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Background paper

ECONOMIES OF SCALE AT SMALL INTEGRATED STEELWORKS

Presented by the

Economic Commission for Latin America

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on Integration of Industrial Development

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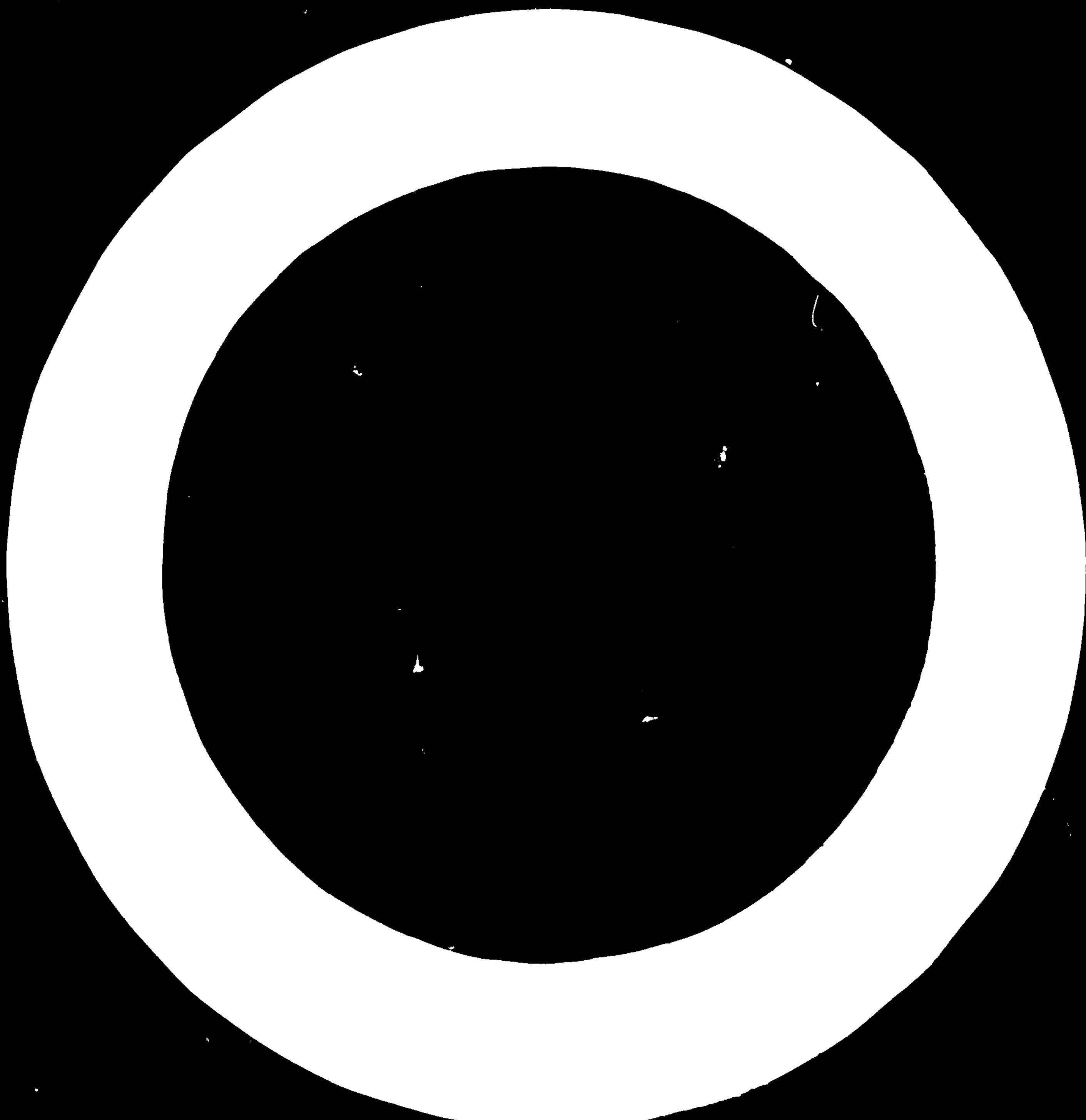
DRAWINGS

/FOREWORD



FOREWORD

Due to the relatively large expansion of steel capacity now contemplated by the developing countries of Latin America and the necessity to use the limited capital available in the most efficient manner, it is highly relevant for the region to carefully investigate, inter alia, economies of scale in the construction of integrated steelworks. The steel industry is particularly sensitive to the effects of plant size on both investment and operating costs. ECLA has already done excellent work in this field, and the present study seeks to extend the size-cost relationships to small integrated steel plants in the range of 25 000 to 300 000 tons of annual capacity.

For this study five plant sizes (25, 50, 100, 200 and 300 thousand tons liquid steel production capacity per year) have been selected. In order to highlight the effects of varying size on steel plant economics, the influence of factors not related to plant sizes have been minimised as far as practicable by holding them constant. Thus, for the purpose of comparability, the same production processes and product-mix pattern have been taken for all cases, in consultation with ECLA. Where feasible, higher production is secured through increased capacity of a single operating unit. All plants are considered to be in the same hypothetical location and to use the same qualities of raw materials. There is no provision of in-built equipment capacity for future expansion although space is provided for such expansion. It is assumed that capacity in all departments is fully utilised, whereas in practice it is desirable for developing countries where steel demands are rising rapidly to provide some extra in-built capacity initially, to facilitate expansion.

The estimates indicate that plant capital costs and production costs of iron, steel, billet and merchant products decrease rapidly as plant size increases from 25 000 tons to 300 000 tons per year. At the 300 000 ton stage, the per ton capital cost is only about 48 per cent and the production cost per ton of rolled product (including depreciation and interest) only 44 per cent of the 25 000 ton plant. This downward trend would continue - but at lower rates - as plant size increases beyond 300 000 tons.

/Our study

Our study indicates that even utilising modern technology which has greatly extended the lower size limit for viable steelworks, small integrated plants below 100 000 tons capacity are likely to be very uncompetitive. At such small capacities, there is a case for semi-integration, that is, an iron and steel making plant located in an area which has a strong raw materials base and supplying semis to two or three rolling mill plants located in areas closer to markets.

It needs to be emphasized that the techno-economic considerations outlined in this report for process and equipment selection as well as for cost estimates are valid only under the specific conditions selected for this study. They cannot be expected to be wholly valid for a specific plant or a particular location. For a specific plant, the type and quality of raw materials actually available, the demand for steel, the availability of power, water, fuel, transport, etc. and other special circumstances peculiar to the location will influence product-mix, process selection, plant capacity and costs.

Nevertheless, information in this report on production techniques and process selection, utilities and services, layout, capital and production costs, and manpower would be applicable even for a specific project, if due consideration is given to locational factors and necessary adjustments effected.

/SUMMARY AND

SUMMARY AND CONCLUSIONS

1. The Latin American countries covered by the United Nations Economic Commission for Latin America represent a wide range in terms of their land area, population, national income, general level of industrial development, raw materials and resources for steelmaking, size of the steel industry where it exists, and steel market. All of them are developing nations with low per capita national incomes in the range of 94 to 716 dollars per annum. The average per capita income for the region as a whole was 303 dollars in 1963. There is thus a substantial leeway to be made up in economic development in these countries.

2. Industrialisation is vital to rapid economic growth of the region and steel is basic to industrial development. Considering only the eight steel producing countries out of twenty-two in the region, the per capita consumption varied in 1964 from about 25 kg in Peru to 86 kg in Chile. The average per capita consumption for the region as a whole is about 50 kg. This is much higher than 15 kg in India, but is much lower than 258 kg in Japan, 357 kg in United Kingdom, 504 kg in West Germany and 540 kg in United States. It is obvious that steel consumption in the Latin American countries should rise considerably from the current low levels.

3. The ECLA region is generally well endowed with raw materials for iron and steelmaking, with the exception of coking coal the major portion of which has to be imported from outside the region, mainly from the United States. At present, the region produces about 75 per cent of the steel consumed in it. Many countries in the region are contemplating expansion of existing steel capacity or installation of new capacity.

/Indications are

Indications are that for the region as a whole the demand for steel would increase to about 19 million ingot tons by 1970 and to 28 million ingot tons by 1975. Production of steel is expected to increase to 16.25 million tons by [illegible]. At the current rate of population growth (about [illegible] per cent per annum in [illegible]) the per capita steel consumption in the region may thus be about 68 kg in 1970 and 88 kg in 1975.

Purpose of study

4\. Due to the relatively large expansion of steel capacity contemplated, and the necessity to use the limited capital available in the most efficient manner, it is highly relevant for the region to carefully investigate, inter alia, the economies of scale in the construction of integrated steelworks. As raw material and economic resources as well as potential market for steel vary widely from country to country, there is widespread interest in the installation of small as well as large integrated steel plants. The scope of the present study, commissioned in September 1965, is limited to small integrated steel plants in the range of 25 000 to 300 000 tons annual capacity.

Approach and assumptions

5\. The effect of plant size on capital and operating costs is influenced by many elements, and these have to be analysed project by project. For the purpose of this study, a number of assumptions necessarily had to be made. The object of the study is limited; namely, to secure a broad perspective on the size-cost relationship at the lower end of the size spectrum. While the trends indicated and the relative cost data are valid for this purpose, actual cost at specific installations may be widely different.

Estimates only indicative

6\. The study relates to hypothetical plants at a typical location in a developing country well served with road and rail communications. By the very nature of the study, the cost estimates and the conclusions drawn therefrom are likely to be only approximate and indicative.

/7. To

Provision for expansion

7. To facilitate comparative study of the economies of scale, the plant design and equipment considered for the plants do not have any in-built capacity for future expansion. In actual practice, however, this is not the right approach, particularly for a developing country where steel demand rises rapidly and where some in-built capacity in expensive equipment (such as rolling mills) would pay handsome dividends in future. In this study, while no in-built capacity has been provided, the plant has been laid out and space provided to facilitate expansion from three to five times the initial capacity. Such provision need not add much to initial investment if the plant is properly engineered.

Process of expansion

8. The steel industry is particularly sensitive to economies of scale. The extent of economies would depend on how expansion is effected. Expansion can be brought about by increasing the number of production units of the same capacity in each production department, in which case economies result from reduced overheads, reduced costs for repairs and maintenance, supply and service facilities, etc. which need not increase in the same proportion. Greater economies result from increasing the sizes of the production units themselves. In this study, plant size is increased through increased capacity of a single operating unit, wherever feasible, as for instance in the case of blast furnace for iron making, LD converted for steelmaking and rolling mills for the production of wire-rods and merchant products.

Same processes and product-mix pattern

9. Adoption of modern iron and steelmaking technologies have been considered. In order to isolate and highlight the effects of varying size on steel plant economy the effect of factors not related to plant size have been minimised as far as practicable by keeping them constant. Thus, to make the comparisons meaningful the same production processes have been assumed for all the selected plant capacities, although strictly the most economical processes could be considered for each size of plant.

/In integrated

In integrated plants with large capacities, product-mix may be diversified and the tonnages of different types of rolled products may still be adequate to install mill units of economic size. But product diversification in a small plant will largely result in elimination of economies of scale so far as the rolling operation is concerned. In fact, over-diversification of output to meet the requirements of a limited home market is one of the reasons for high cost of steel produced in many Latin American countries.

<u>LD steelmaking unsuitable for very small plants</u>

10. Whilst selection of the same production processes in all cases, as in this study, serves the purpose of comparability, it results in the selection of processes suited to the majority of cases but not to all cases. Thus, the adoption of LD process for the 25 000 ton and 50 000 ton plants, taken in conjunction with the other limiting assumption of full utilisation of installed capacity, has resulted in the choice of 3-ton and 6-ton LD converters, more suited to steel foundries or pilot plants than for economic operations in a steel plant. Electric arc furnace steelmaking has been considered as an alternative for the 50 000 ton plant.

<u>Raw materials and operating conditions</u>

11. The selection of process for a specific plant is influenced by locational factors. The data on available raw material resources and other operating conditions obtaining in Latin American countries furnished by ECLA have been assumed as holding good for all plant capacities under study.

<u>Selected processes</u>

12. The processes and major equipment selected for this study are indicated in Table 1. Some alternatives have also been considered, such as electric smelting compared to blast furnace for iron making in the 25 000 ton and 50 000 ton plants, and electric arc furnace as compared to LD converters for steelmaking in the 50 000 ton plant, to broadly evaluate the relative economics of these alternative processes for small steel plant capacities.

/Table 1

Table 1

SUMMARY OF MAJOR FACILITIES

	Case I - 25 000 T/yr	Case II - 50 000 T/yr	Case III - 100 000 T/yr	Case IV - 200 000 T/yr	Case V - 300 000 T/yr
Coke making	-	-	One - battery of 40 pusher type non-recovery ovens	One - battery of 20 by-product ovens	One - battery of 30 by-product ovens
Sintering	-	-	-	One - GHM pan type sintering machine, 4 pans of 4.62 sq m area each	One - GHM pan type sintering machine, 4 pans of 7 sq m area each
Ironmaking	One - 2 m hearth dia blast furnace	One - 2.75 m hearth dia blast furnace	One - 3.5 m hearth dia blast furnace	One - 4.3 m hearth dia blast furnace	One - 5.0 m hearth dia blast furnace
Steelmaking	One - 3-ton LD converter installation; one spare vessel	One - 6-ton LD converter installation; one spare vessel	One - 12-ton LD converter installation; one spare vessel	One - 25-ton LD converter installation; one spare vessel	One - 35-ton LD converter installation, one spare vessel
Continuous casting	Two - single strand continuous casting machines (curved mould type)	Two - single strand continuous casting machines (curved mould type)	Two - twin strand continuous casting machines (curved mould type)	Three - triple strand continuous casting machines (curved mould type)	Three - four strand continuous casting machines (curved mould type)
Rolling mills					
Reheating furnace	8-ton per hour continuous pusher type	12-ton per hour continuous pusher type	25-ton per hour continuous pusher type	50-ton per hour continuous pusher type	70-ton per hour continuous pusher type
Roughing mill	Two - 3-hi, 400 mm stands; 500 kW AC Drive	Two - 3-hi, 400 mm stands; 500 kW AC Drive	One - 550 mm vertical stand; 300 kW DC Drive Four - 2-hi 400 mm stands; two - 500 kW DC Drives	Four - 2-hi 450 mm stands; two - 500 kW DC Drives Four - 400 mm stands (second stand-vertical); four 500 kW DC Drives Four - 380 mm alternate vertical & horizontal stands; four 500 kW DC Drives	Four - 2-hi 450 mm stands; two 500 kW DC Drives Four - 2-hi 420 mm stands; four 500 kW DC Drives Seven - 380 mm stand (fifth stand-vertical) Seven 600 kW DC Drives
Finishing mill	Seven - 3-hi, 300 mm stands; two - 500 kW AC Drives	Seven - 3-hi, 300 mm stands; two - 500 kW AC Drives Four - 2-hi, 250 mm cont. wire rod finishing stands; 500 kW AC Drive	One - 550 mm vertical stand; 300 kW DC Drive Two - 300 mm & Three - 300 mm stands - zig-zag two 600 kW DC Drives One 550 vertical stand; 300 kW DC Drive Six - 2-hi 250 mm wire rod finishing stands; three - 220 kW DC Drives	Five - 300 mm stands - zig-zag; two - 400 kW DC Drives Six - 2-hi, 250 mm wire rod finishing stands; three - 220 kW DC Drives	Five - 340 mm stands (alt. horizontal & vertical); five 600 kW DC Drives Wire rod finishing - two trains each consisting of: six - 200 mm (alternate vertical and horizontal) stands, six - 220 kW DC Drives for each train

Layout

13. Plant general layout envisaged is compact, and designed for unidirectional flow with minimum handling by road or rail transport of "in-process" materials. The mixer building of the steelmelt shop is located adjacent to the blast furnace cast house. Continuous cast steel billets are delivered direct to cooling beds located in the billet storage bay of the mill building. Hot metal, liquid steel, and semis traffic is thus reduced to a minimum. The layout is such as to facilitate future expansion but no in-built provision is made for the same.

Capital cost estimate

14. The plant capital investment estimates are not derived from investments on any actual existing steelworks, but have been developed on the basis of estimates for buildings, equipment, civil and structural works, erection, etc., for selected processes and typical plant layouts. This approach permits a more rational and accurate comparison of investments for the different plant capacities. Capital cost estimates are in dollars and based on the same unit construction and materials costs which have been used in other ECLA studies, and on United States equipment costs.

Auxiliary facilities

15. Auxiliary departments such as power, water and utilities systems, internal transport, repair and maintenance shops, laboratories, miscellaneous buildings, storages, etc., account for a substantial proportion of the cost, increasing from 23 per cent of the total plant cost for the 300 000 ton plant to 32 per cent for the 25 000 ton plant. There are no recognised standards for the extent of provision to be made for repair and maintenance shops, service and other facilities. For steel plants located in countries without well developed engineering industries such provision has to be on an ampler scale than in highly industrialised countries

/where spares

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Background paper

THE ... OF ... OF SMALL INTEGRATED STEELWORKS

Corrigendum

... should appear on the cover ...:

... report entitled "Las ... de Escala en Plantas Siderurgicas ... y la Influencia de los Adelantos Tecnologicos en las Inversiones y Costos de Produccion" has been prepared for the United Nations Economic Commission for Latin America by a consultant, Ing. Armando P. Martijena, and issued as document E/CN.12/766.

...-15684

where spares and replacements are procurable at short notice. The provision made for the plants under consideration may appear excessive, but the bias, if any, extends in the same measure to all cases and therefore does not affect comparability.

Capital costs of the auxiliary departments have been estimated separately, and then allocated to the production departments on the basis of relative utilisation of the supply and service facilities for calculating the "fixed charges" component of production cost. Plant capital costs and costs per ton annual capacity are summarised in Table 2.

Manpower

16. The estimates of manpower requirements, primarily intended for the purpose of evaluating production costs of typical plants, are optimum levels to be aimed at, and are based on general study of the various operations involved. Extra manpower for "off", leave and absenteeism has not been included, as due allowance has been made for this in the hourly wage rates.

The total labour force, liquid steel production in tons per man-year and capital investment per person employed for the selected plant capacities are given below:

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
Total force	949	1 122	1 410	1 900	2 146
Tons/man-year	26	45	71	105	139
Investment per worker	$11 730	$15 180	$21 190	$25 980	$30 900

/Table 2

Table 2

PLANT CAPITAL COST FOR SELECTED CAPACITIES a/

Production departments	Case I- 25 000 T/yr		Case II- 50 000 T/yr		Case III- 100 000 T/yr		Case IV- 200 000 T/yr		Case V- 300 000 T/yr	
	Total cost '000 $	Cost per ton $	Total cost '000 $	Cost per ton $	Total cost '000 $	Cost per ton $	Total cost '000 $	Cost per ton $	Total cost '000 $	Cost per ton $
Coke ovens	-	-	-	-	1 812	35.85	4 354	47.12	5 628	40.49
Sinter plant	-	-	-	-	-	-	2 093	27.85	2 602	23.65
Blast furnace	3 291	144.34	5 253	115.20	7 895	89.21	12 086	72.16	15 855	62.92
Steelmelt shop (LD)	2 763	110.52	4 192	83.84	6 692	66.92	9 574	47.87	11 852	39.51
Continuous casting	1 348	52.00	1 809	37.69	2 767	28.82	4 693	24.44	6 200	21.53
Rolling mills	3 835	174.02	5 778	131.44	10 716	120.00	16 618	92.00	22 456	82.95
Total	11 127		17 032		29 882		49 358		64 593	
Total plant cost per ton annual capacity:										
In terms of liquid steel		445.48		340.64		298.82		246.79		215.31
In terms of rolled product		506.30		387.47		334.64		273.49		238.59

a/ The capital costs of production departments include the allocations for capital costs of auxiliary facilities on the basis of relative utilization of these supply and service facilities.

/Capital investment

Capital investment per worker increases nearly threefold and productivity increases over fivefold with increasing plant capacity. The low labour productivity in Cases I and II, despite the adoption of advanced techniques of proved economy, indicates that these very small capacity plants are inherently unsuited to full integration.

Production costs

17. Broad estimates of production costs per ton output of the production departments in each of the plant sizes considered are arrived at on the basis of specific consumption of raw materials computed from their chemical analysis, and physical inputs of other items such as supplies, fuels, power, etc., on the basis of average efficient practices. In estimating production costs it is assumed that the plants are utilised fully. Works production costs and total production costs (including fixed charges at [illegible] per cent of capital investment) are summarised in Table 3. These costs are indicative and valid only under the specific conditions selected for study. While they serve well for the purpose of assessing the relative economies of operations as affected by plant size, they cannot be expected to be wholly valid for a specific plant or a particular location. For a particular plant, the quality of the raw materials actually available and other locational factors will influence costs.

Economies of scale

18. Capital and production costs increase gradually from 300 000 tons capacity down to about 100 000 tons capacity, but below 100 000 tons the rates of increase are rapid, and below 50 000 tons capacity they become quite steep. Capital cost indices per ton annual capacity and production cost indices per ton rolled product decrease with rise in plant capacity, as follow:

/Table 3

Table 3

PRODUCTION COST ESTIMATES FOR PLANTS OF SELECTED CAPACITIES

(All costs in dollars per ton)

	Case I- 25 000 T/yr	Case II- 50 000 T/yr	Case III- 100 000 T/yr	Case IV- 200 000 T/yr	Case V- 300 000 T/yr
1. **Coke**					
Cost of materials	-	-	27.59	26.60	26.60
Cost above materials a/	-	-	2.24	1.65	-0.04
Works production cost	-	-	29.83	28.25	26.56
Fixed charges	-	-	3.43	4.63	4.01
Total cost			33.26	32.88	30.57
2. **Sinter**					
Cost of materials	-	-	-	10.63	10.63
Cost above materials	-	-	-	2.81	2.19
Works production cost	-	-	-	13.44	12.82
Fixed charges	-	-	-	2.51	2.13
Total cost				15.95	14.95
3. **Iron**					
Cost of materials	33.26	32.80	32.40	32.36	31.10
Cost above materials b/	25.26	15.34	10.37	7.03	5.40
Works production cost	58.52	48.14	42.77	39.39	36.50
Fixed charges	12.99	10.37	9.87	9.93	8.58
Total cost	71.51	58.51	52.64	49.32	45.08
4. **Liquid steel (LD)**					
Cost of materials c/	64.44	54.39	49.29	45.69	43.18
Cost above materials	43.88	31.37	22.32	16.21	13.68
Works production cost	108.32	85.76	71.61	61.90	56.86
Fixed charges	22.19	17.00	14.76	12.62	10.78
Total cost	130.51	102.76	86.37	74.52	67.64
5. **Compact billet**					
Cost of materials c/	111.90	88.44	73.72	63.63	58.38
Cost above materials	16.45	9.89	7.74	5.73	4.67
Works production cost	128.35	98.33	81.46	69.36	63.05
Fixed charges	27.38	21.10	17.97	15.35	13.17
Total cost	155.73	119.43	99.43	84.71	76.22
6. **Rolling**					
Cost of materials c/	138.06	105.28	85.95	72.51	65.80
Cost above materials	34.88	22.45	13.97	11.22	9.64
Works production cost	172.94	127.73	99.92	83.73	75.44
Fixed charges	45.72	34.86	30.12	24.61	21.48
Total cost	218.66	162.59	130.04	108.34	96.92

a/ Net after allowing credit for gas, tar and breeze.

b/ Net after allowing credit for B.F. gas.

c/ Net after allowing credit for recoverable scrap.

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
Capital cost per ton nominal capacity	100	76.5	67.1	55.5	48.4
Production cost per ton rolled product	100	74.4	59.5	49.6	44.3

All the major elements constituting production cost viz, cost of materials, cost above materials, and fixed charges, per ton of finished product decrease with increasing plant capacity.

Cost structure

19. Production cost structures for the five plant sizes under study (Table 4) indicate that the proportion of "wages and salaries" to "total costs" varies from 19 per cent for the 300 ton plant to 41 per cent for the 25 000 ton plant. The rapid increase in the proportion of wages and salaries is due to decrease in productivity. The effect of rising wages on production costs can be effectively countered only by increased productivity, by the adoption of improved processes and through economies of scale.

Table 4

COST STRUCTURE FOR STEEL PRODUCTION

(Percentage of total)

	Case I	Case II	Case III	Case IV	Case V
Raw materials	20	26	31	37	41
Power and fuel	4	4	5	5	6
Wages & salaries	41	33	27	22	19
All others	35	37	37	36	34
Total	100	100	100	100	100

/20. Within

Capital/output ratio

20. Within limitations depending on the type of industry, tax rates, etc., the ratio of capital investment to gross sales value of annual output serves as an indicator of the effectiveness of investment. Assuming an average selling price of 150 dollars per ton of rolled product, the capital/output ratio for the five plant capacities under study, in order of increasing size, are 1:0.30, 1:0.39, 1:0.45, 1:0.55, and 1:0.63 respectively.

Electric smelting of iron

21. Comparison of iron production by blast furnace as against electric smelting process, both with and without pre-reduction, is as follows:

Cost items	Cost indices		
	Blast furnace	Electric smelting (with pre-reduction)	Electric smelting (without pre-reduction)
25 000 ton plant:			
Capital cost	100	87.1	77.0
Production cost/t	100	111.4	126.7
50 000 ton plant:			
Capital cost	100	85.4	76.9
Production cost/t	100	118.3	138.3

For the conditions assumed in this study, therefore, the blast furnace produces the cheapest iron even in the smallest size of plant, in spite of the higher capital investment required.

22. It is understood that in Latin America scrap is not readily available in large quantities or at competitive prices and, therefore, plants based on market scrap are likely to run into trouble. However, as a matter of interest, alternative combinations of iron and steelmaking processes are considered

/for the

for the 50 000 ton plant. Plant capital cost per ton annual capacity and production cost per ton of rolled product with these alternative process combinations are given as percentages of the capital and production cost of the blast furnace - LD converter combination selected for this study, in Table 5.

Table 5

CAPITAL AND PRODUCTION COST INDICES FOR ALTERNATIVE IRON AND STEELMAKING PROCESSES
(CASE II - 50 000 T/YR)

Iron & steelmaking units	Total plant capital cost/ton annual capacity	Production cost a/ per ton rolled products
1. Blast furnace - LD converter	100.0	100.0
2. Blast furnace - Arc furnace b/	86.4	91.7
3. Electric smelting (with pre-reduction) - Arc furnace b/	84.3	94.6
4. Electric smelting (without pre-reduction) - Arc furnace b/	82.6	98.3
5. Arc furnace c/	65.1	79.1

a/ Scrap price assumed at 30 dollars per ton for calculating production costs.

b/ 50 per cent scrap - 50 per cent hot metal charge for steelmaking.

c/ 100 per cent scrap charge for steelmaking.

/Project costs

Project costs

23. The capital cost estimates cover costs within the plant boundary. In estimating total project cost, all off-site cost such as township, bringing water, power and railroads to site, etc., have also to be considered. These costs as well as the costs of infrastructure items of strengthening the region, such as transport, water and power resources, are higher in a developing country. But their provision should be regarded as an essential social investment in the larger context of raising the living standards of the people as a whole, accelerating the development process.

Plan construction

24. While considering total project cost, the time taken for the completion of the project is of significance. Normally, small integrated plants of the type envisaged should not take more than about three years for completion, from the date of placement of orders for equipment. Delays beyond the scheduled period of completion will greatly increase total costs of the project, by additional interest charges during construction, escalation in the costs of contruction and equipment, administrative overheads, etc., and will prevent the large investment from being utilised quickly.

Organisation of projects

25. To ensure speedy execution of the project, arrangements have to be made at the start for appointment of a project head and of a steel plant design organisation for the engineering of the project, procurement of equipment, supervision and management of construction. The project head and other personnel appointed for supervision and management of construction should be qualified and experienced to take up operation jobs, if necessary, when the plant goes into production. Advance action has also to be taken regarding financial and other arrangements, government and local procedural requirements, site

/acquisition and

acquisition and preparation, provision of infrastructure facilities, recruitment and training. These will remove many of the bottlenecks that hamper the smooth progress of the project and its completion within the scheduled programmed period.

Conclusion

26. For this study of economies of scale at small steelworks, five integrated steelworks having capacities of 25 000, 50 000, 100 000, 200 000 and 300 000 tons per year respectively are considered. The production processes selected are based on efficient and modern techniques of proved economy viz. blast furnace operation with oil injection, high blast temperature and prepared burden, LD steelmaking, continuous casting of billets, and merchant mill. The major raw materials considered are of high quality - iron ore with 65 per cent Fe, coke with 8 per cent ash and 90 per cent FC and limestone with 52 per cent CaO and 5 per cent insolubles. Despite these favourable conditions, very small integrated steelworks of 25 000 ton and 50 000 ton annual capacities, producing ordinary varieties of merchant steel products, are not likely to be economically viable under normal market conditions. Study of alternative iron and steelmaking processes indicates that for small size plants of 50 000 tons capacity or less semi-integration with only steelmaking in arc furnace would prove more economical provided purchased scrap is readily available at reasonable prices.
Another possibility that can be considered in the interest of stimulating regional development within a large country is to separate rolling from steelmaking. Production of steel and semis could be confined to medium and large integrated steel plants located in areas with a strong raw materials base, and the semis could be rolled into

/finished products

finished products in satellite mills set up in the same area to roll a diverse range of products, or in market based mills dispersed in various regions of the country. These mills could be of economic sizes for rolling products which would find a ready market in the region.

The above concept can be extended to encompass several adjacently located countries in the region or even Latin America as a whole, if decided advantages in terms of raw materials, economic resources and enlarged markets offer greater scope for exploiting economies of scale.

While the information given in this report on production techniques and process selection, utilities and services, layout, capital and production costs and manpower are relevant only in the context of the specific conditions assumed for this study, they would be applicable to a specific project if due consideration were given to locational factors which differ, and necessary adjustments effected.

