5.4	3.6	14.7	128.14
	d/	72.3	6.3	4.2	17.2	109.78
	e/	71.1	6.6	4.4	17.9	105.34
Volta Redonda		70.6	6.4	4.6	18.4	102.08
Huachipato		65.5	6.5	5.5	22.5	83.62
Belencito		59.6	9.6	6.1	24.7	76.12
Monclova		67.1	6.7	5.2	21.0	89.91
Chimbote		65.2	6.1	5.7	23.0	81.79
Barcelona	a/	58.8	21.0	4.0	16.2	116.39
Barcelona	b/	59.1	20.9	4.0	16.0	117.20
Sparrows Point		62.3	19.2	4.6	13.9	100.25

a/ Using asphalt or petroleum residue coke.

b/ Using coke from imported coal.

c/ Using Zapla ore.

d/ Using Itabira ore.

e/ Using Sierra Grande ore.

As in the previous chapter, the high wage rate in Venezuela causes an increase in the cost of finished steel, placing it well above that of the other plants, including Sparrows Point.

/CHAPTER V.

CHAPTER V. ANALYSIS OF COMBINED COSTS OF BLAST FURNACE, STEEL SHOP AND ROLLING MILLS

By suitable computation of the data shown in Table 5, it can be found that, in addition to circulating scrap and purchased scrap, it would be necessary to use the following amounts of pig iron per ton of finished steel for the various steelmaking processes: a) 1,013 kilogrammes for the basic open hearth; b) 1,023 kilogrammes for the combination of 80 per cent basic open hearth and 20 per cent of Bessemer, and finally, c) 1.143 kilogrammes for the combination of basic converter and electric re-melting furnace.

In order to obtain an overall picture of the cost structure of the steel industry, the classified cost data obtained in the previous chapter for pig iron, steel ingot and rolled products have been combined, and they have been weighted according to their consumption of raw materials; Table 11 shows the results of this calculation. Taking final costs as a basis, three groups can be separated: first, Belencito, Chimbote, Huachipato and Monclova, for which costs are lower than at Sparrows Point; secondly, Volta Redonda with figures approximately equivalent to those of the United States, and lastly Barcelona and to lesser degree San Nicolás, where costs are above those of Sparrows Point. The reason, in the case of Barcelona, are the higher wage rates and for San Nicolás, the higher raw material costs even under the most favourable conditions possible, i.e. using Sierra Grande ore.

/Table 11

Table 11 Cost Structure of Iron and Steel Production
Pig Iron, Steel Ingots, Finished Steel Products
(1948 dollars per ton of finished steel)

Plant		Raw Materials	Wages and salaries	Other costs	Capital charges	Total
San Nicolás	c/	70.04	11.12	10.89	36.09	128.14
San Nicolás	d/	51.48	11.12	11.09	36.09	109.78
San Nicolás	e/	47.08	11.12	11.05	36.09	105.34
Volta Redonda		45.62	10.04	10.84	35.58	102.08
Huachipato		29.03	8.35	10.66	35.58	83.62
Belencito		15.47	10.81	13.17	36.97	76.42
Monclova		33.31	9.57	10.93	36.10	89.91
Chimbote		24.55	7.76	13.90	35.58	81.79
Barcelona	a/	28.31	37.90	14.68	35.58	116.47
Barcelona	b/	33.23	37.90	10.49	35.58	117.20
Sparrows Point		33.68	29.75	10.45	26.37	100.25

Table 12 Cost Structure of Iron and Steel Production
Pig Iron, Steel Ingots, Finished Steel Products
(Percentages of the total)

Plant		Raw materials	Wages and salaries	Other costs	Capital charges	Total (dollars)
San Nicolás	c/	54.6	8.7	8.5	28.2	128.14
San Nicolás	d/	46.9	10.1	10.1	32.9	109.78
San Nicolás	e/	44.7	10.6	10.5	34.2	105.34
Volta Redonda		44.7	9.8	10.6	34.9	102.08
Huachipato		34.7	10.0	12.7	42.6	83.62
Belencito		20.2	14.1	17.2	48.5	76.42
Monclova		37.0	10.6	12.2	40.2	89.91
Chimbote		30.0	9.5	17.0	43.5	81.79
Barcelona	a/	24.3	32.5	12.6	30.6	116.47
Barcelona	b/	28.4	32.3	9.0	30.3	117.20
Sparrows Point		33.6	29.7	10.4	26.3	100.25

a/ Blast furnaces using coke made from asphalt or petroleum residues. b/ Blast furnaces using coke made from imported coal. c/ Using Zapla's ore. d/ Using Itabira (Brazil)'s ore. e/ Using Sierra Grande's ore.

/CHAPTER VI.

CHAPTER VI. COST OF FINISHED STEEL IN INTEGRATED PLANTS

1. General Remarks

An integrated plant is one which mines at least part of its raw materials, in addition to carrying out the complete conversion process from pig iron to finished steel. In the following Chapter it will be assumed that the plants referred to, so far, are integrated and individually mine all the iron ore, domestically produced coal and limestone they require. This does not always correspond to reality in the region, as some plants, such as Huachipato, are buying iron ore and coal from undertakings already producing it prior to their installation.

Raw materials that remain to be purchased, such as imported coal, will be accounted for separately. Similarly an account will be opened for materials such as purchased scrap, since use of the latter will not be omitted from the manufacturing programme. Investments necessary for the opening of mines will increase the capital charges correspondingly, and wages and other expenses will be added to the respective items. Summarizing, the analysis will begin by breaking down the overall pig iron assembly costs into the main primary factors and distributing them within the corresponding accounts. For this analysis, it is necessary to formulate several additional general assumptions, which are included in Annexes 12 and 13. It also becomes essential to isolate some types of expenses such as transport costs, purchased scrap, imported fuel or ore, etc.

In Table 13 this breakdown of raw material costs has been made. The most outstanding point is the importance of transport costs in some of the examples. For instace, in Argentina, with the use of Zapla ore, it is almost 32 dollars per ton of finished steel as compared with about 14 dollars at Monclova and 11 at Volta Redonda. Since transport costs have been estimated at 17.5 dollars per ton at Sparrows Point, San Nicolás is the only plant which appears to be in a really unfavourable position as regards assembly costs.

/Table 13

Table 13 **Distribution of Raw Materials Costs by Items**
(1948 dollars per ton of finished steel)

Plant		Wages and salaries	Miscellaneous costs	Capital charges	Transport	Imported fuel and ore	Purchased scrap and ferroalloys	Total raw materials
San Nicolas	d/	2.36	2.15	1.42	26.65	27.36	10.10	70.04
San Nicolas	e/	1.58	1.44	0.95	17.63	21.65	8.23	51.48
San Nicolas	f/	1.85	1.69	1.11	11.42	23.28	7.73	47.08
Volta Redonda		3.87	3.22	2.52	10.62	18	7.39	45.62
Huachipato		5.57	4.17	4.18	5.25	4.38	5.48	29.03
Belencito		7.12	5.33	4.14	3.53	-	4.02	15.47 a/
Monclova		5.23	3.94	3.92	13.97	-	6.25	33.31
Chimbote		3.16	2.55	2.60	7.84	3.09	5.31	24.55
Barcelona	b/	3.48	2.21	2.39	14.12	-	6.11	28.31
Barcelona	c/	1.90	1.16	0.96	8.24	14.77	6.20	33.23
Sparrows Point		4.21	2.69	3.59	17.30	-	5.89	33.68

a/ Credit of $ 8.67, being the value of Thomas slag per ton of finished steel. ($ 6.50 ingot steel).
b/ Blast furnaces using coke made from asphalt or petroleum residues.
c/ Blast furnaces using coke from imported coal.
d/ Using Zapla ore.
e/ Using ore from Itabira (Brazil).
f/ Using ore from Sierra Grande.

/2. Distribution

2. Distribution of Finished Steel Costs in an Integrated Plant

Dollar values for the different types of expenses are shown in Table 14, and in Table 15 they appear as percentages of total costs. It may be noted that wages, miscellaneous costs and capital charges have increased slightly as compared with the figures in the preceding chapter, due to the addition of some amounts previously included under assembly, or raw materials costs. The new items, such as cost of transport and imported fuel or ore, are particularly heavy at San Nicolás, Volta Redonda and Barcelona (in the latter case, if imported blast furnace coke is used).

/Table 14

Table 14 Distribution of finished steel costs in integrated plants a/
(1948 dollars per ton of finished steel)

Plant		Imported fuel and ore	Purchased scrap b/	Transport	Wages and salaries	Miscellaneous costs	Capital charges	Credits	Total costs
San Nicolas	e/	27.34	11.21	26.61	13.48	13.90	37.52	-1.92	128.14
San Nicolás	f/	25.17	9.25	17.63	11.31	12.14	36.20	-1.92	109.78
San Nicolás	g/	23.00	8.20	11.28	12.97	14.57	37.22	-1.92	105.34
Volta Redonda		17.58	2.29	10.37	13.91	15.78	38.10	-1.95	102.08
Huachipato		4.28	6.03	5.13	13.91	16.46	39.76	-1.95	83.62
Belencito		-	5.28	3.08	17.93	19.85	41.12	-10.84	76.42
Monclova		-	6.57	13.81	14.80	16.64	40.01	-1.92	89.91
Chimbote		3.02	5.76	7.65	10.92	18.21	38.18	-1.95	81.79
Barcelona	c/	-	6.63	13.79	41.37	18.66	37.97	-1.95	116.47
Barcelona	d/	14.42	6.83	8.05	39.80	13.51	36.54	-1.95	117.20
Sparrows Point		-	6.54	16.89	33.97	14.84	29.96	-1.95	100.25

Table 15 Distribution of finished steel costs in integrated plants a/
(Percantages and 1948 dollars)

Plant		Imported fuel and ore	Purchased scrap b/	Transport	Wages and salaries	Miscellaneous costs	Capital charges	Credits	Total Costs
San Nicolas	e/	21.3	8.7	20.8	10.2	10.9	29.4	- 1.5	128.14
San Nicolás	f/	22.9	8.4	16.1	10.3	11.1	33.	- 1.8	109.78
San Nicolas	g/	21.8	7.8	10.7	12.3	13.8	35.4	- 1.8	105.34
Volta Redonda		17.2	8.1	10.2	13.6	15.5	37.3	- 1.9	102.08
Huachipato		5.1	7.2	6.1	16.6	19.7	47.6	- 2.3	83.62
Belencito		-	6.9	4.0	23.5	26.0	53.8	-14.2	76.42
Monclova		-	7.3	15.4	16.5	18.5	44.4	- 2.1	89.91
Chimbote		3.7	7.0	9.3	13.4	22.3	46.7	- 2.4	81.79
Barcelona	c/	-	5.7	11.8	35.5	16.	32.7	- 1.7	116.47
Barcelona	d/	12.3	5.8	6.9	34.0	11.5	31.2	- 1.7	117.20
Sparrows Point		-	6.5	16.8	33.9	14.8	29.9	- 1.9	100.25

a/ Plants including iron and coal mines.
b/ Purchased scrap plus ferroalloys.
c/ Blast furnaces using coke made from aspahlt and petroleum residues.
d/ Blast furnaces using coke made from imported coal.
e/ Using Zapla ore.
f/ Using ore from Itabira (Brazil).
g/ Using ore from Sierra Grande.