1. INTRODUCTION

The Latin American region comprises twenty-two countries from Mexico in the north to Argentina and Chile in the south, and constitutes nearly half the land area of the Western Hemisphere. Intensive effort is taking place in this region for rapid economic development. The Latin American countries present wide disparities in many aspects, including national income per capita and rate of growth.

Steel in Latin America

It is well-known that industrial expansion is vital to rapid growth and, in turn, requires steel. As the ECLA region is well endowed with economically exploitable supplies of iron ore and, to a limited extent, with coking coal, there has been considerable interest in iron and steel production in the region.

Past consumption

Steel production in Latin America has risen from half-a-million tons in 1940 to about 9 million tons in 1966. The total apparent steel consumption, expressed in terms of equivalent ingot tons and excluding the steel content of imported plant and equipment, was 11.6 million tons in 1964. Of this tonnage, 8.0 million ingot tons were produced in the region and the balance imported. The per capita steel consumption for the region as a whole was 50.4 kg and the over-all average per capita national income was 303 dollars in 1963. Comparing these two indicators of economic well-being with those of developed countries like United States (540 kg of steel and US$ 2 790 per capita in 1963) and Japan (258 kg and US$ 628 per capita) it is obvious that there is still a considerable leeway to be made up by the countries in the region, particularly in respect of steel consumption.

/ECLA's projected

Future capacity

ECLA's projected demand estimates of rolled steel products by 1970 and 1975 are 18.61 and 27.36 million equivalent ingot tons respectively.[1/] Possible production by 1970 has been estimated at 16.25 million tons, that is more than double 1963 production.[1/] A large proportion of the increase in output is expected to be achieved by installation of additional production facilities in existing plants, to reduce or eliminate altogether the present imbalance between ironmaking, steelmaking and rolling mill capacities in these plants. The shortfall that would need to be covered by imports in 1970 would still be considerable.

To establish and develop new steel capacity in any country requires some degree of technological development, large capital investment and an assured market. The Latin American steel industry has therefore tended to concentrate in those countries which have a large domestic market. Costs of steel produced by Latin American plants are, with few exceptions, much higher than imported materials. Protection by the levy of heavy tariff duties has been essential in most cases. As a consequence, costs have tended to remain high which has, in turn, limited consumption.

The main causes of high costs of steel products manufactured by Latin American plants are considered to be unbalanced plant capacities, failure to adopt the latest technological developments, uneconomically small units particularly for flat products, over-diversification of output to meet the requirements of a limited home market, and lack of adequate numbers of trained personnel. When expanding existing capacity or installing new capacity,

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1/ La Economía Siderúrgica de América Latina, ST/ECLA/Conf.23/L.29, E/CN.12/727, preprint, Table 67, p. 271.

/due consideration

due consideration has to be given to factors that can keep down capital investment and production costs, such as limiting the range of products manufactured in case the size of the market does not permit diversity, adoption of proved techniques suited to the raw materials available and production required, and economies of scale.

The fields of choice in regard to size, technology and locations in installing new capacity are now greatly extended as a result of the tremendous technological changes the steel industry has witnessed in recent years. As Latin America - like other developing areas - is generally capital short, it is of the utmost importance that investment in this vital but capital-intensive industry is most effectively utilised.

Purpose of study

ECLA has sponsored a number of conferences and studies on the steel industry in the region, and much valuable data has been compiled and distributed. The current study is in regard to the economies of scale in small integrated steel plants, that is, the effect of plant size on investment and on production costs. An ECLA study on this subject was made in 1965, for integrated steel plants in sizes from 100 000 tons to 2.5 million tons per annum ingot capacity. This study is mainly confined to small plants in the 25 000 tons to 300 000 tons per year range.

Structure of report

Presentation

This report is presented in seven chapters. The scope, general approach and limitations of the study are discussed at the beginning of the report. A number of assumptions have had to be made to make the data comparable with previous ECLA studies, and these have been detailed. The metallurgical and engineering considerations in selecting production processes and major equipment are then discussed

/for each

for each of the five plant sizes in the range of 25 000 to 300 000 tons covered here. The auxiliary facilities and utilities required are outlined. The study then presents the capital and operating cost estimates as well as manpower requirements for each case. The results of the study are presented in appendices and graphs, and conclusions are discussed in the last chapter.

2. APPROACH TO THE STUDY

Plant capital and operating costs at integrated steelworks are influenced by a variety of factors such as plant size, raw materials, product-mix, technological options and locational factors. For the purpose of this report, which is limited to a broad perspective of the economies of scale in the steel industry, the effects of factors not related to plant size have been minimised as far as practicable by keeping them constant, in order to isolate and highlight the effects of plant size on steel plant economics. This section briefly discusses the approach and the major assumptions that have had to be made, as well as the limitations of the study.

Factors affecting plant size and cost relationship

The principal elements which reduce steel production costs as plant size increases are:

(i) Reduction in investment costs

(a) Lower investment per ton capacity of major production facilities, and correspondingly lower interest and depreciation charges per ton output.

(b) Lower investment on auxiliary facilities (tracks, storages, repair and maintenance shops, etc.) per ton of plant output.

/The study

The study is confined to the consideration of investment on production and auxiliary facilities within the plant boundary. In developing countries such as those comprising the Latin American region, however, the steel industry often has to incur expenditure on infrastructure facilities like road and railway links, port facilities, special transport equipment, development of raw material sources like mines and quarries, water and power supply, township, health, education and other social amenities.

Investment on such items may form a substantial proportion of the total, especially if the plant is located in a green-field site remote from existing townships. Such developmental expenditure will also be lower with increasing plant capacity, but the effect of this factor has not been considered in this study.

(ii) Reduction in operating costs

(a) Increase in labour productivity, both as a result of increase in equipment capacity as well as greater degree of mechanisation feasible, and better utilisation of management and supervision.

(b) Reduction in costs of general facilities such as centralised maintenance, transportation, stores-keeping, etc., per ton of output.

The effects of the above factors on the over-all production costs of iron, steel and continuously-cast billets rolled into the same category of products are analysed for five plant sizes having annual capacities of 25 000 tons, 50 000 tons, 100 000 tons, 200 000 tons and 300 000 tons of liquid steel respectively.

/General assumptions

General assumptions

In order to exclude the influence of other factors on the economies of scale, the following general assumptions have been agreed upon with ECLA.

(i) All the plants are built at one typical location in a developing country, well served with road and rail and other communications. The location selected assumes optimum costs for raw materials assembly and dispatch of finished products.

(ii) Starting with ironmaking, identical production processes are first selected for all the five plant sizes for comparability of data. (Some additional studies on alternative processes are also included.)

Whilst the above assumption serves best the purpose of comparative study of economies of scale in hypothetical plants of different sizes, it results in selection of processes which may be well suited to the majority of cases but not necessarily to all the cases. For instance, the top blown oxygen (LD) converter is undoubtedly an appropriate steelmaking process for the high hot metal charges envisaged. However, uniform adoption of this process for all cases results in an extremely small converter size of only 3 tons for the 25 000 ton plant and only 6 tons for the 50 000 ton plant. Such small converters are more suited for pilot-plant or steel foundry operations than for tonnage steel production. Further, to cope with as many as 30 to 35 heats produced with a single small converter in 24 hours it is necessary to have at least two continuous casting machines, resulting in very low machine utilisation.

/(iii) The

(iii) The plant units are expressly designed for the designated production; that is, no "in-built" capacity has been provided for the future. Enough site area is provided and the layout planned for future addition of at least one more meltshop/rolling mill complex. As the size of units at this second complex could be much larger than the initial facilities, plant capacity could be expanded at least three to fivefold.

Designing a steel plant without "in-built" capacity reduces initial investment, but this may not be the right approach for a developing country where steel demand inevitably rises rapidly from a low level at the start, particularly in countries with a good raw materials base and a large internal market. The choice of rolling mill unit for the plant sizes considered may be cited as a specific instance. These are designed to give the specific production required with little potential for increased output in future. A simple cross-country mill with little mechanisation meets the requirements of the 25 000 ton plant; for the 50 000 ton plant a continuous wire rod finishing train is added. For the 100 000 and 200 000 ton plants semi-continuous mechanised mills of increasing sophistication are considered, while for the 300 000 ton plant a continuous mechanised mill is proposed. In the context of a developing region, the 25 000 and 50 000 ton plants will inevitably require expansion quite soon after

/they are

they are commissioned, and it would therefore be advantageous to install a mechanised semi-continuous mill of higher capacity and operate it initially for only one or two shifts a day. In the long-term view, this would prove better than having to duplicate expensive mill facilities when expansion is taken in hand.

However, as noted earlier, in the interest of comparability, the production and auxiliary facilities do not have such "in-built" capacity, although layout provision for expansion has been expressly made.

Capacity and product-mix

Five plant sizes considered

The present study, as stated above, relates to five plant sizes, namely:

Case I	25 000 tons
Case II	50 000 tons
Case III	100 000 tons
Case IV	200 000 tons
Case V	300 000 tons

In order to have a uniform basis of study, the plant capacities given for all five cases are in terms of "liquid steel", and not as ingot or finished product.

Similar product-mix

A similar product-mix pattern of rolled steel products is selected for all of the above cases comprising rods, bars and merchant sections, to use only one rolling mill, the size and sophistication of the mill increases with plant size. The product-mix keeps in view optimum utilisation of plant and equipment.

/Process and

Process and main equipment

Suitable processes selected

For the proposed plant capacities, modern proved processes and equipment are considered. A large number of alternative processes are now available for iron and steel making; for this study, processes and equipment selected are such as to suit operations in the relatively small plant capacities selected. The reasons for adopting a particular iron and steel making process are clearly indicated.

Unit costs

Data on analyses and costs of raw materials and costs of utilities such as power, water, etc., are as indicated by ECLA for this study, and are the same for all plant sizes. Where other data is used, the source is stated.

Coke ovens for larger plants

For the 25 000 and the 50 000 ton plants, coke ovens and sinter plant are not envisaged. Purchased coke will be used as it will be available at a lower price. The 100 000 ton plant will have non-recovery slot-type coke ovens but no sinter plant. The 200 000 and 300 000 ton plants will have regular recovery-type coke ovens and sinter plant.

In view of the high cost of coke in Latin America (US$ 50-60 per ton for foundry coke and US$ 26 for coke produced from partly imported and partly local coal at one steel plant), blast furnace operating techniques considered are such as would minimise the coke requirement for iron making.

Sintering facilities

It has been assumed that mining and sizing of ores will yield about 30 per cent fines below 10 mm size. Availability of adequate quantity of fines and the metallurgical advantages of using agglomerates justify setting up of sintering facilities for the two large plant sizes considered.

/Regarding production

Blast furnace for iron making

Regarding production of iron (hot metal), an analysis of the relative economics of alternative processes for small scale iron making is included for the 50 000 ton plant size, to indicate the choices available and for the sake of completeness. However, to make the comparison meaningful, the same iron making process, namely blast furnace, is selected for the full range of plant capacities.

Of the direct reduction processes, the Hojalata y Lamina (HyL) process has advanced beyond the pilot plant stage. However, the possibility of adopting this process is limited to locations with abundant resources of natural gas in proximity to high grade iron ore. Operating experience is confined to one plant. ECLA has suggested its omission from this study.

Fuel oil injection and high blast temperature operation

The following additional criteria have been applied in this study for iron making, so that the findings from this study could be co-ordinated with other studies.

(i) Coke rate: 500 kg of coke per ton iron for the 300 000 ton plant has been considered. Fuel oil injection of 50 kg per ton of pig iron has been provided for all cases. In spite of the small size of blast furnace adopted, this low coke rate is considered feasible in view of the high grade of raw materials (ore with 65 per cent Fe, coke having only 8 per cent ash and limestone with 52 per cent CaO), use of 30 per cent self-fluxing sinter and fuel oil injection with requisite high blast temperature. Thorough burden preparation is visualised.

(ii) Gas credits: evaluated on the basis of cost of fuel oil for equivalent calorific value, taking the cost of fuel oil at US$ 20 per ton.

(iii) No top pressure is contemplated.

(iv) Temperature of blast: 1 050°C.

/Steam injection

EXPLANATION OF SYMBOLS

The following symbols have been adopted for this report:

(i) Three dots (...) indicate that data are not available or are not separately reported;

(ii) A dash (-) indicates amount is nil or negligible;

(iii) A minus sign (-300) indicates a deficit or decrease;

(iv) A full stop (2.3) is used to indicate decimals;

(v) A space is used to separate thousands and millions (3 123 425);

(vi) A stroke (/) indicates a fiscal year e.g. 1964/65;

(vii) "Tons" and "dollars" are metric tons and United States dollars unless otherwise stated;

(viii) Billions are thousand millions.

Steam injection and oxygen enrichment of the blast were not considered essential because of the quantity of oil injected and high blast temperature. In view of easy availability of oil, the quantity of oil injected could be further increased with higher blast temperatures. The use of oxygen is considered necessary only if adequate hot blast temperature cannot be obtained. Since plants considered are assumed to be new installations with adequate stove capacities for high blast temperatures, expenses incurred on oxygen enrichment would not be justified.

LD steelmaking considered

For steelmaking, the LD converter has been adopted, as being the most efficient and economic steelmaking process under the conditions considered. For one plant size, namely 50 000 tons, cost of electric smelting for iron making together with electric arc furnace for steelmaking have been estimated, as a matter of wider interest, although in Latin America, as in other developing areas, purchased scrap is not readily available.

The proportion of scrap used in the LD converter charge will be 20 to 25 per cent. With continuous casting of billets, plant return scrap will not be adequate to meet even half this requirement and the balance of the scrap will have to be purchased. Originally, 30 per cent scrap charge was considered, for better comparability with other ECLA studies, but on checking the heat balance it was found that due to the small size of converters and the high temperature of liquid steel required for continuous casting of small section billets, the proportion of scrap would have to be reduced.

Continuous casting and rolling mills

Suitable size, type and number of continuous casting machines are provided for producing cast billet, followed by rolling mills for the product-mix indicated. Selection of rolling mill facilities has kept in view the different

/tonnage outputs

tonnage outputs for each case, the range and proportion of different product sizes however remaining more or less the same for all cases. As already mentioned, "in-built" capacity for increased production is limited.

Capital costs

The plant capital investment estimates are not derived from any actual existing steelworks costs, but have been developed on the basis of estimates for buildings, equipment, civil and structural works, erection, etc., for selected processes and typical plant layouts. This approach permits a more rational and accurate comparison of investments for the different plant capacities.

The capital costs of production units have been indicated separately for six major production departments under each of the plant sizes, as follows:

(i) Coke-making
(ii) Sinter-making
(iii) Iron-making
(iv) Steel-making
(v) Continuous casting
(vi) Rolling.

Capital cost estimates are in US dollars and based on typical unit construction and materials costs furnished by ECLA. Estimates cover costs within the plant boundary and exclude "off-site" costs (such as township; bringing water, power and railroads to site; interest on capital employed during construction).

American equipment prices

Estimates of equipment cost are based on United States prices. Experience indicates that if the built-in excess capacity of United States equipment is compared with the capacity of equipment produced to strict specification limits by other countries which quote cheaper prices, the plant may not be more expensive in the end. As suggested by ECLA, 20 per cent is added to the f.o.b. value of imported equipment to cover ocean freight, insurance, clearing charges and inland transportation charges to site.

/In estimating

Service and maintenance facilities

In estimating costs of services and auxiliary facilities, ample provision has been made for efficient operations in developing countries with a relatively small industrial base and depending mostly on imported equipment. Provision for these facilities is to some extent open to the influence of subjective judgement, but the bias, if any, extends in the same measure to all cases, and therefore does not vitiate the validity of the comparison. The costs of necessary utilities and auxiliary facilities and services have been distributed over each of the production departments.

Spares estimated at 5 per cent

The capital cost estimates in the study include a provision of 5 per cent on total equipment costs for spare parts; this is considered a good margin if spares are carefully selected.

Contingencies and engineering charges

Provision for contingencies has been taken at 5 per cent, and for engineering, supervision of construction and client's administration during construction at 7 per cent of the total of the above costs.

The total of the capital cost estimate for production and auxiliary departments represents the total cost of the plant proper, all costs outside the plant boundary being excluded.

Production costs

Based on the estimated inputs of raw materials and supplies and the corresponding unit costs, broad estimates of the cost of the following products have been made:

(i) Coke	(iv) Liquid steel
(ii) Sinter	(v) Cast billet
(iii) Iron (hot metal)	(vi) Rolled product.

Regarding the physical inputs (that is, specific consumption of raw materials, supplies, labour, power, etc., per unit of output), these are generally based on average

/world-wide operating

world-wide operating practices, and normally attainable in an efficiently run plant. Some of these may not correspond with what actually obtains in individual Latin American installations.

Fixed charges

To determine total ex-works production costs for operation of all plants, 9 per cent of the investment figure has been added as capital charges. This is based on the following hypothesis:

(a) an estimated average plant life of 20 years;

(b) a rate of interest on capital of 8 per cent per annum, irrespective of its source, paid yearly on the portion of capital not yet amortized, which results in an average interest rate of 4 per cent per year;

(c) a 5 per cent annual lineal amortization;

(d) interests accruing on the resulting reserves are annually compounded at the same rate as on the capital until the end of the useful life of the respective equipment.

Complexity of the study

The complex nature of the study and the magnitude of work involved will be evident from the fact that the study required consideration of five complete projects, each with six production and seven ancillary departments, for each of which capital and production costs and manpower requirements had to be worked out.

/3. SELECTION

3. SELECTION OF PRODUCTION PROCESS AND MAJOR EQUIPMENT

This chapter discusses the selection of processes and equipment for the production of coke, sinter, iron, steel billets and rolled products in small integrated steel plants of capacities ranging from 25 000 to 300 000 tons a year. As hypothetical plants at a typical location using raw materials of given analyses are considered, only broad indications are possible; detailed studies will be required for any specific case to establish the economics of the process selected in relation to size of plant, raw materials available, patterns of demand and other factors.

Main considerations

The main considerations in the choice of process are technical feasibility and economic viability for the size of operations contemplated based on the quality of raw materials available. The present state of development and future potential of the process are also important factors influencing the choice.

In many situations, economy in both capital and operation costs can best be achieved by selecting equipment of optimum size which may not initially be fully loaded but would offer attractive economies of scale as the plant expands. This in-built provision in design and space, while not adding much to the initial investment, can pay handsome dividends in reduced investment as plant capacity expands, as it inevitably does in a developing economy. However, for the purpose of this study the equipment selected is for the specific output required, with little reserve capacity.

As indicated earlier, for purposes of comparison, the same production processes (with increasing size and sophistication as plant capacity increases) have been

/adopted for

adopted for all five cases. Strictly the most economical processes should be considered for each size of plant even for establishing the relationship between plant size and costs; however, for purposes of comparability with similar ECLA studies, the same processes have been selected for all cases. This serves to portray the economies of scale more vividly than would otherwise be possible.

Choice of technology

The production of steel of acceptable quality at economic costs is largely dependent on the choice of process and facilities. In view of the large capital investments involved in the construction of an integrated steel plant, the most suitable and proved processes should be selected. At the same time, it is desirable to adopt up-to-date technology to reduce the risks of premature obsolescence and prolong the economic life of the plant. There is a fallacy that developing countries have abundant "cheap labour", and because of this there is no over-riding need to employ advanced technology for increasing productivity.

Raw materials

Iron ore

The major raw materials influencing process selection are iron ore and reductant (coal, coke and natural gas). Latin America is endowed with vast iron ore reserves. The iron ore deposits are widely distributed and occur in some 13 countries. The types of ore vary widely and include heamatite, magnetite, limonite and iron sands. Some ores are characterised by chromium and nickel contents and a few by high phosphorous contents.

Of ores of immediate economic value, some 200 million tons are reported to contain 48 to 50 per cent Fe with high phosphorous contents of 0.8 to 1.0 per cent, but the bulk of reserves contain 58 to 67 per cent Fe and fairly low P.

/These rich

These rich ores are being used for smelting in blast furnaces and submerged electric arc furnaces, and for production of sponge iron. Considerable quantities are being exported.

Coal

Coal deposits occur in Colombia, Mexico, Venezuela, Peru, Chile, Argentina and Brazil. Most of these deposits are not suitable for coke making. Coking coal is available in limited quantities in Colombia and Mexico. Blendable coal exists in Brazil, Chile, Colombia, Venezuela and Mexico.

Charcoal is being used in some plants for iron smelting. The production of charcoal is naturally restricted to areas with suitable forests and as such areas in proximity to other major raw materials and markets for steel are limited, use of charcoal is not considered here.

Limestone

Limestone deposits are abundant in Latin America, and it may be expected that limestone of suitable quality would be available in the vicinity of a steelworks location.

Principal raw materials analyses taken for the purpose of this study are indicated in Table 3-1.

Table 3-1

CHEMICAL ANALYSES OF RAW MATERIALS a/

(Percentages)

	Fe	Mn	SiO_2	Al_2O_3	CaO	MgO	S	P	F.C.	V.M./L.O.I.
Iron ore	65	...	4.0(SiO_2+Al_2O_3)		...	...	-	...	-	4.0
Manganese ore	...	35.0	...	...	...	...	-	-	-	-
Coke (dry)	-	-	4.01	2.52	0.27	0.08	0.70	-	90	1.2
Limestone	0.35	-	4.00	1.00	52.0	1.60	-	-	-	...

a/ These are generally the same as have been used in previous ECLA studies and have been adopted for the present study, but conditions in the region vary so widely from country to country that they cannot be called typical.

/Natural gas

Natural gas

Crude petroleum reserves of Latin America are abundant but the deposits are unevenly distributed. Argentina, Colombia, Mexico and Venezuela are the only countries having abundant reserves of natural gas which would allow of its consideration as a fuel. There is one operating steel plant in Latin America using natural gas for reductant. For a general study such as this, use of natural gas as reductant is not considered.

Power

In general, purchased power is not readily available for steelworks use. The potential for hydro-power generation is high, but in view of high capital investment, inconvenient locations, etc., planning of large hydro-power generation primarily for steel plant use may not be justified.

Coke making

Captive coke plant versus purchased coke

The capital cost of a modern coke oven plant is high as an economic unit is fairly large. This raises the question whether to install a captive coke oven or to purchase coke. If the ex-works cost of coke produced in the plant is higher than the market price, it may well be advisable for small plants to purchase coke.

On the other hand, the use of fresh coke of uniform composition delivered direct to the blast furnace is conducive to better blast furnace operation. The moisture content of coke stored in the open varies widely, size degradation takes place due to excessive handling, and there is dust and dirt contamination during storage. These can result in variations of coke quality which are detrimental to good blast furnace operation. Therefore, where feasible, it is desirable to integrate coke making facilities with iron production units.

/Steelworks in

Steelworks in Latin American countries generally use substantial proportions of imported coals in blends. The cost of imported coal is generally US$ 2 to 4 per ton less than the cost of local coal delivered to the plant, except in the case of Mexico and Colombia where costs of local coals are lower. For the purpose of this study, it is assumed that the requirement of coal for coking will be met partly from local sources and partly by imports, and where suitable coking coal is not available indigenously the entire quantity will be imported.

Selection of process

For Case I - 25 000 ton plant and Case II - 50 000 ton plant, the run-of-oven coke requirements are only about 40 tons and 72 tons per day respectively. For plants of these sizes it will be more economical to purchase coke from outside sources than to make their own coke; the technological problems of small-scale coking operations and high production costs would not justify the provision of coke making facilities within the plant.

For Case III - 100 000 ton plant, coke is proposed to be produced at the plant. The coke requirement of about 144 tons per day is too small to justify the operation of a small number of modern by-product coke ovens. Modern non-recovery slot-type coke ovens, which are in operation in United States, and Canada, are considered suitable. The capital cost of this type of plant is low compared to conventional by-product coke ovens, and operating and maintenance costs are also low. The quality of coke produced is comparable to that from conventional plants. For plant capacities of 200 000 and 300 000 tons, the conventional coke oven is adopted.

/Due to

By-product recovery

Due to ample availability of petroleum products in the Latin American countries, there is not much scope for the sale of coke oven by-products such as processed tar, gas and light oil. The recovery of ammonium sulphate in by-product coke plants in the United States has already reached the point where it costs more than its sale price as fertilizer. Most of the fixed nitrogen produced in the United States is now made from natural gas of which some Latin American countries also have a large supply.

Therefore, a simple coke oven plant with recovery of only gas and tar is considered initially; when the plant is expanded, by-product recovery may be considered. However, to give an indication of the effect of extensive by-product recovery on capital and operating costs, a coke oven plant with recovery of bensol products and ammonium sulphate has also been considered for the 300 000 ton plant; capital and operating costs for this alternative identified as Case V (A) are compared with Case V in Appendix 3-1 and Appendix 6-2 respectively.

Coke plant facilities

For the purpose of this study, the following analysis of coal on dry basis is assumed, the analysis being similar to that of coal used in the Argentinian plant, SOMISA:

Volatile matter	29 %
Fixed carbon	66 %
Ash	5 %

The coke yield from the above coal will be about 75 per cent.

Table 3-2 summarises the quantities of coal required for carbonisation, coke requirements and coke yield, and the type and number of ovens.

Table 3-3 indicates the major facilities proposed for each case.

/Table 3-2

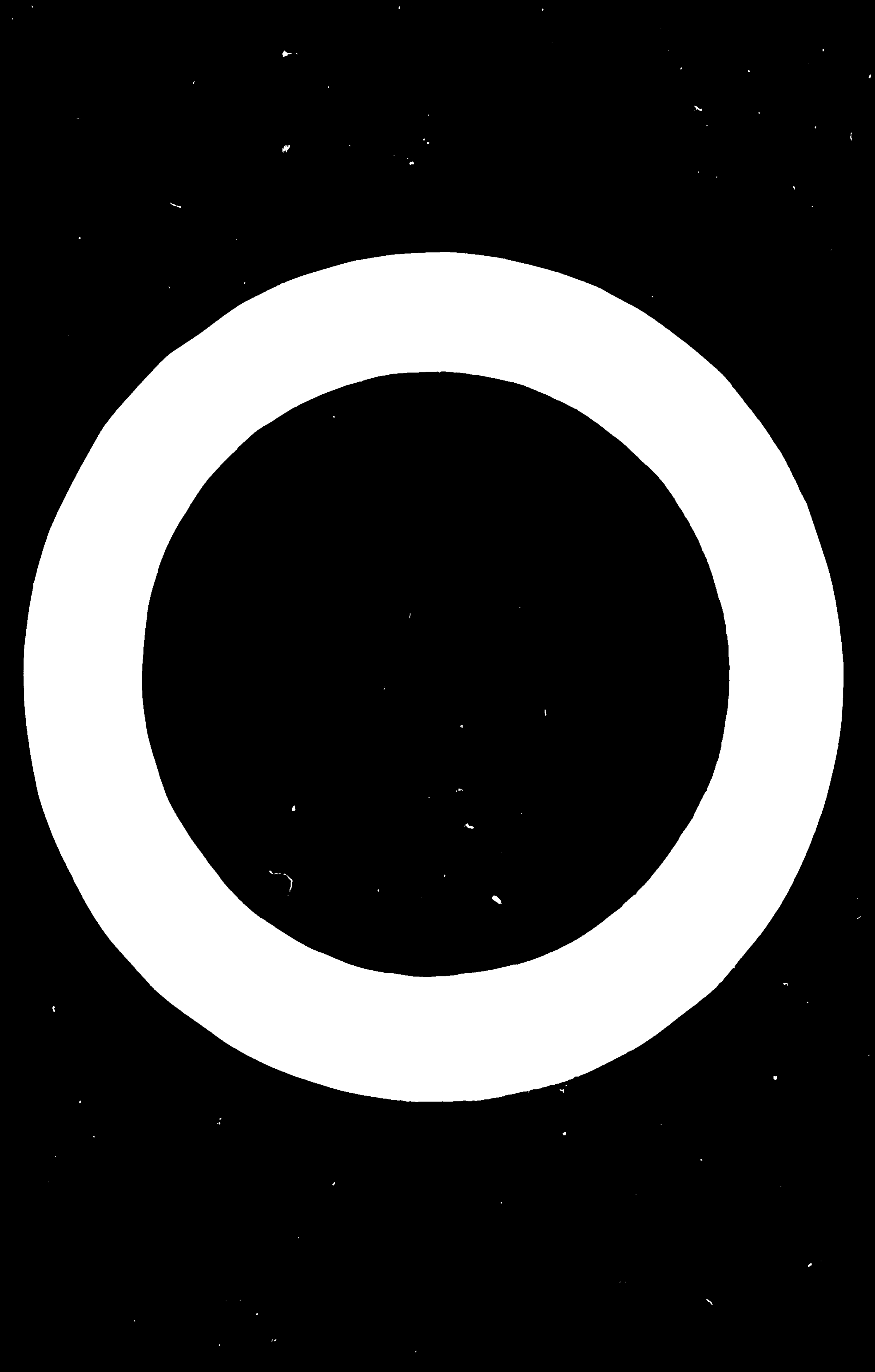

Table 3-2

COKE REQUIREMENTS AND COKING FACILITIES

(Basis: 350 working days/year)

	Case I - 25 000 T/yr	Case II - 50 000 T/yr	Case III - 100 000 T/yr	Case IV - 200 000 T/yr	Case V - 300 000 T/yr
Iron requirement (tons/year)	22 800	45 600	88 500	167 500	252 500
Iron production (tons/day)	65	130	253	479	720
Coke rate (kg/ton iron)	560	545	535	505	500
Blast furnace coke (tons/year)	12 768	24 852	47 348	84 588	126 250
Oven coke required (tons/year)	14 187 a/	27 613 a/	52 608	93 986	140 278
Oven coke required (tons/day)	41	79	150	269	401
Coal requirement (tons/year)	-	-	67 446	125 315	187 037
Coal requirement (tons/day)	-	-	192	358	534
Number of coke ovens	-	-	48	20	30
Type of ovens	-	-	Pusher-type Non-recovery ovens	By-product ovens	By-product ovens
Yield of gas/day @ 300 N cu m/Ton of coal - N cu m	-	-	-	107 400	160 200
Surplus gas (55 % of gas make) - N cu m	-	-	-	59 070	88 110
Yield of tar - Tons/year	-	-	-	5 013	7 482

a/ Purchased coke.