/3. Influence of

3. Influence of Wage Rates and Capital Charges

An analysis of the data of Table 14 shows, as noted several times, the various plants show higher estimated costs than Sparrows Point. The breakdown of the assembly costs permits a more precise analysis of the causes of these abnormalities; in the case of Argentina and Brazil high cost of raw materials and trasport; in that of Venezuela the same factors plus extremely high wage rates.

Consideration of labour costs will show that, except for Venezuela, all Latin-American plants are favoured by lower wage rates. The extreme case is that of Peru, where the difference with the United States is as much as 23 dollars, or 27 per cent of the estimated cost of steel. The wage rates considered, as repeatedly underlined, are somewhat high, and have thus been chosen to constitute, in themselves, an incentive for a proper selection of the labour force.

It is logical to assume that, as economic development of these countries progresses, wage rates will have to be increased. Such an evolution would reduce the present advantage for the plants in the region. But it may be assumed that a limit for such wage rate increases might be reached, when they obtain the same values prevailing in the United States.

Table 16 shows the costs Latin American Steel would reach in the selected plants if wages were equal to those of the United States. The increases vary from 20 per cent in Argentina to 28 per cent in Peru. Venezuela would show a reduction of 6 per cent, as the wage rate considered in the former tables is higher than that of the United States.

On the other hand, it may also be assumed that when economic development in Latin America reaches a level where wage rates equal those of the United States, such evolution would be accompanied by technological progress, more advanced mechanical industries and a higher rate of capital formation. Thus capital charges equal to those prevailing in the United States could also reasonably be expected, This possibility has been taken into account in column C of Table 16, which shows the percentage by which the estimated total cost would decline, as a result of such an improvement in Latin-American economic conditions.

/Table 16

Table 16 Estimated Finished Steel Costs in Latin America, assuming Equal Rates and Capital Charges as in the United States

(1948 dollars and percentages)

		A Total estimated cost (dollars)	B Increases in costs to equal United States wages (percentage)	C Reduction in costs brought about by equivalent capital charges (percentage) c/	D Results (dollars)
San Nicolas	d/	128.14	18.5	- 5.8	144.34
San Nicolas	e/	109.78	19.3	- 6.5	123.83
San Nicolas	f/	105.34	20.0	- 7.0	119.03
Volta Redonda		102.08	19.7	- 8.0	114.02
Huachipato		83.62	23.9	-11.8	93.73
Belencito		76.42	21.0	-14.6	81.30
Monclova		89.91	21.3	-11.3	98.90
Chimbote		81.79	28.1	-10.0	93.32
Barcelona	a/	116.47	-6.3	- 6.9	101.10
Barcelona	b/	117.20	-5.0	- 5.6	104.78
Sparrows Point		100.25	-	-	100.25

a/ Blast furnaces using coke made from asphalt and petroleum residues.
b/ Blast furnaces using coke made from imported coal.
c/ Equal engineering costs and rates of interest.
d/ Using Zapla iron ore.
e/ Using iron ore from Itabira, Brazil.
f/ Using iron ore from Sierra Grande.

/Table 16 also

Table 16 also shows the result of the combined action of these two factors: increase in wage rates and decrease in capital charges, so as to equal throughout conditions prevailing in the United States. In such cases, which might be considered as the extremes, the cost figures move into close proximity to Sparrows Point data. Brazil would still be 14 and Argentina 20 per cent above, in the best of cases. On the other hand, costs at Belencito would be 20 per cent lower, due to the extremely favourable assembly costs.

The high costs in Brazil are entirely due to the high price of its coal. In this connexion a statement made in document L.2, describing the Santa Catarina coal deposits as one of the good coking coal reserves for the future, is extremely striking. Research on coal mining and washing methods in Brazil becomes therefore especially significant.

In order to facilitate final comparisons and conclusions, Table 17 has been prepared. Three sets of figures containing the main conclusions reached in this paper are presented as Indices, with a base Sparrows Point equal 100.

/Table 17

Table 17 Comparative Costs in the Different Plants
(Index: Data for Sparrows Point = 100)

Plant		Assembly costs per ton of pig iron	Cost of finished steel under conditions assumed for Latin America	Costs of finished steel with wages and capital charges equal to those in United States.
San Nicolas	c/	218	128	144
San Nicolas	d/	158	110	123
San Nicolas	e/	143	105	119
Volta Redonda		138	102	114
Huachipato		85	84	94
Belencito		65	76	82
Monclova		99	90	100
Chumbote		69	82	93
Barcelona	a/	80	116	101
Barcelona	b/	97	117	105
Sparrows Point (100)		$ 27.14	$ 100.25	$ 100.25

a/ Blast furnaces using coke made from aspahlt or petroleum residues.
b/ Blast furnaces using coke made from imported coal.
c/ Using Zapla iron ore.
d/ Using iron ore from Itabira, Brazil.
e/ Using iron ore from Sierra Grande.

/Since a

Since a hypothetical plant, located as Sparrows Point 1/ and producing 250 thousand tons of a wide assortment of small amounts of different steels, cannot be taken as representative either of costs or conditions prevailing in the United States, the figures shown in Table 17 have limited validity. They show the respective locational advantages and should have significance as they stand; but if Latin-American markets should develop to dimensions in which large specialized plants are justified, of size producing beyond the range in which scale of operation has a significant bearing on costs.

A study of column A of Table 17 shows that, except in Brazil and Argentina, the sites selected in Latin America have lower assembly costs than those of Sparrows Point in the United States. The high figures for Argentina would probably be lowered by using a substantial percentage of the Rio Turbio coal; those for Brazil, by a greater recovery of metallurgical coal from the Barro Branco run-of-mine; also, in both countries, if all, or a substantial part, of their imported coal is purchased in Colombia, instead of in the United States.

The study of the indices given in column B shows that the influence of conversion costs tends to modify the relative differences arising in assembly costs. Costs at Huachipato, Belencito, Monclova and Chimbote are below those of Sparrows Point; whereas Volta Redonda and San Nicolás are only slightly higher. Finally the high wage rates of Venezuela increase its total costs to about 16 per cent more than Sparrows Point. If, to the costs at Sparrows Point, transport costs to the Latin-American markets are added, a figure much higher than Latin-American estimated costs would generally result; even in the case of Venezuela, the estimated cost would be very close to the c.i.f. cost for imported finished steel.

1/ Sparrows Point has higher assembly costs than the plants in the main steel producing centres of the United States. But as the steel used on the coast or for export would have to carry still higher transport costs within the United States than the difference in assembly costs, the Sparrows Point plant appears more favourably located for serving export markets.

/Column C

Column C shows that if, instead of comparing the influence of actual factors, it is assumed that wages and capital charges are equal to those in the United States, then only the plants of Volta Redonda and San Nicolás show an adverse result. Again this difference would be smaller than the Sparrows Point costs, increased by transport expenses for finished steel. Those Latin-American plants, such as Volta Redonda and San Nicolás, where assembly costs are even higher than the already high figures for Sparrows Point, would still be in a position to compete for their domestic markets. High grade ore, in most cases with sufficient reserves for several centuries, and lower wage rates, offset part of the difficulties which arise from a deficient knowledge of coking coal reserves and of methods for coking the high volatile fuels which are abundant in the region.

This does not justify a general endorsement of the establishment of an industry which happens to have rich ores available and be located close to regional markets. The volume of annual production, that is, the size of plant, influences production costs very considerably. Large scale operations become even more advantageous because an industry operating for a large market may further reduce its costs through specialization. This is the case in the United States, whereas, in Latin America, markets are small and spread over vast areas. A special paper, L.91 deals with this aspect of the problem, analysing the influence of the size of operation on costs and investments for plants assumed to be in the same locations as those studied in this Paper.

Annex 1

General Bases of the Calculations
(Values in 1948 dollars per metric ton)

1.	Cost of open pit mining of iron ore, per metric ton, at loading station of mine	US$ 2.26
2.	Cost of open pit mining of limestone, per metric ton, at loading station of mine	2.26
3.	Cost of cooling water	0.42 a/
4.	Cost of coking coal. Pocahontas. CIF Norfolk, Va.	8.94
5.	Cost of ferro-alloys for 100% open-hearth production	2.17 b/
	Cost of ferro-alloys for 80% open-hearth and 20% acid Bessemer	1.92 b/
	Cost of ferro-alloys for 100% basic Bessemer (Thomas)	1.40 b/
6.	Lime and refractories (Ingot steel)	1.10 b/
	Lime and refractories, Belencito (Thomas ingot steel)	1.60 b/
7.	Refractories and spare parts (finished steel)	2.00 c/
8.	KWH (hydro-electric power)	1.20 c/

9. Unit cost of transport for raw materials in bulk

Railway transport	US$ 0.00848 /ton.kilometre
Inland water-way transport	0.00399 /ton.mile
Maritime transport d/ (normal rate)	0.002341/ton.nautical mile
Maritime transport e/ (low rate)	0.000944/ton.nautical mile
Trans-shipment f/	1.20/ton
Crossing of Panama Canal	1.25/ton

10.	Maintenance materials (Ingot steel)	0.50 b/
	Maintenance materials Belencito (Thomas Ingot Steel)	0.85 b/
11.	Services and overhead (Ingot steel) 100% open-hearth	0.45 b/
	80% open-hearth and 20% Bessemer	0.57 b/
	100% basic Bessemer (Thomas)	1.05 b/
12.	Materials, services, maintenance and overhead (finished steel)	1.45 c/

Capital Charges

Countries	Pig Iron	Finished Steel
Latin-American countries	$ 96	$ 209
United States	80	174.30

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a/ Cost per metric ton of pig iron.
b/ Cost per metric ton of crude steel.
c/ Cost per metric ton of finished steel.
d/ Normal rates.
e/ Reduced rates. Not used in present study.
f/ One loading and one unloading operation.

Annex 2 Costs of Iron Ore, Delivered to 250,000 Ton Plants

(1948 dollars per ton)

Location	Mining costs	Transport costs: Sea	Inland Waterway	Land	Trans-shipments	Total a/
San Nicolás, Zapla ore	2.26	-	-	11.03	1.20	14.49a/
San Nicolás, Itabira ore	2.26	3.85	-	4.85	2.40	13.36b/
San Nicolás, Sierra Grande ore	2.26	2.24	-	1.53	2.40	8.43
Volta Redonda	2.26	-	-	3.34	1.20	6.80
Huachipato	2.26	1.06	-		1.20	4.52
Belencito	2.26	-	-	0.19	1.20	3.65
Monclova	2.26	-	-	6.42	1.20	9.88
Chimbote	2.26	1.05	-	0.34	2.40	6.05
Barcelona	2.26	1.45d/	0.51e/	0.49	2.40	7.11
Sparrows Point, Maryland	2.26	4.97d/	0.51e/	0.49	2.40	10.63

a/ To transport and other costs, a sum of US.$ 2.26 per ton has been added to represent mining costs. This is the price paid by Cía. de Acero del Pacífico, Huachipato, based on US$ of 1948.