/Table 3-3

Table 3-3

COKE PLANT FACILITIES

Plant unit	Case III (B.F. coke - 47 500 T/yr)	Case IV (B.F. coke - 84 600 T/yr)	Case V (B.F. coke - 126 300 T/yr)	Case V (A) (B.F. coke - 126 300 T/yr)
Coal Handling & preparation	Manual unloading of coal. Hoppers and payloaders for stocking. Portable bucket wheel reclaimers, coal crushers, blending bunkers, mixers	Manual unloading in track hoppers. Single boom swivelling stacker, portable bucket wheel reclaimer, coal blending bunkers and blending facilities	Same as in Case IV	Same as in Case V
Coke ovens	48 Nos pusher-type non-recovery ovens	20 Nos by-product ovens	30 Nos by-product ovens. Other facilities same as in Case IV	Same as in Case V
	Coal charging machines, coke pushers, coke cars, door extraction, coke quenching stations	Coal charging cars, coke pushers, coke cars, door extraction, coke quenching station		
By-product plant	-	Gas condensation plant, exhausters, gas cleaning plant, tar decanters and tar storage	Same as in Case IV	Gas condensation plant, exhausters, gas cleaning plant, tar decanters, tar storage, benzol recovery, and distillation, and ammonium sulphate recovery

Note: No coke oven plant is proposed for Cases I and II, which are expected to use purchased coke.

/For Case III,

Plant description

For Case III, coal will be unloaded manually from the wagons standing on an elevated track and will be stacked out on the stocking grounds by means of portable stackers. A coal stock of about two months supply will be kept. Coal will be reclaimed by portable reclaimers and, after crushing, will be stored in the blending bunkers. Blended coal will be sent to the coal service bunkers located in the batteries.

Ovens will be charged by electrically operated charging cars, and coke pushed out after about 72 hours coking period. Hot coke will be received on coke cars, quenched, screened and delivered to the iron-making plant stock bins.

In Cases IV and V and V(A), coal will be manually unloaded from wagons in a track hopper, and stacked out on the coal stockyard by belt conveyors and single boom swivelling stackers. Coal will be reclaimed by portable reclaimers. After crushing, coal will be delivered to blending bunkers, and blended coal will be stored in the service bunkers. The coke ovens will be modern under-jet compound ovens heated by coke oven gas or blast furnace gas and will be provided with usual coke oven equipment and auxiliaries. Coke will be pushed into coke cars, quenched and screened, and sent to the iron-making plant stock bins. The coke handling will be entirely by belt conveyors.

<u>Agglomeration</u>

Mining and sizing of iron ores produces considerable quantities of fines, the amount depending on the type of ore and methods of mining and ore preparation. It is desirable to adopt some method to utilise these fines, specially as agglomeration by itself offers definite metallurgical advantages in iron smelting.

/The use

The use of agglomerate, sinter or pellets, has been increasing all over the world due to its significant contribution in raising blast furnace productivity and in lowering coke rate. For instance, blast furnace productivity is raised by 45 to 60 per cent and coke rate lowered by 25 to 40 per cent when 100 per cent self-fluxing sinter is used in the burden. Sintering is particularly suitable for fines below 10 mm with about 65 per cent in the size range of 1.0 to 0.15 mm. This size range would constitute the bulk of fines arising in ore mining operations.

Pellets

Pelletising is another technique which is being increasingly adopted particularly for agglomerating very fine ores and ore concentrates. Pelletising is best suited for very fine ores of below 0.15 mm, with about 75 per cent below 0.06 mm. Remarkable increases in blast furnace productivity have been achieved by using iron ore pellets in the blast furnace burden. For instance, gradually increasing the proportion of pellets from 10.9 per cent to 77.7 per cent over the period 1954 to 1960, in the burden of the 8.55 m diameter hearth furnace at their Middletown plant, ARMCO Steel Corporation achieved over 84 per cent increase in production rate from 1 230 tons per day to 2 270 tons per day with 30 per cent reduction in coke rate from 847 kg to 592 kg per ton of iron.[1]

Pre-reduction

The most recent development in the field is pre-reduction. The use of pre-reduced material reduces the chemical load on the furnace and thereby increases production rate and reduces coke consumption. The fact

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1/ Economic Commission for Europe, Steel Committee - "Economic efficiency of various methods of iron ore preparation" - STEEL/Working paper N° 279/Add.3, 24th March 1964.

/that pre-reduction

that pre-reduction can be effected by s[illegible] inferior to metallurgical coke, or by gaseous re[illegible] where available, is an added advantage where metallurgical coke is a scarce commodity. The Steel Company of Canada has established that for each 10 per cent metallic iron in burden there is 6 per cent reduction in coke rate and 9 per cent increase in production.[1]

Briquetting

A third alternative of briquetting the ore fines has been tried on an experimental basis, but it has not yet been used on a commercial scale.

Sintering is being practised at a number of Latin American plants, such as Altos Hornos de Mexico, Cía.Siderúrgica Nacional-Volta Redonda, Cía.Acos Especiais Itabira and Planta Siderúrgica del Orinoco, to utilise local ore fines.

Selection of process

Sintering facilities are considered only for Cases IV and V; tonnage of fines involved in other cases will be too small to justify installation of sintering facilities.

Sinter plant capacity....

The sinter plant capacities are based on the assumption that 30 per cent of the ore will constitute fines of minus 10 mm size requiring sintering. Sinter will thus constitute about 30 per cent of metallic burden in terms of Fe content. Production of self-fluxing sinter of unit basicity ($CaO+MgO/SiO_2+Al_2O_3$) is envisaged.

The quantities of ore fines to be sintered and sinter produced for Cases IV and V would be as follows:

1/ J.A. Peart and F.J. Pearce - "The Operation of a Commercial Blast Furnace with a Pre-reduced Burden" - Journal of Metals, December 1965.

/Case IV

	Case IV	Case V
Quantity of ore fines to be sintered, tons/year	[illegible] 500	104 [illegible]
Sinter make, tons/year	73 000	110 000
Sinter make, tons/day	225	335

Pan-type sintering machine

Sintering of iron ore fines can be accomplished in a continuous process or an intermittent process. For continuous sintering chain grate machines of the Dwight-Lloyd type are used, while for sintering in batches, pan-type machines of the Greenwalt (stationary pan) or the AIB (moving pan) design are used.

The pan-type machines have advantages over the chain grate machines up to a production level of about 300 000 tons per year sinter. For higher outputs, the chain grate machines are definitely superior both in terms of output and production costs.

The advantages of the pan-type sinter plants for small tonnages are:

(i) Flexibility in the control of sintering operations for each batch which results in high quality sinter.

(ii) Lower operating and maintenance costs of small capacity plants.

(iii) Additional capacity can be easily accommodated as needed.

In view of the limited production involved and the advantages of batch sintering operations for such small tonnages, pan-type sinter plants are considered. Both the stationary (Greenwalt type) and the moving (AIB type) machines are suitable for the capacities envisaged. The AIB type which is more flexible than the stationary type has been adopted for this study.

Sintering area

AIB type sintering machines can give a daily production rate of 10 to 30 tons per sq m. In the absence of actual test data on sintering rates with Latin American

/iron ores,

iron ores, a daily production rate of 1[illegible] t [illegible] sq m, which is normally attainable in average practice, has been assumed. The total sintering areas required for Cases IV and V are about 15 sq m and 23 sq m respectively.

Sinter plant facilities

The major plant facilities are given in Table 3-4.

Table 3-4

MAJOR FACILITIES FOR SINTER PLANTS

	Case IV	Case V
Plant capacity, tons/day	225	335
Type of machine	AIB pan	AIB pan
Total pan area under suction, sq m	15.0	25.0
Number of pans	3	5
Suction fan capacity, cu m/hr	10 000	1[illegible] 000
Number of fans	3	5
Type of dust collector	Cyclone	Cyclone

Raw materials

Iron ore fines, limestone, coke breeze and flux dust from the stockyard will be conveyed by belt conveyors to sinter plant. Limestone and coke breeze will be crushed and screened at the sinter plant to minus 3 mm size. Raw materials and return sinter will be stored in individual bins. Weighed quantities of raw materials will be drawn from the bins and conveyed to a mixer fitted with fixtures for addition of water. The mixed charge will be stored in a bin. Adjacent to it will be another bin for hearth layer sinter.

/The movable

Charging, ignition and sintering

The movable pans will be brought under the hearth layer bin, charged with bed layer and then moved under the charge-mix bin for charging. Pans will be ignited by a moving ignition hood. Each pan will be provided with individual air suction fan. The pans will be moved to the sinter breaker and tilted by a common motor. The broken sinter will be screened to the various size fractions - blast furnace grade, bedding layer and return sinter.

Sinter quality

Based on chemical analyses of raw materials given in Table 3-1 and assumed production of self-fluxing sinter of unit basicity, the sinter is expected to analyse approximate 63.0 per cent Fe, 5.1 per cent SiO_2+Al_2O_3 and 5.1 per cent CaO+MgO.

Iron-making

Selection of process

The process to be adopted for iron-making will depend on the available raw materials and energy sources. Under the conditions considered for this study, iron production has to be based on the use of solid reductants such as coal and coke. Both sponge iron produced by direct reduction processes and molten iron produced either by electric smelting or by blast furnace, can be used for steel production.

Direct reduction processes not considered

A number of direct reduction processes which appear attractive are found on scrutiny to be suitable only for a given set of conditions and not generally applicable. In most cases development and application of specific processes are still confined to the original sponsors. Also, reliable capital and operating cost data are not readily available. In a general study like this only broad considerations of suitability of a particular process can be indicated. For consideration of a direct reduction process, detailed investigations of the process in relation

/to specific

7. 10. 71

TABLE OF CONTENTS

INDEX OF TABLES

/Table 5-4

/DRAWINGS

2 OF 4

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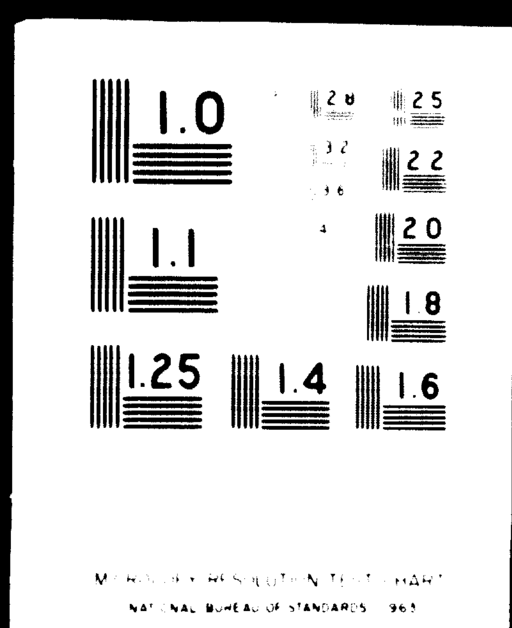
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963

Table 3-8

CONVERTER SIZES AND HEAT TIMES

Case	Production of liquid steel (tons/year)	Converter size (tons)	Average heat cycle, tap-to-tap (min)
I	25 000	3	38
II	50 000	6	38
III	100 000	12	40
IV	200 000	25	42
V	300 000	35	42

In all the above cases, the plant will have only one converter blowing station and one operating vessel; a spare shell and jacking transfer car for relining and replacement of the vessel will be provided. With this arrangement, the investment for the LD vessel and auxiliaries is only about 70 per cent of that required for two vessels both complete with blowing stations, drives and other auxiliaries, one vessel operating and the other under reline.

It is to be noted that apart from pilot plant and steel foundry installations, there are no 3-ton and 6-ton vessels in operation for the production of tonnage steel on a commercial basis. These have been adopted here only for the sake of comparability. For the small plant sizes (Cases I and II), electric arc furnace steelmaking with high hot metal charge would deserve consideration if scrap availability to make up the balance of the charge were assured.

<u>Description of the process</u>

The LD process consists of charging approximately 20 to 30 per cent scrap and 70 to 80 per cent hot metal into the converter and blowing with oxygen at supersonic velocities. Oxigen consumption averages about 50 cu m/ton of steel

/produced. Flux

produced. Flux and other additions are also made during the blow. The exact weight of scrap, hot metal, fluxes and miscellaneous additives and quantity of oxygen to be blown are all calculated and pre-determined on the basis of the analysis and temperature of the hot metal, proportion of scrap and grade of steel required.

Operating procedures

Scrap loaded into scrap boxes is weighed and charged into the converter by overhead crane. Hot metal from the mixer is taken in transfer ladles in the required quantities and charged into the converter by overhead cranes.

In Cases I and II (converters of 3-ton and 6-ton capacities), manual feeding of fluxes and additives is proposed with a view to reduce the capital costs. For Cases III, IV and V, lime from the calcining plant and other additives are brought by a system of conveyors and fed into the composite storage bins located above the converter. Additives are discharged from the bottom of the bins into weigh hoppers, and from the weigh hopper through water cooled chutes into the converter.

When the heat is ready to be tapped, the steel is poured into ladles carried on self-propelled transfer cars positioned beneath the vessel. Requisite ladle additions are made during tapping. The steel ladle car moves to the casting bay where the ladle is picked up by the overhead crane and placed on the continuous casting machines.

Slag retained in the converter is poured out into slag pots on self-propelled transfer car positioned below the vessel. The slag pots are transferred to the charging aisle and loaded by overhead crane into road-bound slag pot carriers for disposal to the dump.

/When the

n

s

Converter relining

When the operating vessel is to be relined, it is removed from its trunnion ring by means of a vessel changing jack car travelling on the same track as the steel ladle car. The vessel is brought to the vessel re-lining bay adjoining the converter bay and kept on one of the two vessel relining stands. The spare shell which is kept ready relined in the second relining stand is transferred on the jack car and taken to the operating stand and mounted on the trunnion. The jack car is returned to the vessel relining bay.

Major equipment and facilities

The major equipment and facilities provided for the five cases under study are listed in Table 3-9.

Shop layout

Identical shop layouts have been adopted in all cases, the variations being only in the lengths, widths and heights of the different aisles. The major areas are:

Scrap aisle: equipped with overhead magnet cranes, scrap boxes, tranfer cars, etc., for transporting scrap from scrap yard to converter.

Charging aisle: one end of which forms the casting bay of the pig iron plant. The mixer is located at the far end. The aisle is served by two overhead cranes. Necessary hot metal ladles, transfer ladles and transfer cars for scrap and hot metal are provided.

Converter aisle: which houses the LD vessel, other ancillary facilities on the charging floor provided for operation and maintenance of the LD converters, the control pulpit, etc. Overhead bunkers for fluxes and other additives in Cases III, IV and V are also housed in this aisle.

/Table 3-9

Table 3-9

MAJOR EQUIPMENT AND FACILITIES FOR LD STEELMAKING

Equipment	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
Hot metal mixer	1-100 T	1-100 T	1-250 T	1-500 T	1-500 T
LD converter complete with blowing equipment, etc.	1-3 T	1-6 T	1-12 T	1-25 T	1-35 T
Spare converter shell	1	1	1	1	1
Converter relining stands	2	2	2	2	2
Hot metal transfer ladles	6	6	6	6	6
Steel ladles	10	10	10	10	10
Slag pots	16	16	16	16	16
Steel ladle transfer car	1	1	1	1	1
Slag pot transfer car	1	1	1	1	1
Vessel changing jack car	1	1	1	1	1
Hot metal weighing scale	1	1	1	1	1
Ladle relining and heating stations	4	4	4	4	4
<u>BOF Cranes</u>					
Scrap handling magnet crane	1-3 T	1-3 T	1-5 T	1-10 T	1-10 T
Hot metal charging crane	2-35/10/3 T	2-50/15/5 T	2-50/15/5 T	2-100/20/10 T	2-100/20/10 T
Service crane for vessel reline	1-1 T	1-1 T	1-3 T	1-5 T	1-5 T
Casting cranes	1-5/2 T	2-10/5 T	2-25/10 T	2-50/10 T	2-60/15 T
Oxygen plant	10 T/day	20 T/day	40 T/day	80 T/day	100 T/day
Calcining plant	One shaft kiln 10 Ton per day	One shaft kiln 15 Ton per day	One shaft kiln 30 Ton per day	One shaft kiln 60 Ton per day	One shaft kiln 100 Ton per day

/Converter relining

Converter relining aisle: parallel to and adjoining the converter aisle. It is provided with two relining stands, one at either end, for relining the converter shells. The vessel changing jack car is also stabled in this bay. The track for this car runs along the aisle up to the relining stands at either end.

Casting aisle: parallel to and adjoining the vessel relining aisle, where continuous casting machines and steel ladle relining and heating facilities are located. Two overhead cranes are provided for casting the liquid steel and for handling the ladles for relining and heating up.

Gas cleaning

Pease-Anthony system of venturi scrubbers for gas cleaning are considered in all five cases: there will be no waste heat or gas recovery.

Electric arc furnace as alternative

Steelmaking in electric arc furnace

The electric arc furnace, though primarily considered to be an economical scrap melter and to be particularly suitable for the production of quality and alloy steels, is now being increasingly adopted for large scale production of tonnage carbon steels. Also, its ability to use hot metal in limited proportions has been recognised and utilised at some plants.

Hot metal charge in arc furnace

For instance, at the Brymbo steelworks in United Kingdom, about 50 per cent pre-refined hot metal and 50 per cent scrap are used in 40-ton arc furnaces.[1] The hot metal is pre-refined with oxygen in a special oil fired furnace. By this treatment the silicon is almost wholly oxidized, phosphorous is reduced from 0.4-0.8 per cent

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1/ "The Brymbo Hot Metal Oxy/Electric Steelmaking Process" - by Emrys Davies. Paper presented at the Le Touquet Conference on Oxygen Steelmaking, September 1963.

to between 0.05 and 0.1 per cent, carbon is burned down to between 1 per cent and 2.5 per cent depending on the carbon content required in the finished steel, and the metal temperature is raised by about 300°C. With such a practice, arc furnace power consumption varies from 240 to 340 kWh per ton. The total heat time is reported to be 2 to 3 hours, with a production rate of 15 to 23 tons per hour. Such high production rates are possible with highly pre-refined iron.

At the Chimbote steelworks in Peru, direct hot metal is used to the extent of 45 to 55 per cent of the charge in 25-ton arc furnace. It is reported that power consumption has exceeded 800 kWh per ton.1/

Extensive tests conducted with low phosphorous and high phosphorous pig iron in 12-ton and 40-ton arc furnaces using ore as the main refining agent at the Vol Roll Plant in Switzerland indicate that the power consumption for the melting down period using 50 per cent scrap and 50 per cent hot metal is lower compared to 100 per cent cold charge.2/ The total power consumption was less than 500 kWh per ton of ingot for most of the heats. Trials with 70 to 80 per cent hot metal in the charge have been conducted and it is considered possible to utilise successfully such high proportions of hot metal.

Recent trials carried out by Republic Steel Corporation, United States, in 150-ton arc furnace at their Chicago District Plant, showed that 25-30 per cent hot metal could be used in the charge without difficulty, adopting the

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1/ "The Chimbote Steelworks" - by William Shapiro, Blast Furnace and Steel Plant,

2/ "Hot Metal in Electric Arc Furnace" - by Arthur Durrer and G. Heintze, Journal of the Iron and Steel Institute, London, May 1959, pp. 15-23.

/ore-scrap-hot metal

ore-scrap-hot metal practice without oxygen lancing. Hourly production rate increased by about 19 per cent and power consumption per ton of steel decreased by about 9 per cent. It is considered that with suitable oxygen lancing technique up to 50 per cent hot metal could be used, and tap-to-tap time for single slag heats reduced from 6.00 hours to 3.20 hours.1/

Alternatives considered for Case II

In Latin American countries, where availability of purchased scrap is limited, electric arc furnace steelmaking even with only 50 per cent scrap in the charge may not be feasible in regular practice. The Chimbote plant based on this practice frequently gets into difficulties for want of scrap. However, for purposes of comparative study, capital and production costs for different combinations of iron and steelmaking processes have been estimated for Case II - 50 000 t/yr plant and indicated in Appendices 5-16, 5-17 and 6-11 and summarised in Table 3-10.

The alternatives considered for steelmaking in electric arc furnace are 100 per cent scrap charge and 50 per cent hot metal-50 per cent scrap charge. One 20/25 ton arc furnace of 10 000 kVA transformer capacity is proposed. With 100 per cent scrap charge six to eight 25-ton heats per day, and with 50 per cent hot metal-50 per cent scrap charge eight to ten 20-ton heats per day can be made, giving a total production of 50 000 tons per year in both cases. Capital and production costs for the various alternatives considered are summarised in Table 3-10.

1/ "Use of Hot Metal in Electric Arc Furnaces" - by Arthur W. Schmudde, Journal of Metals, April 1966, pp. 501-503.

/Table 3-10

Table 3-10

CAPITAL AND PRODUCTION COSTS FOR ALTERNATIVE COMBINATIONS OF IRON AND STEELMAKING PROCESSES

(Case II - 50 000 tons/year)

	BF+LD a/		BF+EAF a/		ESF(PR)+EAF a/		ESF+EAF a/		EAF a/	
	Total b/ '000 $	Per ton annual capacity $	Total b/ '000 $	Per ton annual capacity $	Total b/ '000 $	Per ton annual capacity $	Total b/ '000 $	Per ton annual capacity $	Total b/ '000 $	Per ton annual capacity $
Capital costs										
Departments:										
Iron making	5 253	115.2	3 650 c/	160.1 c/	3 283 c/	144.0 c/	2 991 c/	131.2 c/	-	-
Steel making	4 142	83.8	3 672	73.5	3 672	73.5	3 672	73.5	3 667	73.3
Continuous casting	1 807	37.7	1 620	33.8	1 620	33.8	1 620	33.8	1 769	36.9
Rolling	5 778	131.4	5 778	131.4	5 778	131.4	5 778	131.4	5 650	128.5
Total d/	17 032		14 720		14 353		14 061		11 086	
Investment per ton:										
Rolled product		387.4		394.8		326.5		319.9		252.2
Production costs e/ ($/ton)										
Iron (hot metal)		58.51		71.51 c/		79.65 c/		90.61 c/		-
Steel (liquid)		102.76		92.24		96.25		101.64		74.26
Continuous cast billet		119.48		107.13		111.30		116.96		88.69
Rolled product		162.59		149.15		153.72		159.84		128.58

a/ BF+LD - Iron making in blast furnace and steelmaking in LD converter, the process considered for all cases in this report.
BF+EAF - Iron making in blast furnace and steelmaking in electric arc furnace with 50 per cent hot metal - 50 per cent scrap charge.
ESF(PR)+EAF - Iron making in electric smelting furnace with pre-reduction and steelmaking in electric arc furnace with 50 per cent hot metal - 50 per cent scrap charge.
ESF+EAF - Iron making in electric smelting furnace without pre-reduction and steelmaking in electric arc furnace with 50 per cent hot metal - 50 per cent scrap charge.
EAF - Steel making in electric arc furnace with 100 per cent scrap charge.

b/ Including allocations for auxiliary departments.

c/ Since hot metal constitutes only 50 per cent of the charge, iron making capacity of Case I is adequate; capital and production costs considered for hot metal are therefore those of Case I.

d/ Complete plant capital cost including all the facilities within the plant boundary.

e/ Ex-works cost including fixed charges @ 9 per cent of capital cost.

/Continuous casting

Continuous casting plant

Continuous casting of mild steel billets of the quality required for merchant products is now an established and proved process. Compared to ingot casting and rolling into intermediate products, continuous casting results in better operating yields, savings in space requirements and elimination of all facilities for ingot teeming, stripping, soaking and rolling into intermediate products, thus reducing capital investment and operation costs to a marked extent.

A study was made to determine the magnitude of investment required for conventional ingot practice for Case V of this study under comparable conditions. It was estimated that the capital outlay required for the conventional ingot casting, stripping, soaking and cogging facilities replaced by continuous casting was about 13.1 million dollars as against an outlay of about 4.7 million dollars for continuous casting for a throughput of 300 000 tons/year of liquid steel. The production costs per ton of billet would also be lower by about 18 per cent in the case of continuous casting on account of about 10 per cent higher yield and lower operating costs as well as lower capital charges. Continuous casting, is therefore the ideal choice for throughputs which are too small for conventional blooming/billet mills, such as the five cases under study. Indeed, today the process is being given serious consideration even for large plant throughputs of over one million tons per year.

Production programme

Based on the requirements of the product-mix and maximum and minimum section sizes to be rolled, the billet sizes selected are 75 mm and 100 mm square for Cases I, II and III, and 75 mm square, 100 mm square and 125 mm square

/for Cases

for Cases IV and V. An important consideration in this selection is that continuous cast billets require a certain minimum amount of hot reduction to break the "as cast" structure.

Mild steel is to be cast in all five cases. Considering the rolled steel product-mix, production of light, medium and heavy billets would be as given in Table 3-11.

Table 3-11

CONTINUOUS CAST BILLETS REQUIREMENTS

Billet size	Case I T/yr	Case II T/yr	Case III T/yr	Case IV T/yr	Case V T/yr
75 mm square	19 200	38 400	76 800	96 000	144 000
100 mm square	4 800	9 600	19 200	57 600	86 400
125 mm square	-	-	-	38 400	57 600
Total	24 000	48 000	96 000	192 000	288 000

Selection of process and equipment

A variety of steels are now being successfully produced by continuous casting. These include plain carbon steels of low carbon content considered in this study steels of high carbon contents, low alloy constructional steels, silico-manganese and chrome-vanadium spring steels, stainless steels of both ordinary and stabilised varieties and some special high alloy steels.

Killed steel required

The continuous casting process is suitable for casting killed steels. Rimming steels can be cast only in large sections. Though a fully rimmed structure is not obtained, it meets most of the physical requirements of rimmed steel. Semi-killed steels cannot be continuously cast, but killed steels can generally be substituted for semi-killed steels.

/The main

to specific raw material sources and size of the plant are obviously necessary. Therefore, the adoption of direct reduction processes to produce sponge iron is not considered for this study.

Electric smelting

The choice of the electric smelting process is largely determined by the cost and availability of power. Recent developments indicate that pre-reduction of ore in rotary kilns could substantially reduce power consumption for the smelting process. A further reduction in power consumption is also possible if the prereduced material is charged hot. The use of hot prereduced charge in electric smelting is not yet a well-established practice. The use of cold prereduced charge has been adopted in Japan for production of iron from iron sands, but the application of this process also is mainly limited to the original promoters.

Blast furnace versus electric smelting of iron

In the light of the above facts, electric smelting and blast furnace smelting of iron are considered to be the only processes generally suitable. For the production of one ton of hot metal by electric smelting from the given raw materials, theoretical power consumption is about 1 850 kWh for raw ore practice and about 950 kWh for hot prereduced charge. Comparative estimates of capital investment and production costs for iron production by the blast furnace and the electric smelting processes are given for Case I and Case II in Appendix 6-8, and summarised in Table 3-5.

Blast furnace process considered

The above evaluation indicates that under the conditions of relative coke and power costs assumed, the blast furnace process is more economical and is accordingly considered for this study.

/Table 3-5

The main reason for using semi-killed steels in ingot casting practice is their high yields. But killed steels can give even higher yields in continuous casting, and therefore, the fact that semi-killed steels cannot be continuous cast is no deterrent to the selection of this process. For casting free-cutting steels, a vertical continuous casting machine which would require a high building or deep pit is necessary.

Product quality

Metallurgically, continuous cast material is generally uniform, of good quality, free from segregation and relatively clean in respect of non-metallic inclusions though some central porosity is found. The sections cast are for the most part regular in shape. The slight "ripple" marks formed by mould reciprocation do not affect the surface quality of the finished materials and with proper care surface dressing can be reduced to a minimum. Wide ranges of billet, bloom and slab sizes have been cast successfully by continuous casting.

Curved mould type machine selected

Various designs of continuous casting machines have been developed. The recently developed curved mould type of machine (the so-called "S" type) has a lower height of machine structure than the earlier vertical and bending-straightening types of machines; also, it needs less mechanical and electrical equipment due to the combination of withdrawal and straightening rolls in a single unit. The "S" type machine has thus the advantages of lower initial cost of machine, building and foundations. The curved mould type continuous casting machine is therefore selected for continuous casting of billets for all the five cases under study.

The number of machines and the number of strands required per machine, for each case under study have been estimated on the basis of the following assumptions:

/Number of

Number of LD heats/day	35 (average)
Type of ladle	Lip-pour
Machine availability	80 per cent
Machine set-up time	20 min (for single-strand machines in Cases I and II)
	30 min (for two-strand machines in Case III)
	45 min (for three and four strand machines in Cases IV and V)
Casting speed	Billet 65 mm sq - 4.80 m/min Billet 75 mm sq - 4.00 m/min Billet 100 mm sq - 3.00 m/min Billet 125 mm sq - 2.40 m/min
Max casting time	60 minutes
Yield (liquid steel to billets)	96 per cent

In view of the large number of LD heats to be handled (as many as 35 heats in 24 hours), a minimum of two machines are required in each case. An average of 18 casts per day for single-strand and twin-strand machines, and an average of 12 casts per day for triple-strand and four-strand machines are assumed. It may be noted that teeming of the 3-ton ladle in Case I would require only about 15 to 20 minutes, depending on the billet size, even with the single-strand machine. But, because of the set-up time require, a minimum of two machines are necessary, and the utilisation coefficient of the equipment is thus necessarily low. In Cases IV and V three machines have been provided in view of the long set-up time required with multi-strand machines.

Lip pouring ladles are used to facilitate heating them during the casting operation for maintaining correct temperature of steel, which is an important requirement for continuous casting of the small billet sizes envisaged.