b/ Does not include profit for the company owning the Itabira deposit in Brazil.

c/ Includes cost of railway transport to Puerto Madryn (180 kilometres) and maritime freight at the usual rate, from Puerto Madryn to San Nicolás (955 nautical miles)

d/ Corresponds to inland water-way and meritime transport. Normal tariffs of direct transport were used, along the Orinoco River and sea-ways, to the steel plant.

e/ Covers debt service, corresponding to the dredging of the Orinoco River and cost of maintenance of the water-way for a yearly transport of 5 million tons of ore. According to Journal of Metals and Mining Engineering February 1950, the cost of dredging the Orinoco can be estimated at 18,000,000 dollars. Assuming an interest rate of 3% and an amortization rate of 5%, as well as maintenance costs of US.$ 1,100,000 per year, a total cost of US.$ 2,540,000 per year would be obtained. Then, estimating the average annual extraction to be 5,000,000 tons, as the one in question, the average cost per ton exported due to maintenance of the Orinoco River would be US.$ 0.51.

Annex 3. Costs of Iron Ore per Ton of Pig Iron Produced

(Percentage, kilos and 1948 dollars)

Plant	Deposit Location	Fe cont. %	Kgs. of ore per ton of pig iron	Cost of ton of ore	Cost of ore per ton of pig iron
San Nicolás	Zapla	48	2,085	14.49	30.20
San Nicolás	Itabira	65	1,540	13.36	20.57
San Nicolás	Sierra Grande	57	1,755	8.43	14.80
Volta Redonda	Lafaietta	65	1,540	6.80	10.47
Huachipato	El Tofo	60	1,670	4.52	7.55
Belencito	Paz de Río	47	2,120	3.65	7.74
Monclova	Durango	60	1,670	9.88	16.50
Chimbote	Marcona	60	1,670	6.05	10.10
Barcelona	El Pao	65	1,540	7.11	10.95
Sparrows Point, Maryland	El Pao	65	1,540	10.63	16.37

Annex 4 . **Cost of Coking Fuels Delivered to Plant**

(1948 dollars per ton)

Location	Origin	%	Cost of mine	Trans-portation, etc.	Total
San Nicolás, Zapla ore	Imported	100	--	--	20.00
San Nicolás, Itabira ore	Imported	100	--	--	20.00
San Nicolás, Sierra Grande ore	Imported	100	--	--	20.00
Volta Redonda	Imported	70	8.94	14.01	22.95
	Domestic	30	16 a/	6.42	22.42
Huachipato	Imported	15	8.94	12.68	21.62
	Domestic	85	8.19	0.36	8.55
Belencito	Domestic	100	6.02	0.10	6.12
Monclova	Domestic	100	6.80	0.85	7.65
Chimbote	Imported (asphalt)	15	13.20	7.62	20.82
	Domestic	85	4.50	0.85	5.35
Barcelona	Imported	100	8.94	4.54	13.48
	Domestic (asphalt)	100	2.26	3.32	5.58
Sparrows Point, Maryland	Domestic	100			9.10

a/ The original calculation was US$20.50, but it was reduced at the suggestion of the representatives of Volta Redonda to the real figure of US$16.-.

Annex 5 Cost of Coal Delivered to Plant
(per ton of pig iron, in 1948 dollars)

Location	Origin of coal	% in blend	Cost of blend per ton	Tons of coal per ton of pig iron	Cost of coal per ton of pig iron
San Nicolás, Zapla ore	Imported	100	20.00	1,350	27.00
San Nicolás, Itabira ore	Imported	100	20.00	1,070	21.40
San Nicolás, Sierra Grande ore	Imported	100	20.00	1,150	23.00
Volta Redonda	Santa Catarina Imported	30 70	22.79	1,095	24.96
Huachipato	Golfo Arauco Imported	85 15	10.54	1,320	13.91
Balencito	Paz de Río	100	6.12	1,420	8.75
Monclova	Coahuilas	100	7.65	1,250	9.56
Chimbote	Anthracite Santa Asphalt Imported	85 15	7.68	970	7.45
Barcelona	Domestic asphalt	100	5.58	1,600	8.93
Barcelona	Imported	100	13.48	1,070	14.42
Sparrows Point, Maryland	West Virginia	100	9.10	1,070	9.74

Annex 6

Costs of Limestone

(1948 dollars per ton)

Location	Trans-port costs ton	Total cost per ton of lime stone	Kg.s. of limestone per ton of pig iron	Cost of limestone per ton of pig iron
San Nicolás, Zapla ore	1.60	3.86	505	1.95
San Nicolás, Itabira ore	1.60	3.86	200	0.77
San Nicolás, Sierra Grande ore	1.60	3.86	200	1.08
Volta Redonda	4.54	6.80	280	1.90
Huachipato	3.41	5.67	280	1.59
Belencito	0.00	2.26	500	1.13
Monclova	0.09	2.35	290	0.68
Chimbote	2.22	4.48	280	1.25
Barcelona a/	2.90	5.16	350	1.80
Barcelona b/	2.90	5.16	200	1.03
Sparrows Point	2.90	5.16	200	1.03

Average (Venezuela b/ only) $ 1.74

a/ Coke produced with asphalt or petroleum residues

b/ Coke produced from imported coal

Annex 7 Costs of Coking Operations

The "Mineral Yearbook" gives the cost of production of metallurgical coke in the United States in coke-ovens, for 1948 in short tons of 2.000 lbs., these figures, reduced to metric tons, give the following values:

Gross cost per metric ton of coke	US$	18.58
Cost of coking coal per metric ton of coke		12.77
Coking cost per metric ton of coke		5.81
which includes capital charges of		2.27
Coking cost per metric ton of coke		3.54
Therefore, the approximate coking cost per metric ton of coking coal, would be		2.48
and the credit for by-products would represent		3.09

Annex 8

Coke plant costs and credits

(1948 dollars)

	Costs of coking per ton of coal	Credits for by-products per ton of coal	Net cost or credit per ton of coal	Coal consumed per ton of pig iron	Coking per ton of pig iron
San Nicolás, Zapla ore	2.48	3.09	-0.61	1,350	-0.86
San Nicolás, Itabira ore	2.48	3,09	-0.61	1,070	-0.65
San Nicolás, Sierra Grande ore	2.48	3.09	-0.61	1,150	-0.70
Volta Redonda	2.48	3.09	-0.61	1,095	-0.67
Huachipato	2.48	3.09	-0.61	1,320	-0.81
Belencito	2.48	3.09	-0.61	1,430	-0.88
Monclova	2.48	3.09	-0.61	1,250	-0.76
Chimbote	2.48	-	+2.48	970	+2.40
Barcelona a/	2.48	-	+2.48	1,270	+3.15
Barcelona b/	2.48	3.09	-0.61	1,070	-0.65
Sparrows Point	2.10	3.09	-0.99	1,070	-1.06

(+) Costs

(-) Credits

a/ Coke produced with asphalt or petroleum residues.

b/ Coke produced from imported coal.

Annex 9

Cost of Pig Iron Production in 250,000 Ton Plants

(1948 dollars per ton)

Item	San Nicolás Zapla	San Nicolás Itabira	San Nicolás Sierra Grande	Volta Redonda	Huachipato	Belencito	Monclova	Chimbote	Barcelona asphalt a/	Barcelona coal b/	Sparrows Point
Iron ore	30.20	20.57	14.80	10.47	7.55	7.74	16.50	10.10	10.95	10.95	16.37
Coking coal	27.00	21.40	23.00	24.96	13.99	8.75	9.56	7.45	8.93	14.42	9.74
Limestone	1.95	0.77	1.08	1.90	1.59	1.13	0.68	1.25	1.80	1.03	1.03
Less, credit for blast furnace gas	-1.90	-1.90	-1.90	-1.90	-1.90	-1.90	-1.90	-1.90	-1.90	-1.90	-1.90
Assembly costs	57.25	40.84	36.98	35.43	21.15	15.72	24.84	16.90	19.78	24.50	25.24
Direct wages	0.45	0.45	0.45	0.41	0.35	0.47	0.38	0.32	1.56	1.56	1.22
Indirect wages and salaries	0.57	0.57	0.57	0.53	0.44	0.60	0.49	0.41	2.00	2.00	1.57
Total, wages and salaries	1.02	1.02	1.02	0.94	0.79	1.07	0.87	0.73	3.56	3.56	2.79
Cooling water	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Net coking costs								†2.40	†3.15		
Less net coking credits	-0.86	-0.65	-0.70	-0.67	-0.81	-0.38	-0.76			-0.65	-1.06
Repairs and overhead	2.16	2.16	2.16	2.09	2.06	2.49	2.11	2.01	2.40	2.10	2.10
Total, other transformation costs	1.72	1.93	1.88	1.84	1.67	2.53	1.77	4.83	5.97	1.87	1.46
Direct costs	59.99	43.79	39.88	38.21	23.61	19.32	27.48	22.46	29.31	29.93	29.49
Capital charges	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	6.40
Total costs	68.63	52.43	48.52	46.85	32.25	27.96	36.12	31.10	37.95	38.57	35.89

a/ Coke produced with asphalt or petroleum residues.

b/ Coke produced from imported coal.

Annex 10

Cost of Steel Ingot in 250,000 Ton Plants

(1948 dollars per ton)

	San Nicolás										
	Zapla	Itabira	Sierra Grande	Volta Redonda	Huachipato 20% Bessemer	Belencito 100% Thomas	Monclova 100% open hearth	Chimbote 20% Bessemer	Barcelona a/ 20% Bessemer	Barcelona b/ 20% Bessemer	Sparrows Point 20% Bessemer
Liquid pig iron	52.10	39.80	36.83	35.98	24.77	23.96	27.42	23.90	29.14	29.62	27.56
Circulating scrap	12.54	9.58	8.87	8.65	5.78	5.13	6.61	5.57	6.80	6.91	6.43
Purchased scrap	6.24	4.77	4.41	4.42	2.95	2.54	3.30	2.84	3.47	3.53	3.30
Ferro-alloys	2.17	2.17	2.17	1.92	1.92	1.40	2.17	1.92	1.92	1.92	1.92
-Credit for Thomas slag						-6.50					
Total, ferrous material cost	73.05	56.32	52.28	50.97	35.42	26.53	39.50	34.23	41.33	41.98	39.21
Direct wages	2.00	2.00	2.00	1.60	1.33	0.90	1.72	1.24	6.04	6.04	4.74
Indirect wages	0.35	0.35	0.35	0.35	0.29	0.60	0.30	0.27	1.33	1.33	1.05
Total wages	2.35	2.35	2.35	1.95	1.62	1.50	2.02	1.51	7.37	7.37	5.79
Fuel oil	1.32	1.32	1.32	1.06	1.06	—	1.32	1.06	0.77	0.77	1.06
Limestone and refractories	1.10	1.10	1.10	1.10	1.10	1.60	1.10	1.10	1.10	1.10	1.10
Purchased electric energy	c/	c/	c/	c/	c/	1.05 d/	c/	c/	c/	c/	c/
Maintenance materials	0.50	0.50	0.50	0.50	0.50	0.85	0.50	0.50	0.50	0.50	0.50
Overhead, materials and services	0.45	0.45	0.45	0.57	0.57	0.72	0.45	0.57	0.57	0.57	0.57
Total, fixed production expenses	3.37	3.37	3.37	3.23	3.23	4.22	3.37	3.23	2.94	2.94	3.23
Total direct costs	78.77	62.04	58,00	56.15	40.27	32.25	44.89	38.97	51.64	52.29	48.23
Capital charges	6.40	6.40	6.40	5.94	5.94	6.22	6.40	5.94	5.94	5.94	4.40
Total cost	85.17	68.44	64.40	62.09	46.21	38.47	51.29	44.91	57.58	58.23	