/Major equipment

Major equipment and facilities

Major equipment required for the continuous casting plant are listed in Table 3-12.

Each machine is housed in an independent structure with three levels. The casting platform will be at the top level, the ladle operator's platform at the next level, and the main drives, fans and pumps, withdrawal units and billet delivery tables will be at the ground floor level.

Layout

The continuous casting building consists of three covered aisles - machine, billet discharge and billet storage - adequately ventilated and lighted. The machine is located in the machine aisle which is a part of the LD shop casting bay. The discharge aisle connects the machine aisle with the billet storage aisle.

For Cases II to V, the billet discharge aisle is long enough to accommodate a "wash heating furnace", if required. All roller tables are installed in the discharge aisle and cooling skids in the storage aisle. The storage aisle has sufficient room to accommodate one month's stock of billets.

Rolling mills

The type and general arrangement of the rolling mills will depend upon product-mix and tonnage to be rolled.

Production programme

Rolled steel products demand in Latin America

The patterns of steel consumption, by product categories, in United States, Japan, India and Latin America are indicated in Appendix 3-2. The apparent annual consumptions of rolled steel products in Latin America for the five year period 1961-64 are given in Table 3-13. The total consumption has increased from 3.53 million tons in 1952 to 8.398 million tons in 1964, but the proportion of rails and heavy sections has declined from 14.7 per cent to 7.7 per cent and the proportion of bars, light sections and wire products taken together has decreased from

/Table 3-12

Table 3-12

CONTINUOUS CASTING FACILITIES a/

Equipment particulars	Case I 24 000 T/yr billets	Case II 48 000 T/yr billets	Case III 96 000 T/yr billets	Case IV 192 000 T/yr billets	Case V 288 000 T/yr billets
Number of continuous casting m.	2	2	2	3	3
Number of strands per machine	Single-strand	Single-strand	Twin-strand	Triple-strand	Four-strand
Number of discharge roller tables	2	2	4	9	12
Length of discharge roller tables	25 m	40 m	40 m	40 m	40 m
Number of cooling banks	2	2	2	6	6
Size of cooling banks	7 m x 8 m	13 m x 8 m	26 m x 8 m	20 m x 8 m	27 m x 8 m
Number and capacity of billet handling cranes	One 5-ton	One 5-ton	One 10-ton	One 15-ton	Two 15-ton

a/ Lip-pour type casting ladles included in steelmelt shop facilities.

/Table 3-13

Table 3-13

APPARENT ANNUAL CONSUMPTION OF ROLLED STEEL PRODUCTS IN LATIN AMERICA FOR THE FIVE YEAR PERIOD 1960-1964 a/

(Including imports)

	1960		1961		1962		1963		1964	
	'000 tons	Percentage	'000 tons	Percentage	'000 tons	Percentage	'000 tons	Percentage	'000 tons	Percentage
Bars and light sections	2 343	36.53	2 301	34.28	2 438	35.55	2 340	33.08	2 931	34.92
Wire products	747	11.66	778	11.56	867	12.65	966	13.65	959	11.41
Rails and heavy sections	669	10.42	492	7.32	535	7.80	458	6.46	650	7.73
Flat products	2 655	41.39	3 147	46.84	3 016	44.00	3 320	46.86	3 858	45.94
Total	6 414		6 718		6 856		7 084		8 398	

a/ "Consumo Aparente Latinoamericano de Productos Laminados Siderúrgicos en el Quinquenio 1960-64", ILAFA, Servicio de Socios, Nº 29, abril de 1966.

/51.5 per

51.5 per cent to 46.37 per cent, while the consumption of flat products has increased from 33.8 per cent to 45.9 per cent. However, bars and light sections together with wire rods, the basic material for drawing wires and manufacturing wire products, still constitute the bulk of the demand.

Flat products

Installation of modern strip mill facilities for rolling flat products is not an economically viable proposition for the small-scale plants under study. Further, in many Latin American countries where the steel plant has to depend on the internal market for disposal of its products, and the total internal demand itself is not high, there will be no ready market for the output of a modern strip mill. With continuous casting of steels and hot strip rolling in planetary mills, economic production of flat products in plants of 200 000 to 300 000 tons per year capacity may be feasible, but not in the much smaller plants of 25 000 to 100 000 tons per year capacity. Moreover, continuous casting of thin slabs, less than 130 mm thick, for these mills in rimming steel quality presents difficulties which have not yet been overcome. Many of these problems are still in the exploratory stage.

Heavy structurals and rails

Large mills and heavy equipment will be required for heavy structurals and rails because of the large size of these sections. The output capacities of the mills will be much too large for the production programme envisaged, especially in Cases I, II and III. Installation of a mill to produce these heavy sections will be justified only if these sections constitute the entire output in Case III and the greater part of the output in Cases IV and V. A ready market is not likely to be found for such large outputs.

/As wire

Product-mix - merchant sections and wire rods

As wire rods and merchant bars constitute the bulk demand, only these are considered for a typical product-mix. This is also helpful for purposes of comparison, as the mill arrangement and equipment selected for a product-mix entirely composed of wire rods and merchant bars are readily adaptable to installation as a single unit with only the required capacity for each case.

Similar products for all cases

To minimise the effect of factors not related to plant size and thus to make the comparison of costs with mills of differing capacities more meaninful, a similar range of products for all the plant sizes has been selected and the same pattern of production has also been assumed.

The product-mix envisaged for the five steel plant capacities under study is given in Table 3-14.

Table 3-14

ROLLED PRODUCTS FOR DIFFERENT CASES

	Case I t/yr	Case II t/yr	Case III t/yr	Case IV t/yr	Case V t/yr
Rolled products					
Rounds & squares (6 to 40 mm)	13 980	27 960	60 300	120 480	180 720
Flats (8 to 60 mm)	4 000	8 000	15 000	30 000	45 000
Angles & equivalent sections (15 to 55 mm)	4 000	8 000	14 000	30 000	45 000
Total	21 980	43 960	89 300	180 480	270 720

/Selection of

Selection of mill

The following considerations are basic to the selection of the mill unit:

(i) Its suitability for the range and volume of production envisaged.

(ii) Full utilisation of the rated capacity for the product-mix envisaged. This is important for cost comparison.

Cross-country mill

The mill arrangements usually employed for rolling merchant bars and wire rods are cross-country, semi-continuous and continuous. In the cross-country type, mill stands are placed side by side and driven by a common driving unit. The complete mill arrangement can be made up of either one, two or more groups of similar stands. Cross-country arrangement is economical in equipment cost, but is somewhat costly in operation. However, for small production requirements, this arrangement is invariably used.

Semi-continuous mill

The semi-continuous mill is a combination of high production continuous mill and cross-country mill. The arrangement is flexible enough to suit varying production requirements in the intermediate range and is therefore generally adopted for moderate production. Semi-continuous mills can be mechanised to a considerable extent.

Continuous mill

The continuous mill is a high production unit requiring heavy capital investment. Mill stands are arranged in tandem and rolling is continuous, that is, the material being rolled undergoes reduction in a number of stands at the same time. The incoming billets enter the mill at one end and finish rolled sections come out of the mill stands at the other end.

Degree of mechanisation

Equipment cost of a mill complex increases with increasing mechanisation and automation. This increase in investment should be justified by a corresponding decrease

/in production

in production cost. In an economically advanced country with high labour costs, it is essential to adopt sophisticated mechanised equipment. However, for the selection of mill complex, the product-mix and capacity required should be the guiding factors in determining the degree of mechanisation desirable. In the first two of the five cases under study, production requirements will not justify a high degree of mechanisation.

From Case III onwards the mills are increasingly mechanised. This characteristic of the mills accounts for the break in the curve for capital cost per ton of annual capacity from Case II to Case III (Fig. 2).

Rolling mill proposed

A simple cross-country mill has been provided for Case I; in Case II, a continuous wire rod rolling train has been provided in addition. For Cases III and IV, a semi-continuous mill has been provided, with the difference that in Case IV the mill has a greater number of continuous stands than in Case III. In Case V, the mill unit is fully continuous. There will be little in-built capacity, and mill facilities will have to be fully utilised for achieving the required production. A brief description of the facilities is given below.

Mill for Case I

For Case I, the roughing mill consists of two 3-high 400 mm stands driven by a 500 kW AC mill motor through gear box and pinion stand. The finishing mill consists of seven 3-high 300 mm stands. The first four of these stands are driven by a 500 kW AC motor through gear box and pinion stand and the other three stands by a separate 500 kW AC motor through gear box and pinion stand at a higher speed.

/One pouring

One pouring type coiler suitable for coiling 5.5 mm to 16 mm wire rods and an ordinary gravity type cooling bed for rolled material in straight lengths are included. An 8-ton/hr continuous pusher-type reheating furnace with side-discharge arrangement, rollshop and cranes are included. The mill equipment is complete for the envisaged production of 21 980 tons per year.

Mill for <u>Case II</u>

The first nine stands of the mill selected for rolling 43 960 tons per year of finished merchant bars and wire rods in Case II, are similar to that for Case I. In addition, four 2-high 250 mm continuous stands are incorporated for rolling wire rods. Two coilers and bigger cooling beds have been included. The furnace capacity is 12 tons per hour.

Mill for <u>Case III</u>

For Case III, a semi-continuous mill with continuous roughing and cross country finishing stands with mechanised skew tables, etc., is provided for rolling in straight lengths. For rolling wire rods in coils, a wire rod finishing train for double-strand rolling and suitable coilers are incorporated. The mill will be capable of rolling 89 300 tons per year as envisaged.

The mill arrangement consists of one 550 mm vertical stand with 200 kW drive, followed by four 2-high 400 mm continuous roughing stands with two 500 kW drives. These are followed by two 550 mm vertical stands each with 200 kW drive, and five 2-high 300 mm stands arranged cross-country fashion in two trains, one of two stands and the other of three stands, each train being driven by a 600 kW motor. The mill arrangement is completely mechanised and rolling progression can be controlled from the control desk and pulpit. Six 2-high 250 mm wire rod finishing stands, suitable for double-strand rolling, are also included; each two of these stands are driven by a common 220 kW motor. Four pouring type coilers and a mechanised cooling bed are provided. The reheating furnace capacity is 25 tons/hour.

/To meet

Table 3-5

CAPITAL AND PRODUCTION COSTS FOR BLAST FURNACE SMELTING AND ELECTRIC SMELTING OF IRON

	Case I - 25 000 T/yr steel			Case II - 50 000 T/yr steel		
	Blast furnace	Electric smelting		Blast furnace	Electric smelting	
		With pre-reduction	Without pre-reduction		With pre-reduction	Without pre-reduction
Iron requirement (tons/year)	22 800	22 800	22 800	45 600	45 600	45 600
Furnace size	2.0 m hearth dia	4 700 kVA transf capacity	7 500 kVA transf capacity	2.75 m hearth dia	9 500 kVA transf capacity	15 000 kVA transf capacity
Capital cost	$ 2 652 000	$ 2 310 000	$ 2 043 000	$ 4 255 000	$ 3 635 000	$ 3 273 000
	$/ton	$/ton	$/ton	$/ton	$/ton	$/ton
Production cost/ton iron:						
Cost of materials	33.26	28.32	27.40	32.80	28.32	27.40
Smelting power	-	15.20	29.60	-	15.20	29.60
Cost Above Materials (less gas credit)	25.26	24.49	23.04	15.34	16.55	15.50
Fixed charges @ 9 % a/	12.99	11.64	10.57	10.37	9.14	8.43
Total ex-works cost of hot metal (including fixed charges)	71.51	79.65	90.61	58.51	69.21	80.93

a/ Fixed charges calculated at 9 per cent on the capital cost of ironmaking plant, including allocations for auxiliary departments.

/The hot

Mill for Case IV

To meet the production requirement of 180 480 tons per year a semi-continuous mill with higher capacity is selected. There is a continuous train consisting of twelve stands in three groups followed by five stands in cross-country arrangement. Six horizontal stands are also included to provide for double-strand rolling of wire rods.

The mill arrangement consists of a first group of four 2-high 450 mm stands, each pair of stands being driven by a common 500 kW motor. This is followed by a group of four 400 mm stands each separately driven by 500 kW motor, the second stand being vertical. The next group consists of four 380 mm alternate vertical and horizontal stands, each separately driven by 500 kW motor. The cross-country portion of the mill arrangement consists of five 300 mm stands arranged in two groups, each group driven by a 400 kW motor. A mechanised high capacity cooling bed has been provided for materials rolled in straight lengths. Six 2-high 250 mm wire rod finishing stands suitable for double-strand rolling are also provided, of which every pair of stands are driven by a 220 kW motor. The continuous billet reheating furnace has a capacity of 50 tons/hour. Four pouring type coilers are provided for wire rods.

Mill for Case V

For Case V, the mill is a high-capacity continuous merchant mill with two wire rod finishing trains capable of meeting the production requirement of 288 000 tons per year. The continuous mill arrangement ensures fast rolling and a high rate of production.

The mill consists of a first group of four 2-high 450 mm stands, each pair of stands being driven by a 500 kW motor. The next group consists of four 2-high 420 mm stands, each stand driven by a 500 kW motor. The intermediate mill train consists of seven 380 mm stands each driven separately by a 600 kW motor, of which the fifth stand is vertical.

/The finishing

The finishing train is made up of five 340 mm stands, alternately horizontal and vertical, each of which is driven by a separate 600 kW motor. A mechanised high-capacity cooling bed is included. For fast wire rod finishing, two separate trains are provided. Each train consists of six 280 mm stands, alternately vertical and horizontal, each stand being driven by a separate 200 kW motor. Four wire rod coilers are provided. The reheating furnace is of 70 tons/hour capacity.

4. AUXILIARY FACILITIES

Scope

This chapter discusses the auxiliary facilities required for smooth operation of the small integrated steel plants under study. When thinking of a steelworks one is apt to think more in terms of the major production facilities such as blast furnaces, steel melting shops and rolling mills than of the complex network of utility systems, which are in effect the arteries of the plant, or of auxiliary departments like repair and maintenance shops, which are essential for continuous, efficient operation. These ancillary facilities not only play a key role but also constitute a large proportion (32 per cent to 23 per cent in the five cases under study) of the plant cost.

Laboratories

In all the cases under study the plants will have laboratories to provide essential services to production processes and to exercise control on product quality. As the plants are all of small capacity and produce only common types of rolled steel products in regular demand, no research facilities are envisaged.

Laboratory work

The work of the laboratories will therefore generally be limited to the performance of those tasks which are essential to process and product control, namely:

/(i) Chemical

(i) Chemical analysis of samples of raw materials, coke, sinter, iron, steel, slag refractories, etc.

(ii) Analysis of gas, oils and lubricants, water, etc.

(iii) Testing of steel and rolled products for physical properties and metallurgical quality.

(iv) Testing of refractories used in the plant.

(v) Observational and investigational studies of production processes and suggestions of methods for improving plant performance.

(vi) Library and information service to disseminate technical information.

For the effective performance of the above tasks, certain minimum facilities are essential in all cases; with increasing plant size, wider range of equipment and more extensive facilities are envisaged.

The facilities are generally as follows:

<u>Facilities</u>

1. <u>Chemical laboratory</u>: In Cases I and II, the laboratory is provided with sections for sampling of materials, wet chemical analysis and testing of coke, oils, lubricants, etc. In Case III, where coke ovens also are included in the plant, essentially the same facilities are provided but on a slightly bigger scale together with facilities for physical and chemical testing of coal and coke. In Case IV and V, which include sintering facilities also, the volume of analytical work will increase considerably. In these cases, routine iron and steel analysis will be done by direct reading optical spectrograph. This would enable quicker analysis of iron and steel and the installation of such expensive equipment will be justified by the volume of work turned out.

/2. Metallurgical

2. Metallurgical section: The metallurgical testing facilities provided will enable physical property and metallurgical quality tests to be carried out primarily for checking and certifying whether the products conform to specifications. Tensile and bend testing facilities are provided in Case I, impact testing facilities are added in Cases II and III, and hardness testing and laboratory heat-treating facilities are also included for Cases IV and V.

3. Inspection section: The inspection section will be provided with gauges and instruments for checking dimensions of products during rolling and afterwards. With increasing plant size, inspection facilities will increase in number and diversity. Ultrasonic testing and magnetic particle testing of products are provided for Cases IV and V.

4. Library and information section: The size of this unit will be related to the total manpower of the plant, and the services to be provided.

Building

All the above sections, except inspection, are accommodated in one building, to be located centrally. There will be no area laboratories. The laboratory may be housed in a single or double storey building, depending on the space available and size of the steelworks. Floor areas of the laboratories range from about 500 sq m in Case I to about 900 sq m in Case V.

Electrical power system

Planning of the electric system for the different plant sizes takes into consideration well-tried practices followed in steel plants all over the world for efficient plant operation and maintenance.

/The electric

Power requirements

The electric power requirements of various plant sections have been estimated using data on energy consumption available from similar existing plants. While the actual consumptions could in practice vary somewhat depending on several factors, the averages assumed will give a good approximation of the electrical load demands for the given production.

The annual energy consumptions for the different sizes of plants under study are estimated to be as follows:

Table 4-1

ANNUAL ENERGY CONSUMPTION

	Plant size T/yr	30-minute max. demand kVA	Annual energy consumption kWh x 10^3	Annual electricity bill a/ $
Case I	25 000	2 500	12 500	200 000
Case II	50 000	3 700	18 250	292 000
Case III	100 000	7 900	39 000	624 000
Case IV	200 000	14 700	71 300	1 140 800
Case V	300 000	22 000	104 400	1 670 400

a/ Calculated on the basis of an average rate of $ 0.016 per kWh energy consumed.

Selection of power system voltages

Selection of power system

The incoming power supply to the steel plants in all cases is assumed at 34.5 kV. The incoming power supply for Cases I and II is considered to be over single-circuit lines, and for the three larger sizes of plants over double-circuit lines. In the interests of reliability of power supply it would be desirable to have a double-circuit line for incoming power for Cases I and II also, but a single-circuit incoming line is proposed to keep down the initial cost. A double-circuit line could be considered at a later date if the

/need for

need for greater reliability is felt. The step-down power receiving substations for conversion to plant distribution supply voltage are of the outdoor type. It is assumed that the system from which power is fed to the plant will be rigid enough to take care of the peaks imposed on the system by the mill drive.

Taking into consideration the motor sizes for the mills and for other applications and the likely load-centre capacities, a plant H.T. power distribution supply voltage of 4 160 volts would be satisfactory for all the five cases. The low tension power distribution considered is 480 V, 3-phase, 60 cycles.

Plant power distribution

Power distribution

Power at 4 160 volts from the step-down outdoor receiving station would be carried to appropriate load-centres over cables. The location of the load-centres would depend on the layout of the various facilities, but generally speaking there would be two main H.T. load-centres for each plant, one located near the rolling mills and the other in the blast furnace - steelmelt shop area. H.T. power to individual facilities would be distributed from these load-centres over cables. The shop L.T. distribution would be at 480 V, 3-phase, 60 cycles, 3-wire, and the light supply at 110 V, single-phase.

In this connexion it is to be noted that the blast furnace blowers for the 25 000 ton/yr plant would be electric motor driven, while for the other plant sizes under consideration the blowers would be steam turbine driven.

Blast furnace gas would be used for steam generation, coke oven gas being taken for plant use. In all cases the entire quantity of steam raised is used for process requirements and turbo-blower drives; no steam will be available for power generation.

/Cranes

Cranes

All cranes operate on 480 V, 3-phase, 60 cycles supply. Wherever cranes are to be provided with lifting magnets, additional cost of suitable rectifier conversion equipment has been taken into account.

Power generation

No power generation within the plant is envisaged, as the fuel required would in any case have to be purchased. As indicated in Appendix 4-1, Plant Fuel Balance, purchased fuels like fuel oil and LPG gas would have to be used even for some of the other heating requirements such as calcining, billet reheating, torch cutting, etc.

Water supply system

A well designed system to supply adequate quantity of water, suitable treated to meet the requirements of various production processes and equipment and at the required pressure, is essential for satisfactory operation of an integrated steel plant.

Basic considerations

The cooling water supply system differs according to the composition of raw water and conditions of use such as once-through or recirculated. Once-through cooling system may prove to be economical where the source of water is close to the plant site, the water does not require any treatment and discharge does not create pollution problems. Keeping in view the need to conserve water in a rapidly developing economy and the problem of water pollution, the open recirculating cooling system has been adopted for all cases.

Water requirements

The total estimated water requirements in cu m per hour are given in Table 4-2.

/Table 4-2

Table 4-2

PLANT WATER REQUIREMENTS

	Case I cu m/hr	Case II cu m/hr	Case III cu m/hr	Case IV cu m/hr	Case V cu m/hr
Cooling water:					
Water in circulation	1 100	2 100	4 000	7 300	10 000
Make-up water	160	290	515	880	1 130
Boiler feed water	5	6	11	16	24
General purpose water	20	30	50	80	100
Total make-up system	185	326	576	976	1 254

The quality of water available at plant site is assumed to be normal surface water, requiring only flocculation and clarification with adequate chemical dosing for make-up cooling water. Boiler feed water is given a further filtration and demineralisation treatment. Filtered water with chlorine dosing for drinking and general purpose use is supplied throughout the plant.

Water distribution system

The clarified water having turbidity not more than 10 ppm (silica scale), total hardness not more than 40 ppm (expressed as $CaCO_3$) and pH value in the range of 7.0 to 7.5 is stored in a ground reservoir with storage capacity adequate to meet the plant's water requirement for twenty-four hours. Make-up and drinking water pumps, filtration units and chlorination units are provided. Separate mains with appurtenances supply make-up to the various recirculation systems, drinking water and general service water. Demineralisation plant for boiler feed water is included.

/Separate recirculation

Separate recirculation systems are provided for clear water and for contaminated water with pumping station, hot well, cold well, cooling tower, supply and return pipes complete with valves and controls.

Recirculating system

All raw water and recirculating water treatment units are located centrally in Cases I and II. In the other three cases individual recirculating systems are located close to the respective production units which they are intended to supply. Horizontal centrifugal pumps are of positive suction type. Vertical pumps are provided in the scale pit pumphouses of the mills and continuous casting machines. All pumphouses are provided with about 30 per cent standby capacity.

Piping system

All pipes and specials above 65 mm nominal bore are mild steel welded, and below 65 mm galvanised iron screwed. Mild steel pipes in the yards will be laid underground with a minimum cover of one metre and properly protected. In the plant buildings, mild steel pipes carried on trestles and column brackets will be protected with anti-corrosive paints. Valves and instruments are located generally inside the shops and buildings. In the yard, they are installed in valve pits. Air relief and scour valves are to be provided as required.

Standby pumps

The standby pump will oome into operation to maintain continuity of supply when a pumping unit fails. In an emergency arising from power failure, supply of cooling water to minimise risk of damage to blast furnace, reheating furnaces, LD lances, etc., will be met from overhead storage tanks, with adequate capacity and staging height, floating on the supply lines.

Fire hydrants

For fire fighting purposes, adequate number of stand post type fire hydrants in the yard, and wall mounting type hydrants in the shops and building are provided on the

/drinking water

drinking water main. An overhead tank with adequate capacity and staging height is connected to the drinking water main to take care of fluctuations of demand during peak hours and during fire fighting.

Utilities

Fuel system

The fuel balance of an integrated iron and steel plant is largely influenced by the production processes and techniques selected. Adoption of basic oxygen furnace steelmaking and continuous casting of billets for the small scale integrated steel plants under study, has eliminated conventional fuel needs for steelmaking and ingot heating. Oil injection in blast furnaces is envisaged to reduce coke consumption.

Fuel availability

In large integrated steel plants, the greater part of the heat requirements are normally met from by-product gaseous fuels (blast furnace and coke oven gas), the balance being met by purchased fuels. However, for the cases under study availability of by-product gaseous fuels will be limited because of the low coke rates assumed, resulting in lower tonnages of coal being carbonised and correspondingly lower volume of coke oven gas generation, and also lower volume and calorific value of blast furnace gas. The plant will have to depend to a large extent on purchased fuel oil for the heating furnaces.

By-product gaseous fuels

For Cases I and II coke ovens are not considered; for Case III pusher type non-recovery coke ovens are envisaged and hence no coke oven gas would be available for heating purposes. For Cases IV and V, by-product coke ovens have been considered and surplus coke oven gas would be available. But on account of the low coke rates of only 500 kg per ton of hot metal, the volume of gas available would not be adequate to meet all heating requirements.

/Surplus blast

The hot metal requirement for the various cases and the operation practice considered are given in Table 3-6.

Operating technique

The high cost of coke in Latin America as well as efficiency of blast furnace operation necessitate adoption of operating techniques which would reduce the coke consumption in blast furnace. Raw materials preparation has brought about considerable improvement in blast furnace economy, and therefore use of properly-sized raw materials is suggested. It is however assumed that crushing and screening facilities are located at the mines, and the plants are supplied with sized raw materials.

High blast temperature and fuel oil injection

Recent developments in stove design and refractory materials have enabled operation of blast furnaces with high blast temperatures, which has also brought about savings in coke rate. The stoves considered for the study are rated for blast preheat temperatures up to 1 100°C, with normal operation at 1 050°C. For smooth furnace operation and effective utilisation of stove heat it is necessary to control the flame temperature at the tuyere zone. For this purpose, fuel oil injection to the extent of 50 kg per ton is proposed. This would also bring about a saving of at least 1.12 kg coke per kg of oil. In the smaller size plants in which no sinter is used, the replacement ratio could be slightly higher.

For attaining a blast preheat temperature of 1 050°C it would be necessary to use for stove heating a fuel gas having a higher calorific value of about 1 100 Kcal/N cu m (as compared with B.F. gas having a calorific value of about 900 Kcal/N cu m). This can be done by enriching the blast furnace gas with 6 to 7 per cent of coke oven gas. Case IV and Case V under study incorporate recovery-type coke ovens, and the requisite surplus C.O. gas could be made available for this purpose. In other cases, the B.F. gas would have

/to be

Surplus blast furnace gas after providing for stove heating is available for general use in all the five cases. The extent to which heat requirements can be met from surplus gaseous fuels generated in the plant is indicated in Appendix 4-1, Plant Fuel Balance.

Waste heat recovery

In the LD steelmaking process large quantities of gases are generated. During the blowing period the quantities of gases generated fluctuate considerably according to the rates of decarbonisation. The gas temperature at the converter mouth is in the range of 1 400°C to 1 600°C. The gas contains a high proportion of CO amounting to about 70 per cent for nearly three quarters of the duration of the blow. Processes for economic utilisation of the sensible heat content as well as calorific value of the gases have been developed. However, the additional capital investment required for the installation of such waste heat or gas recovery equipment is economically justified only for the larger sizes of converters with more than one operating vessel. Hence, for all the five cases under study waste heat recovery from LD gases is not envisaged.

Fuel requirements

The major fuel consuming units are the blast furnace stoves, coke ovens, sintering plant, lime kilns, billet reheating furnaces and boilers. Fuel is also required for hot metal mixer heating, ladle heating, tundish heating, etc. Surplus blast furnace gas after meeting the requirements of stove heating would be used for boiler firing. In Cases IV and V, surplus coke oven gas after meeting the coke oven requirements would be utilised for sinter-mix ignition, calcining and mixer and ladle heating in the steelmelt shop. Fuel oil would be used for all heating in Cases I, II, III, and for reheating furnaces in Cases IV and V.

/The annual

The annual requirements of purchased fuel oil and liquified petroleum gas are given in Table 4-3.

Table 4-3

PURCHASED FUEL

	Plant capacity T/yr	Fuel oil requirements a/ T/yr	LPG b/ N cu m/year
Case I	25 000	4 600	70 000
Case II	50 000	7 100	81 000
Case III	100 000	13 250	92 000
Case IV	200 000	18 950	100 000
Case V	300 000	27 500	120 000

a/ Includes oil injection in blast furnace at the rate of 50 kg of oil per ton of hot metal.

b/ Liquified petroleum refinery gas (LPG) is a gaseous fuel of high calorific value, very convenient for use in heating the ladles, tundishes and torch cutting of the billets in continuous casting.

Fuel distribution

The main consuming units of blast furnace gas, viz. blast furnace stoves and boiler plant are located near the blast furnace plant. The blast furnace gas would be piped to these at low pressure. A bleeder stack would be used to burn excess blast furnace gas.

Blast furnace gas

Coke oven gas

Coke oven gas would be used in sinter plant, lime kiln, steelmelting shop and continuous casting plant. Two boosters, each of about 250 N cu m per hour capacity for Case IV and 375 N cu m per hour capacity for Case V, would boost the gas pressure to 3 000 mm w.g. For coke oven underfiring low pressure gas would be used. A bleeder stack would be used to burn excess coke oven gas.

/There will

Bleed-off

There will be little excess gas bleed-off in Cases I, II and III. In Cases IV and V excess gas bleed-off may amount to 13 per cent and 22 per cent respectively of the surplus gas make. The total quantity is subject to wide fluctuation and would consist of both blast furnace gas and coke oven gas in varying amounts. If the excess gases were to be used for power generation, it would suffice to meet only 10 to 15 per cent of the plant power requirements, which is too small to justify additional investment for power generation. The gases could be used in the reheating furnace to meet 25 to 35 per cent of the heat requirements, but this proportion is too small to justify installation of gas holders, gas mixing station, mixed gas boosters and additional piping to rolling mills. The reheating furnace moreover would have to be designed for both oil fuel and gas firing.

Fuel oil

Fuel oil is required for injection in blast furnaces and for heating. Since iron and steel production would suffer if oil supply is interrupted, adequate storage facilities to meet about 20 days' requirements, amounting to 370 tons, 680 tons, 1 200 tons, 1 300 tons and 2 000 tons for Cases I to V respectively are provided.