Note: See Annex 10 (continued) "General Basic Assumptions Used in the Comparative Calculation of Costs of Production of Crude Steel"

a/ Coke produced with asphalt or petroleum residues.
b/ Coke produced from imported coal
c/ Assumed to be produced in the plant, included in "General and miscellaneous costs.
d/ 700 KWH per ton of re-melted scrap; 210 KWH per ton of ingot steel at $ 0.005 the KWH.

Annex 10 (Cont.) General Basic Assumptions Used in the Comparative Calculation of Costs of Production of Crude Steel

Item	Unit	100% Open hearth	80% Open hearth and 20% acid Bessemer	100 % Basic Bessemer. Scrap re-melted in electric furnace
Liquid pig iron per 1.000 kgs. of steel ingot	Kgs.	759	768	857
Circulation scrap	Kgs	203	199	205
Purchased scrap (at 90% of pig iron price)	Kgs.	101	102	101
Ferro-alloys per ton of steel ingot	US$	2.17	1.92	1.40
Fuel-oil	Kgs.	110	88	
Limestone and refractories	US$	1.10	1.10	1.60
Direct wages	Hours	3.5	3.02	1.50
Miscellaneous wages and expenses estimated in working hours	Hours	0.30	0.37	0.67
Repairs and maintenance corresponding to labour	Hours	0.32	0.30	0.32
Purchased electric energy	US$	c/	c/	1.05 d/
Maintenance materials	US$	0.50	0.50	0.85
Materials and services under the item "General and miscellaneous costs"	US$	0.45	0.57	1.05
Capital charges in United States 8%; in Latin America 9% on United States capital investment increased by 20% to cover transportation and other costs. This capital is estimated for Latin American plants, per ton of annual capacity at:	US$	73.30	66.-	69.60

c/ Assumed to be produced in the plant, included in "General and miscellaneous costs".
d/ 700 KWH per ton of re-melted scrap; 210 KWH per ton of ingot steel at $ 0.005 the KWH.

Annex 11 **Costs per Ton of Finished Steel in 250,000 Ton Plants**
(1948 dollars per ton)

Item	San Nicolás			Volta Redonda	Huachipato	Belencito	Monclova	Chimbote	Barcelona asphalt a/	Barcelona coke b/	Sparrows Point
	Zapla	Itabira	Sierra Grande								
Steel ingots	113.56	91.25	85.87	82.79	61.61	51.29	68.39	59.88	76.77	77.64	70.17
Fuel blast furnace gas	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Less scrap credit	-16.72	-12.77	-11.83	-11.53	-7.71	-6.84	-8.82	-7.43	-9.07	-9.21	-8.57
Raw materials per ton	97.72	79.36	74.92	72.14	54.78	45.33	60.45	53.33	68.58	69.31	62.48
Rolling wages (10.18 man hour)	5.80	5.80	5.80	5.40	4.48	6.11	5.00	4.17	20.36	20.36	15.98
Maintenance and overhead wages (20%)	1.16	1.16	1.16	1.08	0.90	1.22	1.00	0.83	4.07	4.07	3.20
Total wages	6.96	6.96	6.96	6.48	5.38	7.33	6.00	5.00	24.43	24.43	19.18
Refractories and spare parts	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Maintenance materials for services and overhead	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Electricity	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Total materials and services	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65	4.65
Total direct costs	109.33	90.97	86.53	83.27	64.81	57.31	71.10	62.98	97.66	98.39	86.31
Capital charges	18.81	18.81	18.81	18.81	18.81	18.81	18.81	18.81	18.81	18.81	13.94
Total Cost	128.14	109.78	105.34	102.08	83.62	76.12	89.91	81.79	116.47	117.20	100.25

a/ Coke produced with asphalt or petroleum residue.

b/ Coke produced from imported coke.

Annex 12 A

Breakdown of Iron Ore, Coal and Limestone Costs
(1948 dollars per ton)

Item	San Nicolás (Zapla)		Volta Redonda		Huachipato		Belencito	
	Iron ore	Pig iron	Iron ore	Pig iron	Iron ore	Pig iron	Iron ore	Pig iron
Iron ore								
Wages	0.90	1.88	0.90	1.39	0.90	1.50	1.00	2.12
Miscellaneous	0.82	1.71	0.82	1.26	0.82	1.37	0.86	1.82
Capital charges a/	0.54	1.13	0.54	0.83	0.54	0.90	0.40	0.85
Local transportation	12.23	25.48	4.54	6.99	2.26	3.77	1.39	2.94
Total	14.49	30.20	6.80	10.47	4.52	7.55	3.65	7.74
Fuels (Domestic)								
Wages			9.60	3.16	3.29	3.69	2.53	3.61
Miscellaneous			6.40	2.10	2.20	2.47	1.69	2.41
Capital charges			4.50	1.48	2.70	3.03	1.80	2.57
Transportation			6.42	2.11	0.36	0.40	0.10	0.14
Imported fuel (Value)	—	27.00	—	14.94	—	4.28	—	—
Total		27.00	26.92	23.79	8.55	13.87	6.12	8.73
Limestone								
Wages	0.90	0.45	0.90	0.25	0.90	0.25	1.00	0.50
Miscellaneous	0.82	0.41	0.82	0.23	0.82	0.23	0.86	0.43
Capital charges	0.54	0.27	0.54	0.15	0.54	0.15	0.40	0.20
Transportation	1.60	0.82	4.54	1.27	3.41	0.96	—	—
Total	3.86	1.95	6.80	1.90	5.67	1.59	2.26	1.13

a/ Investment US$ 6.- per ton/year.