Oxygen

Oxygen **requirements**

The LD converters are the major oxygen consuming units. Oxygen is also required in small quantities for general use such as cutting and welding. The total daily oxygen requirements, estimated on the basis of 65 N cu m of oxygen per ton of steel amount to approximately 10, 20, 40, 80 and 100 tons for Cases I to V respectively. Oxygen plants of these capacities have been considered.

The type of plant to be selected depends on the proportion of liquid to gaseous oxygen that would need to be drawn from the air separation units. In order to

/maintain regular

maintain regular supply of oxygen to the steelmelt shop during short shut-down of oxygen plant, about 7 to 8 per cent of the oxygen generated should be drawn off as liquid and stored. Either a low or medium-pressure plant would be suitable for generating this quantity of liquid oxygen. A low-pressure plant has been considered for this study, as capital and operating costs are lower and plant availability higher compared to a medium-pressure plant. The low-pressure plant can also generate nitrogen of up to 99.99 per cent purity. The oxygen distribution system also includes buffer vessels to augment gaseous oxygen supply during LD blowing.

Compressed air

Compressed air would be required for all hydraulic system in rolling mills, and pneumatic operation of furnace doors, disappearing stops, locking arrangements of slag cars, pneumatic hand tools such as chippers and grinders an for flushing and cleaning.

Air compressors and auxiliaries

Compressed air supply system can either be centralise r zonal. The advantages of the former are less number of standby units and easier maintenance, but larger size distribution pipes are required. For the decentralised system more standby units are required, but piping costs would be less. As a decentralised system could be taken advantage of even during the construction stage, and more units could be added later as required, it is advisable to install decentralised system.

One compressor each would be located in the maintenan shop, rolling mills and steelmelt shop, with two mobile standby units for the whole plant. Line pressure of 7 kg per sq cm gauge would be maintained. Compressed air requirements, the number of air compressors and their capacities are given in Table 4-4.

/Table 4-4

Table 4-4

COMPRESSED AIR SUPPLY

Case	Compressed air requirements		Number of units
	N cu m/hr (Max)	N cu m/day	
I	800	7 000	3- 300 cu m/hr(+2 standby)
II	1 500	12 000	3- 500 " "
III	2 500	20 000	3- 900 " "
IV	3 500	30 000	3-1 200 " "
V	5 000	45 000	3-1 700 " "

Steam

Steam requirements

The main steam consuming units are the turbo blowers. Steam would also be required for coke oven plant, fuel oil heating and atomising, and other miscellaneous uses. The requirements are given below:

Plant/equipment	Steam requirements				
	Case I T/hr	Case II T/hr	Case III T/hr	Case IV T/hr	Case V T/hr
Turbo blowers	-	3.52	4.50	9.20	13.00
Oil heating	0.20	0.36	0.62	0.70	1.10
Other uses	3.00	4.40	8.00	11.50	15.00
Total	3.20	8.28	13.12	21.40	29.10

Steam generation

Water tube steam boilers, generating steam at 16 kg per sq cm gauge pressure and 220°C temperature are considered for all cases. The boiler capacities are 4.0, 9.5, 15, 25 and 35 tons per hour respectively for Cases I to V. The boilers are provided with dual fuel burners, for firing with either blast furnace gas or oil; normally blast furnace gas would be used. The installation would be complete

/with feed

with feed water treatment plant, piping, etc. The boiler would be housed in the same building with the turbo blowers. Process steam would be piped to the various consuming units.

Distribution piping for utilities

The yard piping for all utility services such as fuel oil, coke oven gas, blast furnace gas, steam, compressed air, oxygen, etc., would be grouped together and supported on trestles and pipe bridges. Water piping would be taken underground and generally laid by the side of the pipe trestles. Overhead yard piping would be routed by the side of the plant roads at a height of about 7 metres from ground level.

The distribution piping would be suitably painted and identified by colours, lettering, etc. Ladders, walkways, etc., necessary for the maintenance and operation of valves and accessories are included.

Air conditioning and ventilation systems

Air conditioning

Air conditioning would be required for furnace control rooms and laboratory rooms having sensitive instruments and for comfort cooling of offices and administrative buildings. In this study air conditioning of control rooms and laboratory rooms with room type package air conditioners has been considered.

Ventilation

The systems for room ventilation would generally consist of supply and exhaust fans. For ventilation of shop rooms where a slight positive pressure is to be maintained, the system would consist of filters, fans, air washers, ducting, supply and exhaust grills, etc.. with cooling water systems.

Works transport

As the plants are of relatively small capacity designed to produce in a single mill unit only one category of rolled products, viz. merchant bars and wire rods, systems of transport and mechanised handling of materials have been kept to the minimum required.

/Incoming raw

Internal rail transport

Incoming raw materials, in process materials and outgoing products will be handled mostly by rail transport. Wagons bringing incoming materials will be unloaded at the respective locations and the empties taken to the rolling mills for despatch of finished products. In Cases I and II where production is comparatively small, no large raw material yards are envisaged, but in the other three cases ample provision is made for raw material storage.

Internal road transport

The road network is planned on a grid system. For small capacity plants, materials movement lends itself readily to road transport. All roads are designed for two lane traffic. Ample turn around aprons for trucks and traffic islands are provided for smooth and expeditious movement of materials.

Plant facilities

For transport and handling of materials within the plant, rolling stock and mobile equipment viz. trucks, fork lift, platform trucks, tractors, trailers, etc., are provided in adequate numbers. It is envisaged that all heavy materials and large lots will be moved by rail wagons and the light materials and small lots by mobile equipment. For movement of rolling stock, 150 HP diesel electric locomotives will be used in Cases I and II, and 275 HP diesel electric locomotives will be used in the other three cases. The number of locomotives provided increases from one in Case I to six in Case V.

Road and track weighbridges of required capacities are provided for weighing incoming and outgoing materials. In addition, small weighbridges to weigh materials within the departments are also provided. For loading and unloading of materials to and from wagons and trucks as well as for doing miscellaneous work inside the plant, yard cranes will be used. Mobile cranes are provided for this purpose in Cases I and II and both mobile crawlers and loco cranes for the rest. Refuelling of locos will be done in a loco refuelling station located at a convenient spot.

/Repair and

Repair and maintenance shop

The repair and maintenance shops in an integrated steelworks require to be provided with certain basic facilities even though some of these may be used only occasionally. This is necessary in order that expensive steelworks equipment can be properly maintained and operated at high levels of availability. Unlike industrialised countries where spares can be obtained from original equipment manufacturers at short notice, the repair and maintenance shops at steelworks in developing countries need to be well equipped. They must have adequate capacity and flexibility to cover a broader spectrum of repair jobs and to meet breakdowns.

Functions and facilities provided

The functions of the repair and maintenance complex provided for each case in this study are equipment repairs, manufacture of some spare parts, and general maintenance.

Facilities

As production units are widely dispersed in an integrated steelworks, maintenance is difficult to centralise. On the other hand, it is not desirable to leave maintenance entirely to production departments. In practice, a combination of centralised and decentralised systems of maintenance is considered to be effective. Therefore, in addition to the central workshops where major repairs can be carried out and spares manufactured, a few essential facilities have been provided in the iron/steelmaking and rolling mill areas to carry out the day-to-day work of preventive maintenance and minor repairs.

Purpose

The functions of the various units which comprise the central workshops are as follows:

/Shop

Shop	Purpose of shop
1. Foundry	Manufacture of iron and non-ferrous castings, pattern making and works carpentry
2. Machine shop	Manufacture of spares and repairs of worn out parts; includes forging facilities
3. Structural shop	Repairs to and manufacture of fabricated parts or equipment. Includes facilities for wagon repair
4. Mobile equipment maintenance shop	Servicing and maintenance of plant vehicles including locomotives, mobile cranes and other handling equipment
5. General maintenance, pipe shop and building service	Supplying facilities for major plant overhauls - heavy tools and tackles, maintenance of plant building and roads
6. Electrical repair shop	Overhauling and repair of electrical equipment

For the five sizes of steelworks under study, type and size of equipment commensurate with the requirements have been selected. The number or capacities of maintenance machinery proposed cannot obviously decrease proportionately with decreasing sizes of steelworks. Certain basic machine tools of minimum capacity have to be installed even in the smallest steelworks. Equipment provided may appear to be excessive in some cases, but this is preferable to prolonged break-downs due to lack of adequate maintenance facilities.

Equipment proposed together with their capacities are listed in Appendix 4-2.

/Though the

Though the central repair and maintenance shops are equipped for manufacture of a number of parts which need frequent replacement, certain items such as specially large structures, machined parts, castings or forgings and mill rolls, for which manufacturing capacity is not provided, will have to be procured from outside sources.

Buildings and miscellaneous facilities

The offices and ancillary buildings are generally designed as load bearing structures. The architectural treatment, finishes and other items of civil work will conform to the building practice followed in the country. The building ventilation and other services will be designed to suit the climatic conditions and the local regulations.

Administrative building

This is assumed to be a single-storeyed building in Case I and II and two-storeyed in the other three Cases. The area is calculated on the basis of an average of 10 m^2 per person working in the building. This building will house the offices of the General Manager and his staff of engineering, sales, accounts, purchasing and personnel departments.

Superintendent's office

This office building provides accommodation for the General Superintendent, his assistants and shop superintendents and their staff. Working space has been provided on the basis of 10 sq m per person.

Canteen

Canteen space as well as facilities have been decided on the basis of the labour force for the different sizes of plants.

to be enriched with purchased fuels such as natural gas, liquified petroleum gas, etc., depending on the location. As the required heat input in terms of calories has been taken for stove heating in all cases and as the cost per million kilo-calories is assumed to be the same for all fuels, the estimated cost for heating the blast would not be affected.

Table 3-6

HOT METAL REQUIREMENT AND OPERATING PRACTICE

Hot metal requirement	Case I - 25 000 T/yr	Case II - 50 000 T/yr	Case III - 100 000 T/yr	Case IV - 200 000 T/yr	Case V - 300 000 T/yr
Hot metal/ton liquid steel, kg	909	898	876	833	833
Hot metal make, tons/year	22 800	45 600	88 500	167 000	252 500
Hot metal make, tons/day	65	130	253	479	721
Operating practice					
Ore preparation and agglomeration		100 per cent sized raw ore		Sized ore and self-fluxing sinter in the ratio of 70:30 (in terms of Fe content)	
Hot blast temperature			1 050°C for all cases		
Top pressure			Normal for all cases		
Oil injection per ton			50 kg for all cases		
Coke rate - kg/ton	560	545	535	505	500
Flux rate - kg/ton	126	124	123	103	103
Hot metal analysis			Si-1.0%, S-0.04%, Mn-0.5%, and P-0.30% max in all cases		

/Because of

Change rooms

Change rooms with showers, lockers, toilets and urinals have been taken into consideration in the estimates. To facilitate water piping and sewerage, change room buildings are located next to canteens.

Sanitary blocks

All office buildings and welfare buildings will be provided with adequate toilet facilities. Ablution blocks are provided at suitable locations depending on the labour force for various production and ancillary facilities.

Fire fighting system

No provision has been made for any fire-fighting stations inside the plant boundary. Instead, fire extinguishers and fire hydrants have been provided for all plant buildings. For the fuel oil and lubricant stores provision has been made for foam extinguishers.

Car parks, cycle sheds and other miscellaneous items

The estimate provides for the cost of car parks, cycle sheds, gate house, etc., for each of the plants and they have been suitably designed for size and capacity of the plants.

Fencing

A site perimeter fence about 2.5 m high with precast concrete posts and unclimbable barbed wire fencing has been assumed.

Roads

7.0 metre wide, two lane asphalt roads complete with soling (consisting of stone boulders about 200 mm thick), macadam surface (about 125 mm thick), carpeting (36 mm thick), kerb stones and side berms have been assumed. The roads will have adequate drainage and lighting arrangements.

Tracks

All tracks inside the plant will be standard tracks complete with concrete sleepers, standard rails, ballasts, etc. The turnouts will conform to the regulations governing in the country.

/Separate drainage

Drainage

Separate drainage systems for storm water and plant sewerage have been provided. The storm water drainage system will take care of the run off from plant buildings, roads and open areas of the site. The drainage system has been designed on the basis of maximum rainfall intensity of 25 mm per hour. Lined drains in the plant area are provided on either side of road and railway embankments and for carrying the discharge from roofs through downtake pipes. The types and sections of drains in the plant vary from unlined or lined Vee to rectangular drains. Where drains cross roads and railway sidings, hume pipe or RCC box culverts have been provided.

The plan sewerage system is designed to cater for domestic sewerage from ancillary buildings as well as from production buildings.

5. CAPITAL COST ESTIMATES

This chapter deals with the capital cost of installing integrated steelworks of capacities ranging from 25 000 tons to 300 000 tons a year, based on processes, equipment and facilities provided as discussed in the preceding chapters.

Plant general layout

Typical plant general layout considered for the capital cost estimates is illustrated in Fig. 1, for Case V - 300 000 tons plant. The relative juxtaposition of plants and facilities is similar in all other cases. The layout envisaged is compact, and designed for unidirectional flow with minimum handling by road or rail transport of "in-process" materials.

The blast furnace cast house is adjacent to the mixer building of the steelmelt shop and iron is tapped into ladles placed on a rail track within the mixer building. The casting end of the pig casting machine is located at one end of the mixer building. Thus, hot metal traffic has

/been eliminated.

been eliminated. Liquid steel is cast into billets in continuous casting machines located in the teeming bay of the steelmelt shop, and the continuous cast billets are delivered to cooling beds located in the billet storage bay of the mill building. Thus, liquid steel and semis traffic is also eliminated. The layout is arranged to facilitate future expansion, but except for the land area required no other in-built provision for future expansion is considered.

Scope of the estimates

The estimates cover costs within the plant boundary and also the cost of the administrative building which is located outside the plant boundary, adjacent to the main entrance. (The administrative building is not shown in Fig. 1.) All off-site facilities such as township, water, power supply, rail/road connections to site and development of raw material sources, interest on investment during construction, and recruitment, training and commissioning expenses are excluded.

The estimates are based on representative unit construction and material costs generally prevailing in Latin American countries furnished by ECLA and indicated in Table 5-1.

Estimates indicative

It must be emphasised that the cost estimates presented are indicative and are intended for the purpose of assessing the relative economies of selected steel plant capacities under study. While these estimates, based on assumed average conditions at a hypothetical location, are valid for a comparative study of this nature, they cannot be expected to be entirely valid for a specific plant or a particular location. For an actual plant, product-mix would have to be determined, processes selected and facilities installed to suit the raw materials available and other circumstances peculiar to the locality. The capital and operating costs of such a plant can differ from the estimates presented here.

/Table 5-1

Table 5-1

INDICATIVE LABOUR AND MATERIAL PRICES FOR HEAVY CONSTRUCTION

	Unit	Average cost US$
A. Labour		
1. Unskilled labour	hour	1.20
2. Skilled labour		
Foremen	hour	2.10
Erection riggers and welding	hour	2.00
Bricklayers, carpenters	hour	1.80
B. Materials		
1. Structural steel shapes and plates	ton	180.00
2. Reinforcing steel	ton	140.00
3. Gravel, all types	cu m	3.75
4. Sand	cu m	2.00
5. Cement	ton	22.00
6. Bricks	1 000 Nos	20.00
7. Lumber for shuttering	cu m	100.00
C. Unit rates (important civil engineering items)		
1. Excavation in ordinary soil including back filling and necessary lead and shift:		
a) Mechanised	cu m	0.70
b) Shovel	cu m	1.75
2. Placing reinforced concrete for foundations, basements, walls	cu m	25.00
3. Supplying, cutting, bending and placing steel reinforcement	ton	200.00
4. Providing, erecting, striking and removing straight shuttering	sq m	2.00
5. Supplying and fabricating heavy structural steelwork for buildings	ton	330.00
6. Supplying and fixing galvanized steel sheets for roofing and cladding	sq m	3.30
7. Erection of structural steelwork including painting	ton	60.00
8. Erection of equipment and machinery	ton	80.00
D. Other typical costs		
1. Land	hectares	500 to 900
2. Buildings:		
i) Warehouse type, without crane	sq m	63.00
ii) Office type	sq m	85.00
iii) Light industrial building (5-t crane)	sq m	60.00
iv) Heavy industrial building (25-t crane)	sq m	85.00
3. Standard track, complete with concrete sleepers, rails, aggregate, etc.	km	32 000.00
4. Two lane asphalt road (7 m wide) with soling, macadam surface, carpeting and side berms	km	25 000.00

/As noted

Similar facilities

As noted earlier, in order to establish a comparable basis for studying the economies of scale it has been found desirable to consider identical production processes for iron-making steelmaking, billet production and rolling in all cases, although they may not be the most appropriate for the production tonnages involved. For instance, for Case I (25 000 tons per year plant) one operating 3-ton LD converter and two single strand continuous casting machines have been considered, and for Case II (50 000 tons per year plant) one operating 6-ton LD converter and two single strand continuous casting machines have been considered. With such small heats maintenance of the metal temperature at the necessary high level from beginning to end of the continuous casting operation requires preheating of the ladle to very high temperatures and strong heating of the ladle, tundishes, etc., during casting also. Handling numerous small heats and casting as many as 18 heats in one continuous casting machine during 24 hours would present other operational difficulties such as inadequate set up time, etc. For the small daily outputs envisaged, production of a smaller number of larger size heats in electric arc furnaces would better suit the production requirements.

"In-built" capacity not provided

Again, in the interests of comparability, equipment capacities and layout of facilities are tailor-made to meet the requirements of production in all cases, without in-built capacity to facilitate future expansion. In actual practice it would be advisable for developing countries to select production and auxiliary units of optimum size to enable rational expansion to large capacities in future.

Equipment capacity ratings have been taken on a realistic basis. Facilities are assumed to operate at reasonably high levels of efficiency attainable in normal practice.

/Equipment cost

Equipment cost

The capital cost of the plant includes the cost of land, civil work, structural work, mechanical and electrical equipment, erection, spares, c.i.f. charges including ocean freight, insurance, carriage to and delivery at site, design, engineering and supervision of construction and administrative expenses of project during construction.

Equipment costs include mechanical and electrical equipment and spares for all production and auxiliary departments. These costs have been estimated from quotations and estimate prices from several countries, mainly from United States, obtained for a number of projects. It is to be noted, however, that equipment costs can vary merkedly depending on the circumstances under which orders are placed. For ensuring low costs, equipment should be procured on competitive basis against tenders based upon carefully prepared equipment specifications. But if equipment supply is limited to one source due to restricted foreign exchange availability or is tied to financial credit from any particular country, it is possible that equipment may not be the best suited to project requirements nor the prices the lowest obtainable. Under these conditions the capital cost of a plant may be higher than estimated.

The capital cost estimates include a provision of 5 per cent on total equipment costs for spare parts which is considered adequate for a selective spares purchase programme. For ocean freight, insurance, delivery at site and storage up to the time of installation, the amount provided is 20 per cent of equipment costs which proportion is understood to be normal for Latin American plants. The provision for contingencies is 5 per cent of the total cost.

/Civil work

Civil work

The estimate of cost for civil and structural work of building and civil works in equipment is based on preliminary designs and unit prices obtained from two building construction contractors - one in Chile and one in Argentina. All the civil and structural work has been designed in accordance with the Indian Standard Specifications and Codes of Practice in the absence of specifications governing the materials, loading and design in South American countries.

Land

In the plant site considered, area has been provided for additional steelmaking/rolling mill complex within the boundary. There can be a three to fivefold increase in plant capacity when required, depending on equipment types and capacities adopted for future expansion. The area of land within the plant boundary is as follows:

Case	Hectares
I	15
II	23
III	35
IV	45
V	60

Foundation

For the purpose of estimate, it has been assumed that the soil is reasonably firm with an average bearing pressure of 2 kg/cm^2 at a depth of about 1.5 m below ground level and that no piles are necessary for heavy columns and equipment foundations.

Level of ground water table has been assumed to be fairly low as not to warrant any water proofing membrane for basements and tunnels. However, for deeper underground structures cost of water-proofing has been taken into account.

/The floors

Flooring

The floors of the main and auxiliary buildings are reinforced concrete slabs on a well consolidated hard core. In storage areas and scrap yard ordinary hard flooring on boulder soling has been provided.

Structural steelwork

Blast furnace cast house, steelmaking shop, concast buildings, rolling mills, repair and maintenance shops and other production buildings are designed with steel frame work. Sides and gables of buildings are covered with galvanised corrugated iron sheets. LD shop and Blast Furnace cast house roofs are covered with ribbed mild steel plates to guard against the possibility of excessive accumulation of dust, and roofs of all other production buildings are covered with galvanised corrugated iron sheets.

Except for the heavy crane girders in the LD shops which are rivetted, all other crane girders are taken to be of welded construction.

Roof trusses are of Fink type or parallel chord design depending of the size of the building. Buildings are provided with continuous glazing for natural lighting and, in internal bays, transparent sheets at suitable intervals have been taken. Ventilation is provided by opening in the bottom portion of the wall and by continuous monitors at ridge.

Chequered plate access platforms to crane are provided at two end bays only and each access platform is served by one safety cat ladder from the floor level. Adequate gutters and downpipes have been provided for draining roof water to the drainage system around the plant building.

Total plant costs

Capital cost estimates are presented in Appendices 5-1 to 5-6 separately for each of the major production departments, namely:

/(i) Coke

7. 10. 71

Blast humidification and oxygen enrichment not essential

Because of fuel oil injection, blast humidification with steam is likely to confer little additional benefit and is therefore not considered necessary. If furnace operation calls for additional injectant, the quantity of oil could be increased to the required extent. Oxygen enrichment of the blast has to be resorted to only in such cases where high blast temperatures cannot be obtained from existing stoves. In new installations it would be more economical to design the stove facilities with adequate heat capacity rather than to plan for oxygen injection from the inception. (The high purity oxygen used for LD operations is costly and enriching the blast with high purity oxygen is not justifiable. If oxygen addition to the blast is to be adopted in regular practice, consideration should be given to the installation of a separate low cost, low purity tonnage oxygen plant.)

Low coke rates

With the above mentioned operating techniques, it is estimated that the coke rate for the largest unit considered would be 500 kg per ton. For smaller furnace sizes the coke rate will be somewhat higher due to greater heat losses and slightly increased direct reduction. The coke rates are indicated in Table 3-6.

Plant facilities

The major iron-making plant facilities considered suitable for the different plant capacities are summarised in Table 3-7. It is to be noted that for the purpose of proper comparison of capital and operating costs in all the five cases, installation of only one blast furnace of increasing size has been considered for each case.

/Table 3-7

Table 3-7

IRON MAKING PLANT FACILITIES

	Case I (22 800 tons of iron/yr)	Case II (45 600 tons of iron/yr)	Case III (88 500 tons of iron/yr)	Case IV (167 000 tons of iron/yr)	Case V (252 500 tons of iron/yr)
Raw materials handling					
Stocking and reclaiming equipment	Pay loader	Pay loader	Track hopper, conveyors and stacker cum reclaimer	Track hopper, conveyors and stacker cum reclaimer	Track hopper, conveyors and stacker cum reclaimer
Blast furnace					
Number of furnaces	One	One	One	One	One
Furnace volume - cu m	50	90	170	310	465
Hearth diameter - m	2.0	2.75	3.5	4.3	5.0
Hot blast stoves					
Number of stoves	3	3	3	3	3
Gas cleaning plant					
Number of dust catcher	One	One	One	One	One
Gas washers	Two	Two	Two	Two	Two
Electrostatic precipitators	Two	Two	Two	Two	Two
Hot metal handling					
Hot metal ladle capacity	3 Nos - 20T	3 Nos - 30T	4 Nos - 30T	4 Nos - 60T	5 Nos - 60T
For emergency use	-	-	Pig casting machine	Pig casting machine	Pig casting machine
Slag handling					
Mode of handling	Slag pit	Slag pit	Slag pit	Slag pit	Slag pit
Disposal	Dumper	Dumper	Dumper	Dumper	Dumper
Cold blast supply					
Blower	5 800 cum/hr Electric motor driven blower	11 999 cum/hr Steam turbine driven blower	20 800 cum/hr Steam turbine driven blower	39 000 cum/hr Steam turbine driven blower	58 500 cum/hr Steam turbine driven blower

/Steelmaking

Steelmaking

The choice of steelmaking process is governed by the quality of hot metal, availability and price of purchased scrap in relation to hot metal cost, and comparative economics of production by the various alternative processes. In this study, basic oxygen furnace (LD converter) process has been considered for all cases, and for Case II electric furnace steelmaking has also been compared.

Selection of process

Open hearth not considered

Of the several steelmaking processes, the proven ones relevant to this study are the Open Hearth, Electric Arc Furnace and Basic Oxygen (LD) Converter. An open hearth plant requires about 50 per cent more investment than an LD plant of equal capacity, and the production cost of open hearth steel is also higher than LD steel.

The LD steelmaking process combines the advantages of relatively low investment and rapid refining rates of pneumatic converter process with the flexibility and steel quality of the open hearth process. It offers low investment and operating costs for the production of carbon steels. With medium size units, the production of heats at regular short intervals makes the process an ideal choice for use with continuous casting.

Further, the shortage of market scrap in Latin American countries and the limited quantities of internal plant return scrap that would be available due to adoption of continuous casting also favour the choice of LD process. For this study, it is estimated that scrap would constitute 20 to 25 per cent of the metallic charge in the converter. Plant return scrap from all sources, however, amounts to only about 8 to 10 per cent and the balance of scrap

/requirement has

requirement has to be purchased. Cost of purchased scrap has been taken as $ 30 per ton, and credit for plant return scrap has been assumed at the same value.

Side-blown converter

Basic lined side-blown converters can also be used for steelmaking. Its application to commercial steel production has so far been confined to small non-integrated steel plants in China. The size of the converters range from a capacity of ½ ton to 8 tons per blow. Side-blown converters are also used in steel foundries. Investigations made in a ½ ton basic lined side-blown converter at the National Metallurgical Laboratory, Jamshedpur (India) with Indian pig irons containing 0.30 to 0.40 per cent phosphorous have demonstrated the technical feasibility of the process.

Though it is feasible to make steel in side-blown converters and small size converters of this type are in operation in China, the process has not yet established itself on a commercial basis. Until large scale plant trials are carried out and critical operating data such as refractory consumption, yield, quality of steel, productivity, etc., are determined and the economics proved, this process cannot be considered.

LD steelmaking selected

In view of its economic and technical advantages for high hot metal charges, LD steelmaking process is considered for all the five different plant capacities under study. Hot metal of the analysis assumed in this study can readily be converted to steel by LD operation, using normal single slag process.

Design basis

Converter sizes and heat times assumed are given in Table 3-8 below. The number of operating days in a year is taken as 330 in all cases.

/Table 3-8

3 OF 4

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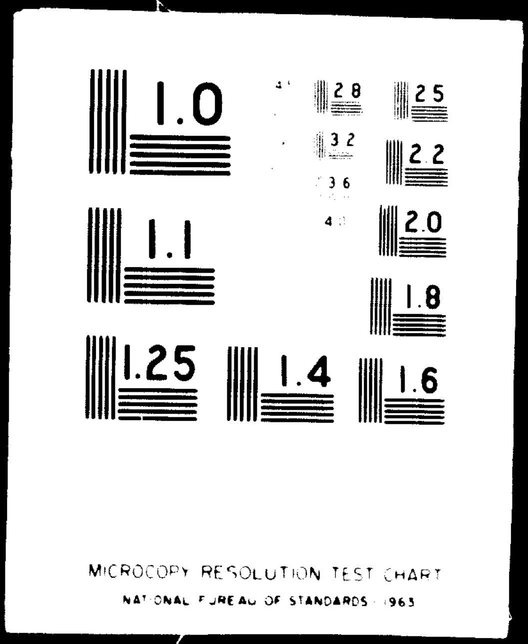
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

Table 6-4

PRODUCTION COST ESTIMATES FOR IRON/STEELMAKING ALTERNATIVES

(Case II - 50 000 tons/year)

Alternatives	Production costs per ton, US$					
	Iron (hot metal)		Liquid steel		Concast billets	
	Without fixed charges	With fixed charges	Without fixed charges	With fixed charges	Without fixed charges	With fixed charges
1. Blast furnace - LD converters	48.14	58.51	85.76	102.76	98.33	119.43
2. Blast furnace - Arc furnace	58.52	71.51	79.06	92.24	90.37	107.13
3. Electric smelting (with pre-reduction) - Arc furnace	68.01	79.65	83.73	96.25	95.23	111.90
4. Electric smelting (without pre-reduction) - Arc furnace	80.04	90.61	89.65	101.64	101.39	116.90
5. Arc furnace (100 per cent scrap charge)	-	-	67.66	74.26	78.50	88.69

/7. ECONOMIES

7. ECONOMIES OF SCALE

This chapter reviews the capital and production cost estimates presented earlier for five integrated steelworks of increasing capacities in the smaller range of the size spectrum. The trend of variations indicated by graphs and tables are discussed, to draw general conclusions in regard to economies of scale.

<u>Capital and production costs</u>

The following relationships are plotted graphically:

Fig. 2 - Capital costs (including allocations for auxiliary departments) of blast furnace plant, LD steelmelt shop, continuous casting plant and rolling mills per ton annual capacity of respective product against nominal plant capacity.

Fig. 3 - Capital costs of the seven auxiliary departments against nominal plant capacity.

Fig. 4 - Total plant capital costs per ton annual capacity in terms of liquid steel against nominal plant capacity.

Fig. 5 - Production costs (including fixed charges) per ton of product against nominal plant capacity.

Rapid cost increase below 100 000 tons capacity

It will be noted (Fig. 2 and 5) that there is a steady increase in departmental capital and operating costs with decreasing capacity down to about 100 000 tons capacity, below which costs increase at much more rapid rates. The negative slope of the curves approaches or exceeds unity at about 50 000 tons capacity. These trends are clearly marked in the case of total plant capital cost (Fig. 4). If coke and sinter plant facilities has also been provided in Cases I and II, the rate of increase in plant capital cost below 100 000 tons capacity would have been even more marked.

/The curves

Auxiliary department costs

The curves in Fig. 3 depicting the auxiliary department costs per ton annual capacity show a similar trend, the slope of the curves generally indicating a slightly greater rate of increase in costs with decreasing plant capacity than production department costs. This, as has already been indicated, is due to the fact that for each plant capacity certain minimum essential facilities are necessary which cannot be reduced at the same rate as the plant capacity. On account of this, the cost of auxiliary departments increases from 23 per cent to 32 per cent of total plant cost with decreasing plant capacity.

Break in mill capital cost curve

The curves in all cases are fairly smooth, except in the case of departmental capital cost per ton annual capacity of the rolling mills which shows a distinct break between 100 000 tons and 50 000 tons capacity. This arises from the fact that a small capacity mill which is not suitable for a high degree of mechanisation is being changed over to a mill with almost complete mechanisation without which high speed rolling and high production rates cannot be obtained. That higher productivity and lower operating costs adequately compensate for the increase in capital cost will be evident from the production cost curve for rolled products (Fig. 5) which does not show a break at 100 000 ton capacity.

Economic limit for low capacity - 100 000 tons

Based on the trends of the cost-capacity relationship curves, without consideration of actual costs or selling prices and other special circumstances, the lower limit of capacity for integrated steelworks under the conditions assumed and for the processes and products considered in this study, would be placed at around 100 000 tons per year. It is at about this capacity that practically all curves, and particularly those showing total capital cost-capacity relationship (Fig. 4) and production cost per ton - capacity relationship (Fig. 5), commence their rapid upward trend.

/Production cost

Production cost components

"Cost of Materials", "Cost Above Materials", "Fixed Charges" and "Total Cost" for the four major products - iron, steel, concast billets and rolled products - in the five plant sizes considered are given in Table 7-1. The three components of production cost expressed as a percentage of the total cost are also given in the same table. All cost estimates are based on full utilisation of plant.

Total production cost per ton of product decreases steadily with increasing plant size. While the cost of materials per ton of product decreases with increasing plant size, the cost of materials expressed as a percentage of the total production cost increases with increasing plant size. Cost above materials, both in dollars per ton as well as expressed as a percentage of total cost, decrease with increasing plant size. These trends are indicative of the extent of the economies of scale. As regards fixed charges, although actual values decrease as the plant size grows, expressed as a percentage of the total cost they do not show the same steadily decreasing trend. This is because of the addition of coke ovens in Cases III, IV and V and sinter plant in Cases IV and V, which are included in the total plant cost for calculating fixed charges.

Cost indices

Relative capital and production cost indices for the four higher plant capacities are given in Table 7-2, with the 25 000 ton plant taken as 100 index. The plant capital cost per ton annual capacity drops to less than half as the plant expands from 25 000 to 300 000 tons. Production cost indices for the final rolled product drop even more. In deciding plant capacity, these indices suggest that integrated plants below 100 000 tons capacity would be at a considerable disadvantage compared to their larger competitors within the same area.

/Table 7-1

Table 7-1

PRODUCTION COST COMPONENTS

Product	Case I - 25 000 T/yr		Case II - 50 000 T/yr		Case III - 100 000 T/yr		Case IV - 200 000 T/yr		Case V - 300 000 T/yr	
	Cost/ton $	Percentage of total cost	Cost/ton $	Percentage of total cost	Cost/ton $	Percentage of total cost	Cost/ton $	Percentage of total cost	Cost/ton $	Percentage of total cost
Iron (hot metal)										
Cost of materials	33.26	46.50	32.80	56.00	32.40	61.50	32.36	65.60	31.10	69.00
Cost above materials	25.26	35.30	15.34	26.20	10.37	19.70	7.03	14.30	5.40	12.00
Fixed charges	12.99	18.20	10.37	17.80	9.87	18.80 a/	9.93	20.10 a/	8.58	19.00 a/
Total cost	71.51	100.00	58.51	100.00	52.94	100.00	49.32	100.00	45.08	100.00
Liquid steel (LD)										
Cost of materials	64.44	49.40	54.39	52.90	49.29	57.10	45.59	61.20	43.18	63.80
Cost above materials	43.88	33.60	31.37	30.50	22.32	25.80	16.31	21.90	13.68	20.20
Fixed charges	22.19	17.00	17.00	16.60	14.76	17.10 a/	12.62	15.90 a/	10.78	16.00 a/
Total cost	130.51	100.00	102.76	100.00	86.37	100.00	74.52	100.00	67.64	100.00
Concast billet										
Cost of materials	111.90	71.80	88.44	74.00	73.72	74.10	63.63	75.10	58.38	76.60
Cost above materials	16.45	10.50	9.89	8.30	7.74	7.80	5.73	6.80	4.67	6.10
Fixed charges	27.38	17.70	21.10	17.70	17.97	18.10 a/	15.35	18.10 a/	13.17	17.30 a/
Total cost	155.73	100.00	113.43	100.00	99.43	100.00	84.71	100.00	76.22	100.00
Rolling										
Cost of materials	138.06	63.20	105.28	64.70	85.95	66.10	72.51	66.90	65.80	67.90
Cost above materials	34.88	15.90	22.45	13.80	13.97	10.70	11.22	10.40	9.64	10.00
Fixed charges	45.72	20.90	34.86	21.50	30.12	23.20 b/	24.61	22.70 b/	21.48	22.10 b/
Total cost	213.66	100.00	162.59	100.00	130.04	100.00	108.34	100.00	96.92	100.00

a/ Because of the addition of coke ovens in Cases III, IV and V, and sinter plant in Cases IV and V which are included in the total plant cost for calculating fixed charges, the fixed charges expressed as a percentage of the total cost do not show a steadily decreasing trend with increasing plant size although the actual values of the fixed charges do show a decreasing trend. This is the result of the total cost decreasing at a faster rate than the fixed charges.

b/ In the case of rolling mills, higher degree of mechanisation also contributes to some extent to higher proportion of fixed charges in Cases III, IV and V.

/Table 7-2

Table 7-2

CAPITAL AND PRODUCTION COST INDICES

	Case I - 25 000 T/yr	Case II - 50 000 T/yr	Case III - 100 000 T/yr	Case IV - 200 000 T/yr	Case V - 300 000 T/yr
Index of capacity	100	200	400	800	1 200
Capital cost index per ton annual capacity					
Blast furnace	100	79.8	61.8	50.0	43.6
Steelmelt shop	100	75.9	60.6	45.3	35.8
Concast plant	100	72.5	55.4	47.0	41.4
Rolling	100	75.5	69.0	52.9	47.7
Total plant:					
Nominal capacity in terms of liquid steel	100	76.5	67.1 a/	55.5 a/	48.4 a/
In terms of rolled product	100	76.5	66.1 b/	54.0 b/	47.1 b/
Production cost index per ton					
Iron (hot metal)	100	81.8	73.6	69.0	63.0
Liquid steel	100	78.7	66.2	57.1	51.8
Concast billets	100	76.7	66.4	54.4	49.0
Rolled products	100	74.4	59.5	49.6	44.3

a/ In Case III, the plant includes coke ovens (non-recovery type) in addition to blast furnace, steelmelt shop, concast plant and rolling mills; in Cases IV and V the plant includes conventional recovery type coke ovens and also sinter plant. Without these additions, the capital cost indices per ton nominal annual capacity in terms of liquid steel would be only 64.73, 50.38 and 43.98 for Cases III, IV and V respectively as compared to 100 for Case I.

b/ Without coke ovens in Case III, and without coke ovens and sinter plant in Cases IV and V, the capital cost indices per ton annual capacity of rolled product would be 63.73, 49.08 and 42.84 respectively for Cases III, IV and V as compared to 100 for Case I.

/Selling prices

Selling prices

Selling prices of steel materials produced at a steelworks must be fixed at levels which will give a fair return on total investment, including interest during construction, deferred charges, working capital, etc. Assuming say 10 per cent as return on total investment, the average selling prices of rolled products produced in the plants under study would have to be approximately as given in Table 7-3.

Table 7-3

ESTIMATED SELLING PRICES FOR ROLLED PRODUCTS

Plant capacity T/yr	Average works production costs $/ton	Average selling price $/ton
25 000	219	283
50 000	163	212
100 000	130	172
200 000	108	139
300 000	97	127

United States and United Kingdom prices

Current United States and United Kingdom export prices in dollar equivalents are given in Table 7-4.

/Table 7-4

Table 7-4

UNITED STATES AND UNITED KINGDOM PRICES

Product	United States export price a/ $/ton	United Kingdom export price b/ $/ton
Basic pig iron	62	61
Billets	93	93
Merchant bars	139	115
Wire rods	144	122

a/ Iron Age, 21st April 1966.

b/ Metal Bulletin, 5th April 1966.

Comparing the estimated selling prices (Table 7-3) that would have to be fixed for products rolled in plants of the sizes considered in this study with selling prices prevailing in many Latin American countries or with current United States and United Kingdom export prices (Table 7-4), it will be evident that integrated steel plants below about 100 000 tons capacity stand no reasonable chance of being able to compete with imported materials without excessively heavy protective tariffs or with materials produced within the country in larger plants.

Cost indices for alternative iron and steelmaking processes

Taking the capital cost per ton annual capacity and production cost per ton respectively as 100 for the blast furnace-LD converter combination considered in this study, capital cost and production cost indices per ton annual capacity and per ton of product respectively for the four other alternative combinations of iron and steelmaking processes considered for Case II are given in Table 7-5.

/Table 7-5

Table 7-5

CAPITAL AND PRODUCTION COST INDICES FOR ALTERNATIVE COMBINATIONS OF IRON AND STEELMAKING PROCESSES

(Case II - 50 000 ton/year)

	BF-LD	BF-EAF	ESF(FR)-EAF	ESF-EAF	EAF
Capital cost index per ton annual capacity					
Iron making	100.0	130.3 a/	125.0 a/	113.9 a/	-
Steelmaking	100.0	87.7	87.7	87.7	87.5 c/
Continuous casting	100.0	89.7 b/	89.7 b/	89.7 b/	97.9 c/
Rolling	100.0	100.0	100.0	100.0	97.8 c/
Total plant	100.0	86.4	84.3	82.6	65.1
Production cost index per ton					
Iron (hot metal)	100.0	122.2 a/	136.1 a/	154.9 a/	-
Liquid steel	100.0	89.8 d/	93.7 d/	98.9 d/	72.3 e/
Concast billets	100.0	89.7	93.2	97.9	74.3
Rolled products	100.0	91.7	94.5	98.3	79.1

a/ Hot metal constitutes only 50 per cent of the metallic charge for steelmaking in these three cases. Capacity required for iron making plant is only about half that required with LD converter steelmaking. Therefore, capital cost index per ton annual capacity of iron and production cost index per ton are higher than 100, although the total capital cost of the iron making plant is lower.

b/ Lower capital cost as a result of changeover from two single-strand to one double-strand continuous casting machine.

c/ Variations due to difference in allocations of auxiliary department costs.

d/ The low cost of $ 30 per ton assumed for scrap which constitutes 50 per cent of the metallic charge has largely compensated for the high cost of hot metal. To some extent the lower cost is also due to lower "cost above" and lower "fixed charges".

e/ The low cost of steel is mostly due to low cost of scrap which constitutes almost the entire metallic charge and to some extent due to lower "fixed charges".

/For the

Blast furnace metal costs lowest

For the conditions assumed in this study hot metal produced in the blast furnace is found to be the cheapest even for the smallest capacity plant, in spite of somewhat higher fixed charges (see Appendix 6-8) as compared to electric smelting.

Arc furnace steelmaking best choice for small capacity

Scrap is a scarce commodity not readily available in large quantities in Latin America and, therefore, steelmaking in electric arc furnace with 100 per cent scrap charge, or even with 50 per cent hot metal - 50 per cent scrap charge, may not be feasible from this view-point. However, several alternative possibilities with electric arc furnace steelmaking have been considered as a matter of interest. The capital cost of a 50 000 ton per year capacity plant with blast furnace - electric furnace combination is only about 86 per cent of the cost of a plant with blast furnace and LD converter considered in this study; and the same capacity plant based on electric arc furnace steelmaking entirely from scrap charge, without the need for installing ironmaking capacity, costs only about 65 per cent of the plant with blast furnace - LD converter. The production costs per ton of steel for the same two alternatives are 89.8 per cent and 72.3 per cent respectively, and production costs per ton of rolled product are 91.7 per cent and 79.1 per cent respectively. For a small scale plant of 25 000 T/yr or 50 000 T/yr capacity, semi-integrated operation with steelmaking in electric arc furnace from 100 per cent scrap is obviously the best choice. This conclusion would be valid even if the scrap price is somewhat higher than $ 30 per ton, and some of the scrap has to be imported.

The economies of arc furnace steelmaking as compared to LD steelmaking for small capacities, under the specific conditions assumed for this study, arise chiefly from the following sources:

/(i) Lower

(i) Coke making

(ii) Sintering

(iii) Iron making

(iv) Steelmaking (LD)

(v) Continuous casting, and

(vi) Rolling.

Capital costs of auxiliary departments are estimated in Appendices 5-7 to 5-13. The total capital cost is given in Appendix 5-14 and summarised in Table 5-2.

Table 5-2

SUMMARY OF CAPITAL COST

	Case I 25 000 T/yr '000 $	Case II 50 000 T/yr '000 $	Case III 100 000 T/yr '000 $	Case IV 200 000 T/yr '000 $	Case V 300 000 T/yr '000 $
Production departments					
Coke ovens	-	-	1 070	3 180	4 152
Sinter plant	-	-	-	1 329	1 717
Blast furnaces	2 652	4 255	6 659	10 442	13 789
Steelmelt shop	1 910	2 861	4 879	7 226	8 901
Concast plant	761	1 033	1 860	3 519	4 724
Rolling mills	2 262	3 338	7 172	11 921	16 553
Sub-total	7 575	11 487	21 640	37 617	49 836
Auxiliary departments					
Plant laboratory	123	133	142	274	308
Power system	575	990	1 410	1 779	1 957
Water system	676	1 148	1 936	3 088	4 011
Utilities	612	906	1 330	1 746	2 391
Works transport	457	658	1 010	1 488	2 002
Repair and maint. shops	735	1 201	1 652	2 345	2 810
Miscellaneous buildings, facilities and storages	374	509	762	1 021	1 278
Sub-total	3 552	5 545	8 242	11 741	14 757
Total	11 127	17 032	29 882	49 358	64 593

/For estimating

(i) Lower investment on smaller capacity ironmaking plant with 50 per cent hot metal - 50 per cent scrap charge, and complete elimination of ironmaking with 100 per cent scrap charge.

(ii) Lower investment on arc furnace steelmaking plant as compared to LD converter plant with small converters of less than 10 tons capacity.

(iii) Lower cost of metallic charge, if scrap is available at less than $ 40 per ton.

(iv) Lower fixed charges and lower operating costs for continuous casting eight to ten arc furnace heats in one double strand continuous casting machine as against thirty to thirty-five very small LD heats in two single strand continuous casting machines.

Productivity and investment

In Latin America, as in other developing countries, skilled labour and trained technical personnel are not readily available. Operational and technical skills have to be acquired through "on the job" training. Under these conditions the tendency is to employ too many men in the beginning, who later become surplus, but whose services cannot be dispensed with due to restrictive labour union practices or welfare labour legislation. In the cases under study, preliminary manpower estimates are based on operational requirements, without provision for extra labour in the initial phase.

Productivity expressed in tons of liquid steel per man-year and capital investment in thousands of dollars per person employed are given in Table 7-6 and shown in relation to plant capacity in Fig. 6.

/Table 7-6

Table 7-6

PRODUCTIVITY AND CAPITAL INVESTMENT

Plant capacity	Production Tons/man-year	Capital investment '000 $ per worker
25 000	26	11.7
50 000	45	15.2
100 000	71	21.2
200 000	105	26.0
300 000	139	31.0

Capital investment per person employed increases nearly threefold with increasing plant capacity, from $ 11 700 to $ 31 000. Productivity shows even more rapid increase, over fivefold, from 26 tons per man-year to 139 tons per man-year.

Cost structure

The production cost structure for the plant sizes under study is given in Table 7-7.

Table 7-7

COST STRUCTURE FOR STEEL PRODUCTION

	Percentage of total cost				
	Case I	Case II	Case III	Case IV	Case V
Raw materials	20	26	31	37	41
Power and fuel	4	4	5	5	6
Wages and salaries	41	33	27	22	19
All others	35	37	37	36	34
Total	100	100	100	100	100

/The proportion

The proportion of the cost of "raw materials" to the total cost increases from 20 per cent in Case 1 to 41 per cent in Case V, while the proportion of "wages and salaries" decreases from 41 per cent in Case I to 19 per cent in Case V. These variations with plant capacities are shown in Fig. 7. "Power and fuel costs" and "other costs" do not show marked variation.

Wages and salaries

Labour cost amounting to $ 1.50 per man/hour assumed for this study is more than double the labour cost in India but less than half that in United States. The decrease in the proportion of wages and salaries to total cost from 41 per cent in Case I to 19 per cent in Case V is the result of over fivefold increase in productivity. Low productivity and the consequent high proportion of wages and salaries are mainly the result of extending integration to very small scale operations.

Wages are bound to increase with rising standards of living. In a basic industry such as steel, the effect of rising wages on production costs has to be effectively countered by increased productivity, by adoption of improved processes and through economies of scale. Otherwise, the result of increasing wages will not be rising living standards but rising costs.

Capital/output ratio

Within certain limitations depending on type of industry, tax rates, etc., the ratio of capital investment to gross sales value of annual output serves as an indicator of the effectiveness of investment. Assuming an average selling price of $ 150 per ton of rolled product, capital/output ratios for the five cases under study are given in Table 7-8.

/Table 7-8

Table 7-8

RATIO OF CAPITAL INVESTMENT TO VALUE OF ANNUAL OUTPUT

(Capital cost and gross sales value in million dollars)

	Case I	Case II	Case III	Case IV	Case V
Total plant capital cost	11.13a/	17.03a/	29.88	49.36	64.59
Gross sales value b/	3.30	6.59	13.40	27.07	40.62
Capital/output ratio	1:0.30	1:0.39	1:0.45	1:0.55	1:0.63

a/ Cases I and II do not include coke ovens and sinter plant. Capital output ratios would be even more disadvantageous if these facilities were provided.

b/ Average selling price taken at US$ 150 per ton.

The low capital/output ratios for Cases I and II present an unfavourable picture.

Modern technology

The production processes adopted in all five cases under study are based on the most economic, efficient and modern techniques suited to the quality of raw materials assumed viz. blast furnace operation with oil injection, high blast temperature and prepared burden, LD steelmaking and continuous casting. The raw materials considered are of high quality - iron ore with 65 per cent Fe, coke with 8 per cent ash and 90 per cent FC and limestone with 52 per cent CaO and 5 per cent insolubles. It is because of these circumstances that the capital investment required for the 300 000 ton plant is only US$ 215 per ton annual capacity (in terms of liquid steel) which compares favourably with the investment figures of approximately the same order for recently built large integrated steel plants of 1.5 to 2.0 million tons capacity using conventional facilities.

/The capital

Integration un-economic for very small capacities

The capital investment rises rapidly from $ 215 to $ 340 and $ 445 per ton annual capacity and production cost per ton of merchant products rises equally rapidly from $ 97 for the 300 000 ton plant to $ 163 and $ 219 per ton for 50 000 ton plant and 25 000 ton plant respectively. This trend clearly indicates that even with efficient technology and high quality raw materials, integrated operations including ironmaking cease to be economic at small capacities.

Possible alternatives

For plants of annual production capacity below 100 000 tons semi-integration with steelmaking in electric arc furnace would prove economic if regular supplies of scrap at about $ 30 per ton could be ensured.

Separation of rolling facilities

Another alternative that could be considered is to separate rolling from steelmaking. In the interests of stimulating regional economic and industrial development within a large country, rolling mills can be set up in various parts of the country, each mill specialising in the production of a few items which would find a ready market in the region. The semis for these mills - billets, blooms and slabs - could be supplied from medium to large integrated steel plants having capacities of 300 000 tons or more, located in areas which have a strong raw materials base or at locations which would ensure minimum over-all costs for raw materials and other supply and service facilities. Satellite mills could also be set up in the same area. Practically all steel materials other than hot rolled flat products could be economically produced in this manner in mills of small to medium capacity.

The concept of confining steel and semis production to medium and large integrated steel plants, and rolling the semis into finished products in mills of varying capacities set up in widely dispersed areas to suit the

/market demands

market demands of those areas, can be extended, particularly in the case of small countries, to encompass several adjacently located countries in the region taken together, if decided advantages in terms of raw materials, economic resources, transport facilities and enlarged markets offer greater scope for exploiting economies of scale. The concept is feasible only if trade and political barriers do not stand in the way.

/Appendix I-1

Appendix 1-1

BASIC DATA ON LATIN AMERICA

(Data corresponding to the year 1963)

Country	Area a/ (million km²)	Population b/ (millions)	Gross domestic product: Per capita c/ (dollars)	Gross domestic product: Average annual increase 1955-60 d/ (percentages)	Steel (ingot): Production a/ (million tons)	Steel (ingot): Annual consumption e/ Total (million tons)	Steel (ingot): Annual consumption e/ Per capita (kg)
Latin American countries							
Argentina	2.796	22.12	544	0.8	0.913	1.658	75.0
Bolivia	1.098	3.95	94	-2.2	-	0.033	8.4
Brazil	8.513	76.74	156	2.7	2.832	3.838	50.0
Central America	0.464	12.00	235	0.8	-	0.174	14.5
Chile	0.742	8.18	457	1.4	0.521	0.687	84.0
Colombia	1.138	16.82	298	1.1	0.222	0.481	28.6
Cuba	0.114	7.22	...	...	...	0.167	23.0
Dominican Republic	0.048	3.35	201	...	-	0.057	17.0
Ecuador	0.270	4.73	189	1.3	-	0.065	13.8
Haiti	0.028	4.32	...	...	-	...	...
Jamaica	0.011	1.69	...	...	-	0.068	40.9
Mexico	1.969	39.86	394	2.9	2.017	2.046	51.3
Panama	0.075	1.15	427	2.5	-	0.035	...
Paraguay	0.407	1.91	186	-0.1	-	0.015	7.9
Peru	1.285	10.96	220	2.1	0.076	0.271	24.7
Trinidad and Tobago	0.005	0.92	650	...	-	0.117	126.9
Uruguay	0.187	2.59	662	0.09	0.007	0.082	31.7
Venezuela	0.912	8.14	716	2.5	0.358	0.576	70.9
Total Latin American Countries	20.062	226.65	...	1.8	6.946	10.203 f/	46.5 f/
Other selected countries							
United States	9.347	189.37 g/	2 790	1.8 g/	99.120 g/	102.309 h/	540.0 g/
Japan	0.370	95.87 g/	628	10.2 g/	31.501 g/	24.726 h/	258.0 g/
India	3.289	460.49 g/	74	4.0 g/	5.971 g/	7.280 h/	16.0 g/

a/ U.N. Demographic Year Book, 1963.
b/ Anuario Demográfico de Naciones Unidas, 1963.
c/ Year Book of National Accounts Statistics, 1964.
d/ Estudio Económico de América Latina, 1964 (E/CN.12/711 - CEPAL).
e/ Instituto Latinoamericano del Fierro y del Acero y Anuarios de Comercio Exterior, excludes steel content of plant and equipment.
f/ Does not include Cuba for which the data is only provisional.
g/ U.N. Statistical Year Book, 1964.
h/ The European Steel Market in 1963.

Appendix 3-1

CAPITAL COST ESTIMATE FOR COKE PLANT HAVING COAL CARBONISATION CAPACITY OF 186 000 TONS PER YEAR WITH AND WITHOUT AMMONIUM SULPHATE AND BENZOL RECOVERY

(Thousands of £)

	Case V (without Ammonium Sulphate and Benzol recovery)	Case V-A (with Ammonium Sulphate and Benzol recovery)
A. Civil and structural		
1. Civil works:		
Foundations, masonry and RCC works for equipment and miscellaneous building	723	890
2. Structural steelworks:		
Structural work incl. cladding and glazing for building as erected	262	320
Sub-total	985	1 210
B. Mechanical and electrical equipment		
1. Coal processing equipment incl. equipment for coal handling, crushing, blending etc.	232	232
2. Coke ovens incl. refractories, service machine etc.	1 148	1 148
3. Coke handling equipment	125	125
4. Gas condensation plant incl. gas coolers, condensers, exhausters etc.	160	160
5. By-product plant incl. benzol plant, ammonia plant etc.	-	391
6. Instruments and electrical equipment, electrical distribution and fittings inside the plant, building utilities etc.	25	25
7. Equipment erection	592	720
Sub-total	2 282	2 801
Spares at 5% of equipment cost	85	104
Freight, clearance and insurance charges at 20% equipment and spares cost	355	437
Sub-total	3 707	4 552
Contingencies at 5%	185	228
Design, engineering, supervision of construction and client's administration at 7%	260	319
Total	4 152	5 099

Appendix 3-2

STEEL CONSUMPTION BY PRODUCTS IN USA, JAPAN, INDIA AND LATIN AMERICA

	United States a/				Japan b/				India c/				Latin America d/			
	1952		1960		1952		1960		1952		1960		1952		1960	
	Thousands of tons	Percentages	Thousands of tons	Percentages	Thousands of tons	Percentages	Thousands of tons	Percentages	Thousands of tons	Percentages	Thousands of tons	Percentages	Thousands of tons	Percentages	Thousands of tons	Percentages
1. Rail and heavy sections	6 130	9.2	5 530	8.9	612	12.0	2 043	13.7	325	25.0	761	22.6	519	14.7	690	10.8
2. Bars and light sections	12 190	20.6	11 150	17.9	1 420	28.1	3 812	25.6	429	33.3	1 340	40.0	1 392	39.4	2 531	39.6
3. Flat products	27 470	46.5	35 307	56.7	209	41.5	6 204	41.6	447	34.6	1 052	31.4	1 191	33.8	2 472	38.7
4. Other products	13 310	22.7	10 230	16.5	909	18.4	2 841	19.1	95	7.1	196	5.8	428	12.1	701	10.9
Total finished steel	59 100	100.0	62 200	100.0	5 050	100.0	14 900	100.0	1 296	100.0	3 349	100.0	3 530	100.0	6 394	100.0

a/ USA data from the Annual Statistical Report, 1960 published by the American Iron and Steel Institute.

b/ Data for Japan from BISF Statistical Handbook, 1954, 1956 and 1960.

c/ Indian data for 1952 from BISF Statistical Handbook, 1954. For subsequent years, from Statistical Abstract and Steel Ministry Reports.

d/ Statistical data from Instituto Latinoamericano del Fierro y del Acero and Instituto Brasileiro de Siderurgia y Anuarios de Comercio Exterior. Figures were in equivalent ingot tons. Tonnage of finished steel obtained by back-calculation, taking the yield from ingots to flat products as 70% and to other products as 75%. Seamless tubes are included with bars and light sections and tubes with flat products. Only wire rods are included in the group "Other products".

Appendix 4-1

PLANT FUEL BALANCE

Particulars	Specific Heat Generation/ Consumption (mill.Kcal/ ton product)	Heat Generation/Heat Consumption. (million Kcal)									
		Case I		Case II		Case III		Case IV		Case V	
		Per hour	Per year	Per hour	Per year	Per hour	Per year	Per hour	Per year	Per hour	Per year
Heat Available											
1. Blast furnace gas, surplus a/	1 426 - 1 288	3.86	32 504	7.54	63 420	14.23	119 426	26.98	216 933	38.62	321 925
2. Coke oven gas surplus b/	0.693	Nil	Nil	Nil	Nil	Nil	Nil	10.10	84 893	15.30	128 621
3. Fuel oil, purchased c/	-	4.15	24 620	8.25	47 930	14.91	88 864	18.55	106 000	25.00	150 000
4. Fuel gas, purchased d/	-	0.25	2 005	0.29	2 320	0.33	2 636	0.36	2 865	0.43	3 438
Total		8.26	59 129	16.08	113 670	29.47	210 926	54.99	410 591	79.35	603 984
Heat Allocation											
1. Sinter plant e/	0.025	Nil	Nil	Nil	Nil	Nil	Nil	0.24	1 835	0.32	2 750
2. Lime kilns f/	0.65	0.2	1 625	0.38	3 250	0.76	6 500	1.52	13 000	0.28	19 500
3. Steelmelting shop f/	0.2 - 0.1	0.6	5 000	1.04	9 000	1.74	15 000	2.90	25 000	3.48	30 000
4. Continuous casting shop f/	0.2 - 0.1	0.6	5 000	1.04	9 000	1.74	15 000	2.90	25 000	3.48	30 000
5. Rolling Mill furnaces g/	0.6 - 0.5	3.0	15 000	5.80	29 000	11.00	55 000	18.55	106 000	25.00	150 000
6. Boilers h/	0.9	3.6	30 600	7.45	57 000	12.70	107 950	23.11	196 430	31.43	267 150
7. Minor requirements and losses		0.20	1 700	0.25	2 100	0.50	4 200	1.00	8 400	1.50	12 600
Total		8.20	58 525	15.96	109 350	28.44	203 650	50.22	375 665	67.49	512 000
Bleed-off i/		0.06	604	0.12	4 320	1.03	7 276	4.77	35 026	11.86	91 984

a/ Calorific value of gas - 900 Kcal/Ncum. About 60% of blast furnace gas generated is available as surplus, after meeting stove heating requirement.

b/ Calorific value of gas - 4 200 Kcal/Ncum. About 55% of coke oven gas generated is available as surplus, after meeting coke ovens heating requirements.

c/ Calorific value of oil - 10 000 Kcal/kg. Heat value of oil for blast furnace injection is not included.

d/ Calorific value of liquified petroleum gas - 28 650 Kcal/Ncum. Used only in continuous casting shop.

e/ Coke oven gas used as fuel.

f/ Fuel oil used in cases 1, 2 and 3 and coke oven gas used in cases IV and V; in addition LPG gas used for ladle and tundish heating and torch cutting of billets in continuous casting shop.

g/ Fuel oil used in all cases.

h/ Blast furnace gas used as fuel; provision made for oil firing also as standby.

i/ The surplus coke oven gas can be used to enrich the blast furnace gas for stove heating.