Annex 12 B

Breakdown of Iron Ore, Coal and Limestone Costs
(1948 dollars per ton)

	Monclova		Chimbote		Barcelona a/		Barcelona b/		Sparrows Point	
	Iron ore	Pig iron	Iron ore	Pig iron	Iron ore	Pig iron	Iron ore	Pig iron	Iron ore	Pig iron
Iron ore										
Wages	0.90	1.50	0.90	1.50	0.85	1.31	0.85	1.31	0.85	1.31
Miscellaneous	0.82	1.37	0.82	1.37	0.75	1.00	0.65	1.00	0.65	1.00
Capital charges c/	0.54	0.90	0.54	0.90	0.76	1.17	0.76	1.17	0.76	1.17
Local transportation	7.62	12.73	3.79	6.33	4.85	7.47	4.85	7.47	8.37	12.89
Total	9.88	16.50	6.05	10.10	7.11	10.95	7.11	10.95	10.63	16.37
Fuels (Domestic)										
Wages	2.73	3.41	1.62	1.34	0.86	1.38			2.10	2.24
Miscellaneous	1.82	2.27	1.08	0.89	0.58	0.93			1.40	1.49
Capital charges	2.25	2.81	1.80	1.49	0.80	1.28			2.40	2.56
Transportation	0.85	1.06	0.85	0.70	3.32	5.31			3.20	3.41
Imported Fuel (Value)				3.02				13.48		
Total	7.65	9.56	5.35	7.44	5.56	8.90	13.48	14.37	9.10	9.70
Limestone										
Wages	0.90	0.26	0.90	0.25	0.85	0.30	0.85	0.17	0.85	0.17
Miscellaneous	0.82	0.24	0.82	0.23	0.65	0.23	0.65	0.13	0.65	0.13
Capital charges	0.54	0.16	0.54	0.15	0.76	0.27	0.76	0.15	0.76	0.15
Transportation	0.09	0.02	2.22	0.62	2.90	1.01	2.90	0.58	2.90	0.58
Total	2.35	0.68	4.43	1.25	5.16	1.81	5.16	1.03	5.16	1.03

a/ Coke produced with asphalt or petroleum residue.

b/ Coke produced from imported coke.

c/ Investment US$ 6.- per ton/year.

Annex 13

Distribution of Assembly Costs of Raw Materials
(1948 dollars per ton)

	San Nicolás, with ore from:			Volta Redonda	Huachipato	Belencito	Monclova	Chimbote	Barcelona a/	Barcelona b/	Sparrows Point
	Zapla	Itabira	Sierra Grande								
Wages											
Iron ore	1.88		1.58	1.39	1.50	2.12	1.50	1.50	1.65	1.65	1.65
Coal				2.14	3.69	3.61	3.41	1.34	1.38		2.25
Limestone	0.45	0.18	0.25	0.25	0.25	0.50	0.26	0.25	0.37	0.21	0.21
	2.33	0.18	1.83	3.78	5.44	6.23	5.17	3.09	3.40	1.86	4.11
Miscellaneous											
Iron ore	1.71		1.44	1.26	1.37	1.82	1.37	1.37	1.00	1.00	1.00
Coal				1.65	2.47	2.41	2.28	0.89	0.93		1.50
Limestone	0.41	0.16	0.23	0.23	0.23	0.43	0.24	0.23	0.23	0.13	0.13
	2.12	0.16	1.67	3.14	4.07	4.66	3.89	2.49	2.16	1.13	2.63
Capital charges											
Iron ore	1.13		0.95	0.83	0.90	0.85	0.90	0.90	0.83	0.83	0.83
Coal				1.48	3.03	2.57	2.81	1.49	1.31		2.57
Limestone	0.27	0.11	0.15	0.15	0.15	0.20	0.16	0.15	0.19	0.11	0.11
	1.40	0.11	1.10	2.46	4.08	3.62	3.87	2.54	2.33	0.94	3.51
Transportation											
Iron ore	25.48	17.10	10.83	6.99	3.77	2.95	12.73	6.33	7.47	7.47	12.89
Coal				2.11	0.40	0.14	1.06	0.70	5.31		3.42
Limestone	0.82	0.32	0.45	1.27	0.96	-	0.02	0.62	1.01	0.58	0.58
	26.30	17.42	11.28	10.37	5.13	3.09	13.81	7.65	13.79	8.05	16.89
Fuel											
Imported Coal	27.00	24.87	23.00	17.58	4.28			3.02		14.42	
	59.15	42.74	38.88	37.33	23.01	17.60	26.74	18.80	21.68	26.40	27.14
TOTAL											
Iron ore	30.20	20.57	14.80	10.47	7.55	7.74	16.50	10.10	10.95	10.95	16.37
Coal	27.00	21.40	23.00	24.96	13.87	8.73	9.56	7.45	8.93	14.42	9.74
Limestone	1.95	0.77	1.08	1.90	1.59	1.13	0.68	1.25	1.80	1.03	1.03
	59.15	42.74	38.88	37.33	23.01	17.60	26.74	18.80	21.68	26.40	27.14

a/ Coke produced with asphalt or petroleum residues.
b/ Coke produced from imported coal.