For estimating the investment on production facilities per ton annual capacity of product, the total cost of auxiliary departments has been allocated to production departments on the basis of relative utilisation of facilities, as follows:

Table 5-3

DISTRIBUTION OF AUXILIARY DEPARTMENTS CAPITAL COSTS AMONG PRODUCTIVE DEPARTMENTS

	Case I %	Case II %	Case III %	Case IV %	Case V %
Coke ovens	-	-	9	10	10
Sinter plant	-	-	-	6	6
Blast furnaces	18	18	15	14	14
Steelmelt shop	24	24	22	20	20
Concast plant	14	14	11	10	10
Rolling mills	44	44	43	40	40
Total	100	100	100	100	100

Electric smelting of iron and steel

For Case II, the 50 000 tons per year plant, four alternative combinations of iron and steelmaking processes in addition to the one under study have been considered.

1. Blast Furnace - LD converter (case studied in this report)
2. Blast Furnace - Electric Arc Furnace
3. Electric smelting (with pre-reduction) - Electric Arc Furnace
4. Electric Smelting (without pre-reduction) - Electric Arc Furnace
5. Electric Arc Furnace only (no iron making).

Capital cost estimates of production and auxiliary departments for all the alternatives are presented in Appendix 5-16. Capital costs of production facilities including allocations for auxiliary departments and costs per ton of annual capacity are given in Appendix 5-17 and summarised in Table 5-4.

/Table 5-4

Appendix 4-2

LIST OF EQUIPMENT FOR THE REPAIR AND MAINTENANCE SHOPS

	Unit	Case I	Case II	Case III	Case IV	Case V
1. Foundry						
Medium frequency crucible induction furnace for iron melting a/	Kg	750	750	750	1 500	3 000
Lift coil induction crucible furnace for non-ferrous melting b/	Kg	-	25	50	100	100
Sand plant	t/hr	1	3	3	4	5
Moulding machines	Nos.	1	2	2	2	2
Type		Manual	Manual	Jolt squeeze	Jolt squeeze	Jolt squeeze
Table size	mm	650x450	650x450	650x400	900x600	900x600
Pattern making machines	Nos.	-	-	-	2	2
2. Machine Shop						
Hydraulic press, 500 t	Nos.	-	1	1	1	1
Lathes, 1 000 x 5 000 mm	Nos.	3	6	7	10	-
Lathes, 1 000 x 9 000 mm	Nos.	-	-	-	-	10
Vertical lathe, 1 200 mm	Nos.	1	1	1	1	1
Horizontal boring, 75 mm spindle	Nos.	-	-	-	-	1
Openside planer 900 x 3 000 mm	Nos.	1	1	1	1	1
Shapers, 600 and 900 mm	Nos.	1	2	2	2	3
Slotting machine	No.	1	1	1	1	1
Milling machine, 1 600 x 360 mm	No.	1	1	1	1	1
Radial drill, 50 mm	No.	-	-	-	-	1
Portable radial drill	No.	-	1	1	1	1
Pillar and bench drills	Nos.	2	3	3	3	4
Surface grinder, 300 x 1 200 mm	No.	1	1	1	-	-
Vertical spindle grinder 400 x 1 500 mm	No.	-	-	-	1	1
Cutter, saw blade and carbide tipped tool grinder	Nos.	2	3	3	3	3
Heat treatment furnaces	Nos.	1	2	2	2	2
3. Forge shop						
Pneumatic hammers	Nos, Kg	1-50	1-50	1-100	1-300	1-500
4. Structural shop						
Guillotine shear, 10 mm	Nos.	-	-	-	1	1
Universal punch and shear	Nos.	-	-	-	1	1
Plate bending rolls, 20 x 2 000 mm	Nos.	-	-	-	1	1
Welding equipment (electric and gas)	Nos.	2	2	3	4	4
Radial drill, 50 mm	Nos.	-	-	-	1	1
5. Auto, loco and mobile heavy equipment servicing and repair shop						
Fuel injection test bench	No.	-	1	1	1	1
Hydraulic lift, 5 T and 8 T	Nos.	-	1	1	2	2
Hydraulic press, 25 T	No.	-	1	1	1	1
Drill	Nos.	-	1	1	1	2
Lathe, 300 x 3 000 mm	No.	-	-	-	-	1
6. General maintenance, pipe shop and building services						
Pipe bending and threading machine	Nos.	1	2	3	3	4
Woodworking machine	Nos.	1	2	2	2	2

LIST OF EQUIPMENT... (concluded)

	Unit	Case I	Case II	Case III	Case IV	Case V
7. <u>Electrical repair shop</u>						
Universal coil winding machine	Nos.	1	1	1	1	2
Infra-red heating	Nos.	1	2	4	4	6
Vacuum impregnating, varnishing and drying oven	Set	1	1	1	1	1
MD tests sets and controls	Set	1	1	1	1	1
Constant potential MD sets and controls	Set	1	1	1	1	1
Hydraulic press, 60 T	No.	1	1	1	1	1
Lathe, 250 x 2 500 mm	Nos.	1	1	1	1	1
Shaper, 600 mm	Nos.	1	1	1	1	1
Milling machine, 600 x 355 mm	Nos.	1	1	1	1	1
Portable wood sawing machine	Nos.	1	1	1	1	1
8. <u>Cranes</u>						
3 T x 10 000 mm span	Nos.	-	-	1	1	-
3 T x 21 000 mm span	Nos.	-	-	-	-	1
5 T x 18 000 mm span	Nos.	-	-	-	1	1
5 T x 21 000 mm span	Nos.	1	1	-	-	-
10 T x 18 000 mm span	Nos.	-	-	-	1	-
10 T x 21 000 mm span	Nos.	-	-	1	-	1
Total Cranes	Nos.	1	1	2	3	3
9. Total area, R and M Shop Complex, approx.	sq m	1 800	3 000	4 000	5 300	6 600

a/ This equipment is based on 360, 600, 600, 1 000 and 1 500 tons/year of CI castings, and 750, 750, 750, 1 500 and 3 000 kg maximum 'as cast' weight of individual casting for Cases I to V respectively.

b/ This equipment is based on 25, 50, 100 and 100 tons/year of non-ferrous castings, and 25, 50, 100 and 100 kg maximum 'as cast' weight of individual casting for Cases II to V respectively.

Appendix 5-1

CAPITAL COST ESTIMATE FOR COKE PLANT a/

	Case III 100 000 T/yr (thousands of $)	Case IV 200 000 T/yr (thousands of $)	Case V 300 000 T/yr (thousands of $)
A. Civil and structural			
1. Civil Works: Foundations, masonry and RCC works for equipment and miscellaneous buildings	188	556	723
2. Structural Steelworks: Structural work including cladding and glazing for building as erected	67	204	262
Sub-total	255	760	985
B. Mechanical and electrical equipment			
1. Coal processing equipment including equipment for coal handling, crushing, blending etc.	74	151	232
2. Coke ovens incl.refractories, oven servicing machines etc.	252	918	1 148
3. Coke handling equipment	88	82	125
4. Gas condensation plant incl.gas coolers, condensers, exhausters etc.	-	115	160
5. Instruments and electrical equipment, electrical distribution and fittings inside the plant, building utilities etc.	21	25	25
6. Equipment erection	152	452	592
Sub-total	587	1 743	2 282
Spares at 5% of equipment cost	22	65	85
Freight, clearance and insurance charges at 20% of equipment and spares cost	91	271	385
Sub-total	955	2 839	3 707
Contingencies at 5%	48	142	185
Design, engineering, supervision of construction and client's administration at 7%	67	199	260
Total	1 070	3 180	4 152

a/ Basis: See table 3-5 - Coke Plant Facilities.

Appendix 5-2

CAPITAL COST ESTIMATE FOR SINTER PLANT a/

	Case IV 200 000 T/yr (thousands of $)	Case V 300 000 T/yr (thousands of $)
A. Civil and structural		
1. Civil Works:		
Foundations, masonry and RCC works for equipment and miscellaneous buildings	103	135
2. Structural Steelworks:		
Structural work incl. cladding and glazing for building as erected	180	230
Sub-total	283	365
B. Mechanical and electrical equipment		
1. Material handling and blending equipment incl. vibratory screen conveyor	82	107
2. Mechanical equipment	390	510
3. Electrical equipment	95	124
4. Dedusting equipment	40	51
5. Equipment erection	140	170
Sub-total	747	962
Spares at 5% of equipment cost	30	40
Freight, clearance and insurance charges at 20% of equipment and spares cost	127	166
Sub-total	1 187	1 533
Contingencies at 5%	59	77
Design, engineering, supervision of construction and client's administration at 7%	83	107
Total	1 329	1 717

a/ Basis: See Table 5-6 - Major Facilities for Sinter Plant.

Appendix 5-3

CAPITAL COST ESTIMATE FOR BLAST FURNACE PLANT [a]

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil and structural					
1. Civil Works: Foundations, masonry and RCC works for equipment and miscellaneous buildings	190	230	391	503	677
2. Structural Steelworks: Structural work incl.cladding and glazing for building as erected	90	140	270	417	534
Sub-total	280	370	661	920	1 211
B. Mechanical and electrical equipment					
1. Raw material handling	155	280	410	640	750
2. Stockhouse and charging equipment	80	140	320	620	680
3. Blast furnace incl.refractories and casthouse equipment	410	680	990	1 376	1 508
4. Hot blast stoves incl.refractories	360	510	660	910	1 288
5. Gas cleaning plant	130	230	330	545	786
6. Cold blast supply	105	180	250	410	665
7. Pig casting machine, ladle repair shop and rolling stock	90	160	320	620	798
8. Electrical equipment incl. EOT cranes	95	150	300	580	1 052
9. Building utilities and miscellaneous equipment	25	50	90	150	165
10. Equipment erection	260	430	660	1 030	1 408
Sub-total	1 710	2 810	4 330	6 881	9 100
Spares at 5% of equipment cost	73	119	184	293	385
Freight, clearance and insurance charges at 20% of equipment and spares cost	305	500	771	1 229	1 615
Sub-total	2 368	3 799	5 946	9 323	12 311
Contingencies at 5%	118	190	297	466	616
Design, engineering, supervision of construction and client's administration at 7%	166	266	416	653	862
Total	2 652	4 255	6 659	10 442	13 789

a/ Basis: See Table 3-9 - Iron making plant facilities.

Appendix 5-4

CAPITAL COST ESTIMATE FOR STEELMELT SHOP a/
(INCL. OXYGEN PLANT AND CALCINING PLANT)

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil and structural					
1. Civil works - Foundations, masonry and RCC works for equipment and miscellaneous buildings	206	236	390	562	701
2. Structural steelworks - Structural work incl. cladding, glazing for building as erected	320	423	721	1 039	1 340
Sub-total	526	659	1 111	1 601	2 041
B. Mechanical and electrical equipment					
1. Hot metal mixer incl. refractories	131	131	244	383	383
2. LD Converters incl. lances and refractories	32	69	128	229	296
3. Plant and process auxiliaries such as scrap boxes, ladles, slag pots, transfer cars etc.	48	103	192	344	445
4. Gas cleaning plant: Scrubbers, ducting etc.	70	100	150	200	275
5. Electrical equipment	11	16	29	46	56
6. EOT cranes	265	408	456	791	879
7. Oxygen plant	175	390	900	1 135	1 400
8. Calcining plant	78	90	146	212	335
9. Building utilities incl. lighting	11	17	25	41	48
10. Miscellaneous equipment	15	21	37	60	73
11. Equipment erection	126	201	339	514	627
Sub-total	962	1 546	2 646	3 955	4 817
Spares at 5% of equipment cost	42	67	115	172	210
Freight, clearance and insurance charges at 20% of equipment and spares cost	176	282	484	723	880
Sub-total	1 706	2 554	4 356	6 451	7 948
Contingencies at 5%	85	128	218	323	397
Design, engineering, supervision of construction and client's administration at 7%	119	179	305	452	556
Total	1 910	2 861	4 879	7 226	8 901

a/ Basis: See table 3-11 - Major equipment facilities for LD steelmaking.

Appendix 5-5

CAPITAL COST ESTIMATE FOR CONTINUOUS CASTING PLANT a/

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil and structural					
1. Civil Works: Foundations, masonry and RCC works for equipment and buildings	30	47	92	215	313
2. Structural Steelworks: Structural work including cladding and glazing for buildings as erected	50	87	163	402	571
Sub-total	80	134	255	617	884
B. Mechanical and electrical equipment					
1. Continuous casting machines including cut off equipment, discharge roller tables, cooling banks etc.	400	535	950	1 680	2 200
2. EOT crane	20	25	52	104	150
3. Building utilities incl. lighting	11	18	30	59	83
4. Equipment erection	46	60	105	203	268
Sub-total	477	638	1 137	2 046	2 701
Spares at 5% of equipment cost	22	29	52	92	122
Freight, clearance and insurance charges at 20% of equipment cost	91	121	217	387	511
Sub-total	670	922	1 661	3 142	4 218
Contingencies at 5%	34	46	83	157	211
Design, engineering, supervision of construction and client's administration at 7%	47	65	116	220	295
Total	751	1 033	1 860	3 519	4 724

a/ Basis: See table 3-14 - Continuous Casting Facilities.

Appendix 5-6

CAPITAL COST ESTIMATE FOR ROLLING MILLS a/

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil and structural					
1. Civil works: Foundations, masonry and RCC works for equipment and miscellaneous buildings	203	300	538	1 029	1 357
2. Structural steelworks: Strutural work incl. cladding and glazing for building as erected	302	473	871	1 636	2 045
Sub-total	505	773	1 409	2 665	3 402
B. Mechanical and electrical equipment					
1. Reheating furnace	72	120	208	466	629
2. Mill housings and mechanical equipment	684	1 012	2 079	3 190	4 460
3. Mill electrical equipment	230	304	1 045	1 700	2 670
4. EOT cranes	26	26	146	178	221
5. Other handling facilities	10	10	13	43	51
6. Building utilities incl. lighting	15	20	29	34	43
7. Roll turning shop	64	110	123	213	255
8. Miscellaneous	13	21	30	43	51
9. Equipment erection	111	162	367	587	818
Sub-total	1 225	1 785	4 040	6 454	9 198
Spares at 5% of equipment cost	56	81	184	293	419
Freight, clearance and insurance charges at 20% of equipment and spares cost	234	341	771	1 232	1 760
Sub-total	2 020	2 980	6 404	10 644	14 779
Contingencies at 5%	101	149	320	532	739
Design, engineering, supervision of construction and client's administration at 7%	141	209	448	745	1 035
Total	2 262	3 338	7 172	11 921	16 553

a/ Basis: See mill facilities as detailed in chapter 3.

Appendix 5-7

CAPITAL COST ESTIMATE FOR PLANT LABORATORY

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil					
Civil works:					
Foundations, masonry, RCC works for equipment and miscellaneous buildings and furniture	43.5	46.8	52.0	69.5	76.0
B. Mechanical and electrical equipment					
1. Chemical laboratory equipment	20.0	20.0	20.0	80.0	90.0
2. Metallurgical laboratory equipment	15.0	17.0	17.0	26.2	31.0
3. Inspection equipment	2.0	2.5	3.0	7.0	7.0
4. Electrical (incl. erection)	5.5	6.0	6.6	8.8	9.9
5. Dept. utilities (water, gas, comp. airs)	5.0	5.5	6.0	8.0	9.0
6. Miscellaneous items	5.0	5.4	5.9	7.8	8.8
7. Equipment erection	0.5	0.6	0.7	2.5	3.0
Sub-total	53.0	57.0	59.2	139.3	158.7
Spares at 5% of equipment cost	2.6	2.8	2.9	6.9	7.8
Ocean freight, clearance and insurance charges at 20% of equipment and spares cost	11.0	11.8	12.3	28.7	32.7
Sub-total	110.1	118.4	126.4	244.4	275.2
Contingencies at 5%	5.5	5.9	6.3	12.2	13.8
Design, engineering, supervision of construction and client's administration at 7%	7.7	8.3	8.8	17.1	19.3
Total	123.3	132.6	141.5	273.7	308.3

Appendix 5-8

CAPITAL COST ESTIMATE FOR ELECTRIC POWER SYSTEM

(Thousands of $)

	Case 1 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil					
Civil works:					
Foundations, masonry, RCC works for equipment and miscellaneous buildings	118	218	237	240	260
B. Mechanical and electrical equipment					
1. Electric power distribution and emergency power supply a/	240	390	620	810	875
2. Plant communication	30	70	90	125	150
3. Road, perimeter and yard lighting	10	12	15	22	30
4. Equipment erection	42	71	109	143	158
Sub-total	322	543	834	1 100	1 213
Spares at 5% of equipment cost	14	24	36	48	53
Freight, clearance and insurance charges at 20% of equipment and spares cost	59	99	152	201	222
Sub-total	513	884	1 259	1 589	1 748
Contingencies at 5%	26	44	63	79	87
Design, engineering, supervision of construction and client's administration at 7%	36	62	88	111	122
Total	575	990	1 410	1 779	1 957

a/ For emergency power supply, a stand-by Diesel electric generator set is provided.

Table 5-4

DEPARTMENTAL CAPITAL COSTS AND COSTS PER ANNUAL TON OF CAPACITY FOR PLANTS WITH ALTERNATIVE IRON AND STEELMAKING PROCESSES

(Case II - 50 000 ton/year)

Department	BF - LD		BF - EAF		ESP(FR) - EAF		ESP - EAF		EAF	
	Total a/ cost '000 $	Cost/ ton $	Total a/ cost '000 $	Cost/ ton $	Total a/ cost '000 $	Cost/ ton $	Total a/ cost '000 $	Cost/ ton $	Total a/ cost '000 $	Cost/ ton $
Iron making	5 253	115.2	3 650	160.1	3 283	144.0	2 991	131.2	-	-
Steelmaking	4 192	83.8	3 672	73.5	3 672	73.5	3 672	73.5	3 667	73.3
Continuous casting	1 809	37.7	1 620	33.8	1 620	33.8	1 620	33.8	1 769	36.9
Rolling	5 778	131.4	5 778	131.4	5 778	131.4	5 778	131.4	5 650	128.5
<u>Total</u>	<u>17 032</u>		<u>14 720</u>		<u>14 353</u>		<u>14 061</u>		<u>11 086</u>	
<u>Total capital cost:</u>										
For ton nominal capacity in terms of liquid steel		340.6		294.4		287.1		281.2		221.7
For ton of rolled product		387.4		334.8		326.5		319.9		252.2

a/ Includes allocation for auxiliary departments.

/6. PRODUCTION

Appendix 5-9

CAPITAL COST ESTIMATE FOR WATER SUPPLY SYSTEM

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil					
Civil works - Foundations, masonry and RCC works for equipment and miscellaneous buildings	218	350	600	960	1 243
B. Mechanical and electrical equipment					
1. Water treatment plant	32	54	93	148	192
2. Pumps and ancillaries	116	204	340	540	704
3. Cooling tower and auxiliaries	80	140	236	376	488
4. Piping	29	51	84	131	170
5. Equipment erection	62	110	180	291	380
Sub-total	319	559	933	1 486	1 934
Spares at 5% of equipment cost	13	22	38	60	78
Freight, clearance and insurance charges at 20% of equipment and spares cost	54	94	158	251	326
Sub-total	604	1 025	1 729	2 757	3 581
Contingencies at 5%	30	51	86	138	179
Design, engineering, supervision of construction and client's administration at 7%	42	72	121	193	251
Total	676	1 148	1 936	3 088	4 011

Appendix 5-10

CAPITAL COST ESTIMATE FOR UTILITIES

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil and structural					
1. Civil works:					
Foundations, masonry and RCC works for equipment and miscellaneous buildings	39	62	81	112	135
2. Structural steelworks:					
Structural work including cladding and glazing for building as erected	21	28	40	55	88
Sub-total	60	90	121	167	223
B. Mechanical and electrical equipment					
1. Air compressors and auxiliary equipment:					
3 - Air compressor stations each with one electric driven compressor and 2 mobile compressors	30	50	70	120	180
2. Fuel oil pumping equipment and storage tanks:					
3 - Unloading pumps, 2 - circulating pumps, 2 - steam oil heaters, 1 - main storage tank, 1 - storage tank for blast furnace oil injection	20	36	62	68	105
3. Boilers and auxiliaries:					
2 - water tube package steam boilers, feed water treatment plant, piping etc.	152	214	338	404	518
4. Yard piping, building utilities and miscellaneous	137	195	269	370	516
5. Equipment erection	60	95	136	180	250
Sub-total	399	590	875	1 142	1 569
Spares at 5% of equipment cost	17	25	37	48	66
Freight, clearance and insurance charges at 20% of cost of equipment and spares	71	104	155	202	277
Sub-total	547	809	1 188	1 559	2 135
Contingencies at 5%	27	40	59	78	107
Design, engineering, supervision of construction and client's administration at 7%	38	57	83	109	149
Total	612	906	1 330	1 746	2 391

Appendix 5-11

CAPITAL COST ESTIMATE FOR WORKS TRANSPORT

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil					
1. Civil works - Foundations, masonry and RCC works for equipment and miscellaneous building, all roads within the plant boundary, road bridges etc.	53	59	66	84	104
2. Railway tracks - all tracks, points and crossings etc. within the plant boundary	103	112	160	208	256
Sub-total	156	171	226	292	360
B. Mechanical and electrical equipment					
1. Rolling stock: locomotives, wagons	70	145	240	320	465
2. Trucks: road trucks, rear dump trucks, tractors, trailer, fork lift, side loader etc.	66	105	138	244	330
3. Yard cranes	15	15	70	120	120
4. Weighbridges	24	29	33	49	90
5. Loco refuelling station	4	6	8	15	25
6. Signalling	6	7	8	15	20
7. Equipment erection	19	31	50	76	105
Sub-total	204	338	547	839	1 155
Spares at 5% of equipment cost	9	15	25	38	53
Freight, clearance and insurance charges at 20% of equipment and spares cost	39	64	104	160	220
Sub-total	408	588	902	1 329	1 788
Contingencies at 5%	20	29	45	66	89
Design, engineering, supervision of construction and client's administration at 7%	29	41	63	93	125
Total	457	658	1 010	1 488	2 002

Appendix 5-12

CAPITAL COST ESTIMATE FOR REPAIR AND MAINTENANCE SHOPS

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Civil and structural					
1. Civil works: Foundations, masonry and RCC works for equipment and miscellaneous buildings	32	46	69	115	133
2. Structural steelworks: Structural work including cladding and glazing for building as erected	94	148	214	301	389
Sub-total	126	194	283	416	522
B. Mechanical and electrical equipment					
1. Foundry - Ferrous and non-ferrous incl. pattern shop: Major equipment: Mains frequency coreless induction and lift coil induction and crucible furnaces	40	81	120	160	202
2. Machine shop incl. forge shop and tool room: Major equipment: heavy lathes, vertical borer, openside planner, shaper, milling machines, radial drills and forging hammers	103	228	270	312	410
3. Structural shop incl. wagon repair shop	-	-	-	58	65
4. Mobile equipment repair and servicing shop	12	14	16	23	26
5. General maintenance, pipe shop and building services incl. pipe threading and bending machines, mobile motor generator welding, mobile water pumps, heavy tools and tackles	30	36	38	45	51
6. Electrical repair shop incl. varnish tank and baking oven	106	166	212	342	342
7. EOT cranes	33	38	73	98	110
8. Building utilities	50	81	145	187	250
9. Equipment erection	43	67	90	134	152
Sub-total	430	711	964	1 359	1 608
Spares at 5% of equipment cost	19	32	44	61	73
Freight, clearance and insurance charges at 20% of equipment and spares cost	81	135	184	257	306
Sub-total	656	1 072	1 475	2 093	2 509
Contingencies at 5%	33	54	74	105	125
Design, engineering, supervision of construction and client's administration at 7%	46	75	103	147	176
Total	735	1 201	1 652	2 345	2 810

Appendix 5-13

CAPITAL COST ESTIMATE FOR MISCELLANEOUS BUILDINGS, FACILITIES AND STORAGES

(Thousands of $)

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Land and general site works					
1. Land and site preparation	37	46	84	106	139
2. Perimeter fencing	20	22	25	30	35
3. Sewerage and drainage	54	65	74	90	108
Sub-total	111	133	183	226	282
B. Buildings and ancillary works					
1. Administrative building	56	80	107	145	170
2. General superintendent's office	13	17	26	43	59
3. Canteens	26	40	64	85	102
4. Change rooms	30	43	68	90	105
5. Sanitary blocks	4	4	8	8	12
6. Fire brigade station	3	3	4	4	6
7. Car parks and cycle sheds	4	5	7	8	10
8. Miscellaneous items	5	5	8	14	21
Sub-total	141	198	292	397	485
C. Storages					
1. Buildings	60	90	150	210	270
2. Yards and fencings	5	8	12	18	24
3. Racks and miscellaneous	12	20	35	50	65
4. Cranes and hoists	5	5	8	10	15
Sub-total	82	123	205	288	374
Total	334	454	680	911	1 141
Contingencies at 5%	17	23	34	46	57
Design, engineering, supervision of construction and client's administration at 7%	23	32	48	64	80
Total	374	509	762	1 021	1 278

Appendix 5-14

SUMMARY OF TOTAL PLANT COST

	Case I - 25 000 T/yr		Case II - 50 000 T/yr		Case III - 100 000 T/yr		Case IV - 200 000 T/yr		Case V - 300 000 T/yr	
	Total cost		Total cost		Total cost		Total cost		Total cost	
	Thousands of $	Percentage of total	Thousands of $	Percentage of total	Thousands of $	Percentage of total	Thousands of $	Percentage of total	Thousands of $	Percentage of total
Production departments										
Coke ovens	-	-	-	-	1 070	3.58	3 180	6.44	4 152	6.43
Sinter plant	-	-	-	-	-	-	1 329	2.69	1 717	2.66
Blast furnaces	2 652	23.83	4 255	24.98	6 659	22.28	10 442	21.16	13 789	21.35
Steelment shop	1 910	17.17	2 861	16.80	4 879	16.33	7 226	14.64	8 901	13.77
Concast plant	751	6.75	1 033	6.06	1 860	6.22	3 519	7.13	4 724	7.31
Rolling mills	2 262	20.33	3 338	19.60	7 172	24.00	11 921	24.15	16 553	25.63
Sub-total	7 575	68.08	11 487	67.44	21 640	72.41	37 617	76.21	49 836	77.15
Auxiliary departments										
Plant laboratory	123	1.10	133	0.78	142	0.48	274	0.56	308	0.48
Power system	575	5.17	990	5.82	1 410	4.72	1 779	3.60	1 957	3.03
Water system	676	6.08	1 148	6.74	1 936	6.48	3 088	6.26	4 011	6.21
Utilities	612	5.50	906	5.32	1 330	4.45	1 746	3.54	2 391	3.70
Works transport	457	4.10	658	3.86	1 010	3.38	1 488	3.01	2 002	3.10
Repair and maintenance shops	735	6.61	1 201	7.05	1 652	5.53	2 345	4.75	2 810	4.35
Miscellaneous buildings, facilities and storages	374	3.36	509	2.99	762	2.55	1 021	2.07	1 278	1.98
Sub-total	3 552	31.92	5 545	32.56	8 242	27.59	11 741	23.79	14 757	22.85
Total	11 127	100.00	17 032	100.00	29 882	100.00	49 358	100.00	64 593	100.00

Appendix 5-15

SUMMARY OF DEPARTMENTAL CAPITAL COST AND COST PER ANNUAL TON

	Case I - 25 000 T/yr				Case II - 50 000 T/yr				Case III - 100 000 T/yr				Case IV - 200 000 T/yr				Case V - 300 000 T/yr			
	Production department	Auxiliary department	Total	Cost/ton	Production department	Auxiliary department	Total	Cost/ton	Production department	Auxiliary department	Total	Cost/ton	Production department	Auxiliary department	Total	Cost/ton	Production department	Auxiliary department	Total	Cost/ton
	Thousands of $			$	Thousands of $			$	Thousands of $			$	Thousands of $			$	Thousands of $			$
Coke ovens	-	-	-	-	-	-	-	-	1 070	742	1 812	35.65	3 180	1 174	4 354	47.12	4 152	1 476	5 628	40.43
Sinter plant	-	-	-	-	-	-	-	-	-	-	-	-	1 329	704	2 033	27.65	1 717	885	2 602	23.65
Blast furnaces	2 632	659	3 291	144.54	4 255	998	5 253	115.20	6 659	1 236	7 895	89.21	10 442	1 644	12 086	72.16	13 789	2 066	15 855	62.92
Steelmelt shop	1 910	853	2 763	110.52	2 861	1 331	4 192	83.84	4 879	1 813	6 692	66.92	7 226	2 348	9 574	47.87	8 901	2 951	11 852	39.51
Cement plant	752	497	1 249	52.00	1 033	776	1 809	37.69	1 860	907	2 767	28.82	3 519	1 174	4 693	24.44	4 724	1 476	6 200	21.53
Rolling mills	2 262	1 563	3 825	174.02	3 338	2 440	5 778	131.44	7 172	3 544	10 716	120.00	11 921	4 697	16 618	92.08	16 553	5 903	22 456	82.95
Total	7 575	3 572	11 147		11 487	5 545	17 032		21 640	8 242	29 882		37 617	11 741	49 358		49 836	14 757	64 593	

Appendix 5-16

COMPARISON OF PLANT CAPITAL COSTS FOR ALTERNATIVE IRON AND STEELMAKING PROCESSES, CASE II - 50 000 T/YR

(Thousands of $)

	Case II -				
	Blast furnace[a] - LD converter	Blast furnace[b] - Arc furnace	Electric smelting[b] (with pre-reduction) - Arc furnace	Electric smelting[b] (without pre-reduction) - Arc furnace	Arc furnace-100% scrap charge
Production departments					
Iron making	4 255	2 652	2 310	2 043	Nil
Steelmaking	2 861	2 279	2 279	2 279	2 279
Continuous casting	1 033	844	844	844	844
Rolling	3 338	3 338	3 338	3 338	3 338
Sub-total	11 487	9 113	8 771	8 504	6 461
Auxiliary departments					
Plant laboratory	133	133	133	133	125
Power system	990	1 100	1 175	1 150	850
Water system	1 148	1 100	1 000	1 000	800
Utilities	906	906	906	906	750
Works transport	658	658	658	658	500
Repair and maintenance shops	1 201	1 201	1 201	1 201	1 150
Miscellaneous buildings, facilities and storages	509	509	509	509	450
Sub-total	5 545	5 607	5 582	5 557	4 625
Total	17 032	14 720	14 353	14 061	11 086

a/ Blast furnace hot metal constitutes about 80% of the metallic charge for steelmaking.

b/ Blast furnace or electric smelting furnace hot metal constitutes about 50% of the metallic charge for steelmaking.

Appendix 5-17

DEPARTMENTAL CAPITAL COSTS AND COST PER ANNUAL TON FOR ALTERNATIVE IRON AND STEELMAKING PROCESSES: CASE II - 50 000 T/YR

Department	BF-LD a/				BF-EAF b/				EEF(PR)-EAF c/				EEF-EAF d/				EAF e/			
	Prodn. dept.	Aux. dept.	Total	Cost/ ton	Prodn. dept.	Aux. dept.	Total	Cost/ ton	Prodn. dept.	Aux. dept.	Total	Cost/ ton	Prodn. dept.	Aux. dept.	Total	Cost/ ton	Prodn. dept.	Aux. dept.	Total	Cost/ ton
	Thousands of $			$	Thousands of $			$	Thousands of $			$	Thousands of $			$	Thousands of $			$
Ironmaking	4 255	998	5 253	135.2	2 652	998	3 650	160.1	2 310	973	3 283	144.0	2 043	948	2 991	131.2	-	-	-	-
Steelmaking	2 861	1 331	4 192	83.8	2 279	1 393	3 672	73.5	2 279	1 393	3 672	73.5	2 279	1 393	3 672	73.5	2 279	1 388	3 667	73.3
Continuous casting	1 033	776	1 809	37.7	844	776	1 620	33.8	844	776	1 620	33.8	844	776	1 620	33.8	844	925	1 769	36.9
Rolling	3 338	2 440	5 778	131.4	3 338	2 440	5 778	131.4	3 338	2 440	5 778	131.4	3 338	2 440	5 778	131.4	3 338	2 312	5 650	128.5
Total	11 487	5 545	17 032		9 113	5 607	14 720		8 771	5 582	14 353		6 504	5 557	14 061		6 461	4 625	11 086	252.2
Capital Investment per ton of Rolled Product				387.4				394.8				386.5				369.9				

a/ Ironmaking in blast furnace and steelmaking in LD converter.
b/ Ironmaking in blast furnace and steelmaking in electric arc furnace.
c/ Ironmaking in electric smelter with pre-reduction and steelmaking in electric arc furnace.
d/ Ironmaking in electric smelter without pre-reduction and steelmaking in electric arc furnace.
e/ Steelmaking in electric arc furnace - 100% scrap charge.

Appendix 6-1

ESTIMATE OF TOTAL MANPOWER[a/]

	Case I 25 000 T/yr	Case II 50 000 T/yr	Case III 100 000 T/yr	Case IV 200 000 T/yr	Case V 300 000 T/yr
A. Production departments					
Coke ovens	-	-	39	90	96
Sinter plant	-	-	-	26	26
Blast furnace plant	71	96	121	136	151
Steelmelt shop	90	111	130	141	161
Concast plant	48	48	72	105	117
Rolling mills	140	170	175	288	341
Sub-total	349	425	537	789	892
B. Auxiliary departments					
Electric power and services	103	109	138	175	175
Water system	30	40	50	65	81
Energy and economy	50	60	75	88	100
Plant laboratory	54	96	64	81	81
Repair and maintenance shop	124	134	144	182	200
Transportation	90	120	150	200	220
Sub-total	451	513	621	791	857
C. Administration and general					
General administration	9	13	22	29	36
Planning and control	8	10	12	16	19
Stores and purchase	24	32	42	56	66
Sales	20	23	26	32	39
Chief engineer's office	16	20	27	32	41
Personnel department	52	60	82	105	124
Accounts department	20	26	41	50	72
Sub-total	149	184	252	320	397
Total	949	1 122	1 410	1 900	2 146

a/ Manpower indicated is the working force, calculated on the basis of 48 hour week. Extra manpower for "off", leave and absenteeism has not been included, as due allowance for this has been given in the hourly wage rates.

6. PRODUCTION COSTS AND MANPOWER

Scope

This chapter gives estimates of production costs for various departments, and manpower requirements for each of the typical plant capacities under study. Production costs have been worked out separately for coke, sinter, iron (hot metal), liquid steel, continuous cast billet, and rolled products.

Assumptions

Broad estimates of production costs have been developed for the major products in each typical plant under study on the basis of the specific inputs of raw materials and supplies required and the corresponding unit costs. Unit costs are based on data supplied by ECLA and given in Table 6-1.

Basis of cost estimates

The inputs of raw materials for each production process have been calculated on the basis of their chemical compositions. The estimates of the physical inputs of other items such as supplies, fuels, power, etc. per unit of production, are generally such as would obtain in average operating practices, with a view to arrive at conservative estimates which are considered appropriate. Labour costs are based on detailed manning lists prepared for direct and indirect labour in production and auxiliary departments, and also for administration and general services. Direct and indirect labour costs have been calculated on the basis of the following wage rates which include provision for leave and weekly "offs" and fringe benefits such as pension schemes, health, education, and other social welfare items:

Labour category	Annual remuneration $
Unskilled	2 400
Semi-skilled	3 000
Clerical	3 000
Skilled	3 600
Middle supervision	5 000
Top supervision and administration	10 000

/Table 6-1

Appendix 6-2

PRODUCTION COST ESTIMATE OF BLAST FURNACE COKE a/

	Case III - 100 000 T/yr (B.F. coke - 47 500 T/yr)			Case IV - 200 000 T/yr (B.F. coke - 84 600 T/yr)			Case V - 300 000 T/yr (B.F. coke - 126 300 T/yr)			Case V (A) - 300 000 T/yr (B.F. coke - 126 300 T/yr with recovery of benzol and ammonia products)		
	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)
Cost of materials												
Coal	18.00	1 533	27.59	18.00	1 478	26.60	18.00	1 478	26.60	18.00	1 478	26.60
Consumables e.g. caustic soda, sulphuric acid, wash oil etc.			-			-			-			0.52
Total cost of materials			27.59			26.60			26.60			27.12
Cost above materials												
Direct labour	1.27/mhr	1.720 mhr	2.18	1.32/mhr	2.225 mhr	2.94	1.32/mhr	1.596 mhr	2.11			2.57
Indirect labour	2.33/mhr	0.253 mhr	0.59	2.12/mhr	0.340 mhr	0.72	2.20/mhr	0.220 mhr	0.48			0.57
Power			0.11			0.26			0.26			0.35
Utilities			0.01			0.01			0.01			0.05
Transportation			0.07			0.07			0.07			0.07
Repair and maintenance			0.22			1.51			1.22			1.32
Tools, supplies and lubricants			0.08			0.08			0.08			0.09
General plant expense			0.98			1.83			0.90			1.08
Total cost above materials			4.24			6.82			5.13			6.10
Less by-product credits:												
Coke oven gas b/			-		243 cu m	1.99		243 cu m	1.99		243 cu m	1.99
Tar			-	20	59	1.18	20	59	1.18	20	59	1.18
Coke breeze	20	100	2.00	20	100	2.00	20	100	2.00	20	100	2.00
Benzol products			-			-			-			1.68
Ammonia products			-			-			-			0.86
Total by-product credits			2.00			5.17			5.17			7.71
Total works cost of blast furnace coke			29.83			28.25			26.56			25.51
Fixed charges c/ at 9%			3.43			4.63			4.01			4.93
Total ex-works cost of blast furnace coke (incl. fixed charges)			33.26			32.88			30.57			30.44

a/ All materials input and cost figures are per ton of blast furnace coke, the yield of blast furnace coke being taken as 90% of run-of-oven coke.

b/ Assuming that 45% of the gasmake is utilised for underfiring of ovens, credit taken for 55% of gas only. Calorific value of coke oven gas - 4 500 kcals/cu m and credit for gas estimated on the basis of cost of oil at $ 20/ton for equivalent calorific value.

c/ Fixed charges have been calculated on capital cost of coke oven plant (including allocation for auxiliary departments).

Appendix 6-3

PRODUCTION COST ESTIMATE OF SINTER

	Case IV - 200 000 T/yr (Sinter - 93 000 T/yr)			Case V - 300 000 T/yr (Sinter - 110 000 T/yr)		
	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)
Cost of materials						
Ore fines	9.50	950	9.02	9.50	950	9.02
Flue dust	-	48.5	-	-	48.5	-
Limestone	7.00	91.0	0.64	7.00	91.0	0.64
Coke breeze	20.00	48.5	0.97	20.00	48.5	0.97
Total cost of materials			10.63			10.63
Cost above materials						
Direct labour	1.30/mhr	0.756 mhr	0.98	1.295/mhr	0.502 mhr	0.65
Indirect labour	1.82/mhr	0.099 mhr	0.18	1.846/mhr	0.065 mhr	0.12
Fuel a/		25x10^3 Kcal	0.05		25x10^3 Kcal	0.05
Power			0.24			0.24
Utilities			0.01			0.01
Repair and maintenance			0.55			0.48
Tools, supplies and lubricants			0.25			0.22
General plant expenses			0.55			0.42
Total cost above materials			2.81			2.19
Total works cost of sinter			13.44			12.82
Fixed charges b/ at 9%			2.51			2.13
Total ex-works cost of sinter (incl. fixed charges)			15.95			14.95

a/ Estimated on the basis of cost of oil at $ 20/ton, for equivalent calorific value.

b/ Fixed charges have been calculated on capital cost of sinter plant (including allocation for auxiliary departments).

Appendix 6.4

PRODUCTION COST ESTIMATE OF IRON

	Case I - 25 000 T/yr (Blast Fce. Iron - 22 800 T/yr)			Case II - 50 000 T/yr (Blast Fce. Iron - 45 600 T/yr)			Case III - 100 000 T/yr (Blast Fce. Iron - 88 500 T/yr)			Case IV - 200 000 T/yr (Blast Fce. Iron - 167 500 T/yr)			Case V - 300 000 T/yr (Blast Fce. Iron - 252 500 T/yr)		
	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)
Cost of materials															
Iron ore	9.50	1 450	13.78	9.50	1 450	13.78	9.50	1 450	13.78	9.50	1 021	9.70	9.50	1 021	9.70
Sinter	-	-	-	-	-	-	-	-	-	13.44	437	5.87	12.82	437	5.60
Manganese ore	30.00	265	0.80	30.00	265	0.80	30.00	265	0.80	30.00	265	0.80	30.00	265	0.80
Limestone	7.00	126	0.88	7.00	124	0.87	7.00	123	0.86	7.00	103	0.72	7.00	103	0.72
Coke	30.00	560	16.80	30.00	545	16.35	29.83	535	15.96	28.25	505	14.27	26.56	500	13.28
Fuel oil	20.00	50	1.00	20.00	50	1.00	20.00	50	1.00	20.00	50	1.00	20.00	50	1.00
Total cost of materials			33.26			32.80			32.40			32.36			31.10
Cost above materials															
Direct labour	1.25/mhr	6.74 mhr	8.39	1.30/mhr	4.36 mhr	5.66	1.23/mhr	2.96 mhr	3.64	1.23/mhr	1.80 mhr	2.19	1.20/mhr	1.31 mhr	1.58
Indirect labour	2.16/mhr	0.73 mhr	1.58	2.02/mhr	0.48 mhr	0.97	1.94/mhr	0.33 mhr	0.64	1.84/mhr	0.19 mhr	0.35	1.44/mhr	0.16 mhr	0.23
Cold blast supply	0.016/kwh	196 kwh a/	3.04			0.98 b/			0.69 b/			0.69 b/			0.68 b/
Power			0.48			0.48			0.45			0.45			0.40
Utilities, lab, etc.			0.07			0.07			0.06			0.06			0.06
Transportation			0.90			0.85			0.75			0.70			0.70
Repair and maintenance			2.90			2.20			1.90			1.70			1.40
Tools, supplies and lubricants			1.40			1.10			0.90			0.80			0.60
Relining reserves			1.00			1.00			0.75			0.75			0.75
General plant expense			8.29			4.75			3.27			1.88			1.52
Total cost above materials			28.05			18.06			13.05			9.57			7.92
Less credit: Blast fce gas c/		1 584 cu m	2.79		1 546 cu m	2.72		1 520 cu m	2.68		1 443 cu m	2.54		1 430 cu m	2.52
Total works cost of hot metal			58.52			48.14			42.77			39.39			36.50
Fixed charges d/ at 9%			12.99			10.37			9.87			9.93			8.58
Total ex-works costs of hot metal (incl.fixed charges)			71.51			58.51			52.64			49.32			45.08

a/ Electrically driven blower.

b/ Steam driven turbo-blowers.

c/ Credit for 60% of gas only, balance being consumed in the blast furnace plant for stove heating. Calorific value of blast furnace gas 900 kcal/m^3 and credit for gas estimated on the basis of cost of oil at $20/ton for equivalent calorific value.

d/ Fixed charges have been calculated on total capital cost of coke ovens, sinter plant and blast furnace plant (including allocations for auxiliary departments).

Appendix 6-5
PRODUCTION COST ESTIMATE OF LIQUID STEEL

	Case I - 25 000 T/yr (Liquid steel - 25 000 T/yr)			Case II - 50 000 T/yr (Liquid steel - 50 000 T/yr)			Case III - 100 000 T/yr (Liquid steel - 100 000 T/yr)			Case IV - 200 000 T/yr (Liquid steel - 200 000 T/yr)			Case V - 300 000 T/yr (Liquid steel - 300 000 T/yr)		
	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)
Cost of materials															
Hot metal	58.52	909	53.19	48.14	898	43.23	42.77	876	37.47	39.39	833	32.81	36.50	833	30.40
Scrap	30.00	227	6.81	30.00	224	6.72	30.00	246	7.38	30.00	278	8.34	30.00	278	8.34
Fe-alloys a/ - Fe-Mn	210.00	9	1.89	210.00	9	1.89	210.00	9	1.89	210.00	9	1.89		9	1.89
- Fe-Si	180.00	5	0.90	180.00	5	0.90	180.00	5	0.90	180.00	5	0.90		5	0.90
Total cost of metallics			62.79			52.74			47.64			43.94			41.53
Less credit for scrap	30.00	20	0.60	30.00	20	0.60	30.00	20	0.60	30.00	20	0.60		20	0.60
Net cost of metallics			62.19			52.14			47.04			43.34			40.93
Fluxes - burnt lime	30.00	60	1.80	30.00	60	1.80	30.00	60	1.80	30.00	60	1.80	30.00	60	1.80
- fluorspar	150.00	3	0.45	150.00	3	0.45	150.00	3	0.45	150.00	3	0.45		3	0.45
Total cost of materials			64.44			54.39			49.29			45.59			43.18
Cost above materials															
Direct labour	1.25/mhr	7.87 mhr	9.84	1.23/mhr	4.88 mhr	6.02	1.23/mhr	2.81 mhr	3.47	1.23/mhr	1.48 mhr	1.82	1.20/mhr	1.13 mhr	1.36
Indirect labour	2.03/mhr	0.77 mhr	1.56	1.95/mhr	0.43 mhr	0.84	2.00/mhr	0.31 mhr	0.62	2.05/mhr	0.22 mhr	0.45	2.00/mhr	0.16 mhr	0.32
Oxygen	.0236/cu m	55 cu m	1.30	.0205/cu m	55 cu m	1.13	.015/cu m	50 cu m	0.75	.012/cu m	50 cu m	0.60	.0115/cu m	50 cu m	0.58
Fuel			0.16			0.16			0.16			0.16			0.16
Power			0.48			0.48			0.48			0.48			0.48
Utilities			0.90			0.80			0.70			0.60			0.50
Transportation			1.10			0.95			0.80			0.70			0.60
Laboratory			2.25			1.50			0.75			0.40			0.25
Repair and maintenance			3.60			3.00			2.40			2.10			1.80
Tools, supplies and lubricants			2.40			2.00			1.60			1.40			1.20
Refractories			1.40			1.20			1.00			0.90			0.80
Provision for relining			6.00			5.00			4.00			3.30			3.00
General plant expenses			12.89			8.29			5.59			3.20			2.63
Total cost above materials			43.88			31.37			22.32			16.31			13.68
Total works cost of liquid steel			108.32			85.76			71.61			61.90			56.86
Fixed charges b/ at 5%			22.19			17.00			14.76			12.62			10.78
Total ex-works cost of liquid steel (incl fixed charges)			130.51			102.76			86.37			74.52			67.64

a/ Price of Fe-Mn (74-76% Mn and 50% Si) taken at $ 180 and $ 150 f.o.b., per ton respectively plus $30 for ocean freight and inland freight.
b/ Fixed charges have been calculated on total capital cost of coke ovens, sinter plant, blast furnace plant and LD steel plant (including allocations for auxiliary departments).

Appendix 6-6

PRODUCTION COST ESTIMATE OF CONTINUOUS CAST BILLETS

	Case I - 25 000 T/yr (Concast billet - 24 000 T/yr)			Case II - 50 000 T/yr (Concast billet - 48 000 T/yr)			Case III - 100 000 T/yr (Concast billet - 96 000 T/yr)			Case IV - 200 000 T/yr (Concast billet - 192 000 T/yr)			Case V - 300 000 T/yr (Concast billet - 288 000 T/yr)		
	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)
Cost of materials															
Liquid steel a/	108.32	1 040	112.65	85.76	1 040	89.19	71.61	1 040	74.47	61.90	1 040	64.38	56.86	1 040	59.13
Less credit for scrap	30.00	25	0.75	30.00	25	0.75	30.00	25	0.75	30.00	25	0.75	30.00	25	0.75
Total cost of materials			111.90			88.44			73.72			63.63			58.38
Cost above materials															
Direct labour	1.35/mhr	4.8 mhr	6.48	1.45/mhr	2.40 mhr	3.49	1.43/mhr	1.73 mhr	2.48	1.44/mhr	1.28 mhr	1.84	1.45/mhr	0.95 mhr	1.38
Indirect labour b/			-			-	2.28/mhr	0.07 mhr	0.16	2.00/mhr	0.04/mhr	0.08	2.00/mhr	0.025/mhr	0.05
Fuel			0.62			0.56			0.40			0.54			0.28
Power			0.16			0.16			0.16			0.16			0.16
Utilities			0.85			0.52			0.21			0.14			0.12
Repair and maintenance			0.15			0.15			0.12			0.10			0.10
Tools, supplies and lubricants			0.52			0.21			0.34			0.12			0.11
Copper moulds			0.22			0.22			0.22			0.20			0.20
Refractories			2.40			2.18			1.52			1.63			1.57
General plant expenses			4.05			2.41			1.54			1.12			0.90
Total cost above materials			16.45			9.89			7.74			5.73			4.67
Total works cost of billets			128.35			98.33			81.46			69.36			63.05
Fixed charges c/ at 5%			27.38			21.20			17.57			15.35			13.17
Total ex-works cost of billet (incl. fixed charges)			155.73			119.53			99.03			84.71			76.22

a/ Liquid steel to billet yield 96%.

b/ Included in steelmaking costs for cases I and II.

c/ Fixed charges have been calculated on total capital cost of coke ovens, sinter plant, blast furnace plant, steelmelt shop and continuous casting plant (including allocations for auxiliary departments).

Appendix 6-7

PRODUCTION COST ESTIMATE OF ROLLED PRODUCTS

	Case I - 25 000 T/yr (Rolled products - 21 980 T/yr)			Case II - 50 000 T/yr (Rolled products - 43 960 T/yr)			Case III - 100 000 T/yr (Rolled products - 89 300 T/yr)			Case IV - 200 000 T/yr (Rolled products - 180 480/T/yr)			Case V - 300 000 T/yr (Rolled products - 270 720 T/yr)		
	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)
Cost of materials															
Billet	128.35	1 092	140.16	98.33	1 092	107.38	81.46	1 075	87.57	69.36	1 064	73.80	63.05	1 064	67.09
Less credit for scrap	30.00	70	2.10	30.00	70	2.10	30.00	54	1.62	30.00	43	1.29	30.00	43	1.29
Net cost of materials			138.06			105.28			85.95			72.51			65.80
Cost above materials															
Direct labour	1.24/mhr	14.52 mhr	18.03	1.25/mhr	8.68 mhr	10.87	1.25/mhr	4.35 mhr	5.45	1.25/mhr	3.51 mhr	4.38	1.26/mhr	2.79 mhr	3.51
Indirect labour	2.04/mhr	0.76 mhr	1.55	1.97/mhr	0.60 mhr	1.18	1.91/mhr	0.35 mhr	0.67	1.78/mhr	0.32 mhr	0.57	1.96/mhr	0.23 mhr	0.45
Fuel oil			0.96			0.96			0.86			0.86			0.76
Power			1.92			1.76			1.60			1.36			1.28
Utilities			0.07			0.05			0.02			0.02			0.02
Transportation			0.22			0.22			0.22			0.20			0.15
Repair and maintenance			0.95			0.60			0.72			0.70			0.70
Tools, supplies and lubricants			0.30			0.25			0.30			0.30			0.30
Reserve for rolls			0.63			0.63			0.63			0.63			0.63
General plant expenses			10.25			5.93			3.50			2.20			1.85
Total cost above materials			34.88			22.45			13.97			11.22			9.64
Total works cost of rolled products			172.94			127.73			99.92			83.73			75.44
Fixed charges a/ at 5%			45.72			34.86			30.12			24.61			21.43
Total ex-works cost of rolled products (incl. fixed charges)			218.66			162.59			130.04			108.34			96.92

a/ Fixed charges have been calculated on the capital costs of coke making, sintering, ironmaking, steelmaking and rolling facilities (including allocations for auxiliary departments, that is, the entire capital cost of the plant).

Appendix 6-8

CAPITAL AND PRODUCTION COSTS FOR BLAST FURNACE SMELTING AND ELECTRIC SMELTING OF IRON

	Case I - 25 000 T/yr			Case II - 50 000 T/yr		
	Blast furnace	Electric Smelting: Without pre-reduction	Electric Smelting: With pre-reduction and hot charging	Blast furnace	Electric Smelting: Without pre-reduction	Electric Smelting: With pre-reduction and hot charging
Plant Particulars						
Steelmake - Tons/yr	25 000	25 000	25 000	50 000	50 000	50 000
Ironmake - Tons/yr	22 800	22 800	22 800	45 600	45 600	45 600
Furnace	2 metre hearth dia.	7 500 kVA	4 700 kVA	2.75 metre hearth dia.	15 000 kVA	9 500 kVA
Capital cost (thousands of $)						
Civil and structural	280	490	550	370	755	840
Plant and equipment	1 450	910	1 050	2 380	1 540	1 710
Equipment erection	260	200	210	430	230	250
Spares at 5% equipment cost	73	45	52	119	77	85
Freight, clearance and insurance charges at 20% of equipment and spares cost	305	182	210	500	323	360
Contingencies at 5%	118	90	94	190	145	160
Design, engineering etc. at 7%	166	126	144	266	203	230
Total	2 652	2 043	2 310	4 255	3 273	3 635
Production cost/ton ($/ton)						
Cost of materials a/	33.26	27.40	28.32	32.80	27.40	28.32
Smelting power	-	29.60	15.20	-	29.60	15.20
Cost above materials	28.05	23.84	24.49	18.06	16.30	16.55
Less gas credit	2.79	0.80	-	2.72	0.80	-
Total works cost of hot metal	58.52	80.04	68.01	48.14	72.50	60.07
Fixed charges b/ at 9%	12.99	10.57	11.64	10.37	8.43	9.14
Total ex-works cost of hot metal (incl. fixed charges)	71.51	90.61	79.65	58.51	80.93	69.21

a/ Cost of coke for blast furnaces and electric smelting taken at US $ 30.00 and US $ 25.75 per ton respectively.

b/ Fixed charges calculated on capital cost of ironmaking plant, including allocations for auxiliary departments.

Appendix 6-9

ESTIMATE OF COST ABOVE MATERIALS FOR LIQUID STEEL MADE IN ELECTRIC ARC FURNACE CASE II - 50 000 TONS/YEAR

	50% Hot Metal - 50% Scrap Charge	100% Scrap Charge
	Cost/ton US $	Cost/ton US $
Cost above materials		
Direct labour	3.90	3.90
Indirect labour	0.84	0.84
Fuel	0.16	0.16
Power	7.20	8.80
Utilities	0.45	0.45
Transportation	0.55	0.55
Laboratory	0.50	0.50
Repair and maintenance	1.20	1.20
Tools, supplies and lubricants	0.80	0.80
Electrodes	2.00	2.50
Refractories	1.50	1.50
Provision for relining	3.00	3.00
General plant expenses	8.30	8.30
Total cost above materials	30.40	32.50

7. 10. 71

Table 6-1

INDICATIVE COSTS OF RAW MATERIALS AND SUPPLIES

	Typical cost US$/ton
Iron ore	9.50
Coal	18.00
B.F. coke, purchased	30.00
Manganese ore	30.00
Quartzite	2.00
B.F. limestone	7.00
Steel scrap	30.00 a/
SMS grade limestone	7.00
Burnt lime	30.00
Dolomite, refractory grade	10.00
Bauxite	9.00
Fluorspar (imported)	150.00
Fuel oil	20.00
Mill scale	6.00
Oxygen (varies with size of plant)	
Average labour (plant), man-hours	1.50
Power, kWh	0.016
Gas credit, evaluated at equivalent fuel oil price	
Water, cu m	0.005

a/ A flat rate of US$ 30 per ton of scrap has been taken as the price of 90 per cent of the cost of hot metal used in other ECLA studies was found to unduly inflate the already high cost of steel produced in the smaller size integrated steel plants on account of the high cost of hot metal.

Major production cost items

The production costs include cost of materials and cost above materials (comprising labour and supervision costs, cost of fuel, water, power and other supplies and services, maintenance and general plant expenses, etc.). Fixed charges on capital invested is calculated at 9 per cent, as suggested by ECLA. Credits for gas, scrap and other by-products have been given where these are recovered.

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Production cost estimates

On the above basis, production cost estimates for coke, sinter, iron (hot metal), liquid steel, continuous cast billet and rolled products are presented in Appendices 6-2 to 6-7 and summarised in Table 6-2.

Table 6-2

PRODUCTION COSTS INCLUDING FIXED CHARGES

Product	Case I US$/t	Case II US$/t	Case III US$/t	Case IV US$/t	Case V US$/t
Coke	-	-	33.26	32.88	30.57
Sinter	-	-	-	15.95	14.95
Iron (hot metal)	71.51	58.51	52.64	49.32	45.08
Liquid steel	130.51	102.76	86.37	74.52	67.64
Concast billets	155.73	119.43	99.43	84.71	76.22
Rolled product	218.66	162.59	130.04	106.34	96.92

Cost structure

The production cost structure in terms of total cost incurred annually for raw materials, power and fuel, wages and salaries, and all other items (including depreciation) are given in Table 6-3.

Production cost estimates for iron, steel and continuous cast billets for the five alternative combinations of iron and steelmaking processes considered for Case II - 50 000 T/yr plant are presented in Appendix 6-11 and summarised in Table 6-4.

Manpower

The total manpower requirements of production, maintenance, service and administrative departments for all the five cases under study are given in Appendix 6-1. These estimates of manpower requirements are based on the study of the various operations involved in the operation of the plant capacities envisaged and are primarily intended

/to derive

to derive the labour component of production costs for various departments. In each case, the standard force required for each operation for the specific size of plant is taken into consideration.

Productivity

Productivity in terms of tons of liquid steel production per man-year are indicated below.

Case	Total manpower T/man-yr	Direct labour T/man-yr 1/
I	26	46
II	45	80
III	71	136
IV	105	194
V	139	270

1/ Direct labour excludes administration services, top and middle departmental supervision, and clerical staff not working on the production floor.

/Table 6-3

Table 6-3

PRODUCTION COST STRUCTURE

	Case I - 25 000 T/yr		Case II - 50 000 T/yr		Case III - 100 000 T/yr		Case IV - 200 000 T/yr		Case V - 300 000 T/yr	
	Cost/yr 1000 $	Percentage	Cost/yr 1000 $	Percentage	Cost/yr 1000 $	Percentage	Cost/yr 1000 $	Percentage	Cost/yr 1000 $	Percentage
Raw materials a/	938	19.5	1 849	26.0	3 675	31.7	7 127	36.5	10 721	40.9
Power and fuel b/	201	4.2	298	4.2	532	4.6	1 028	5.3	1 463	5.6
Labour	1 963	40.8	2 360	33.0	3 125	26.9	4 285	21.9	4 993	19.0
Net others c/	1 704	35.5	2 640	36.8	4 280	36.8	7 113	36.3	9 061	34.5
Total	4 806	100.0	7 147	100.0	11 612	100.0	19 553	100.0	26 238	100.0

a/ Includes iron ore, coal, limestone, Mn ore, alloy additions, burnt lime, fluorspar, and purchased coke and scrap.

b/ Includes electric power, steam and fuel oil.

c/ Includes fixed charges and all other components of production cost.

/Table 6-4

4 OF 4

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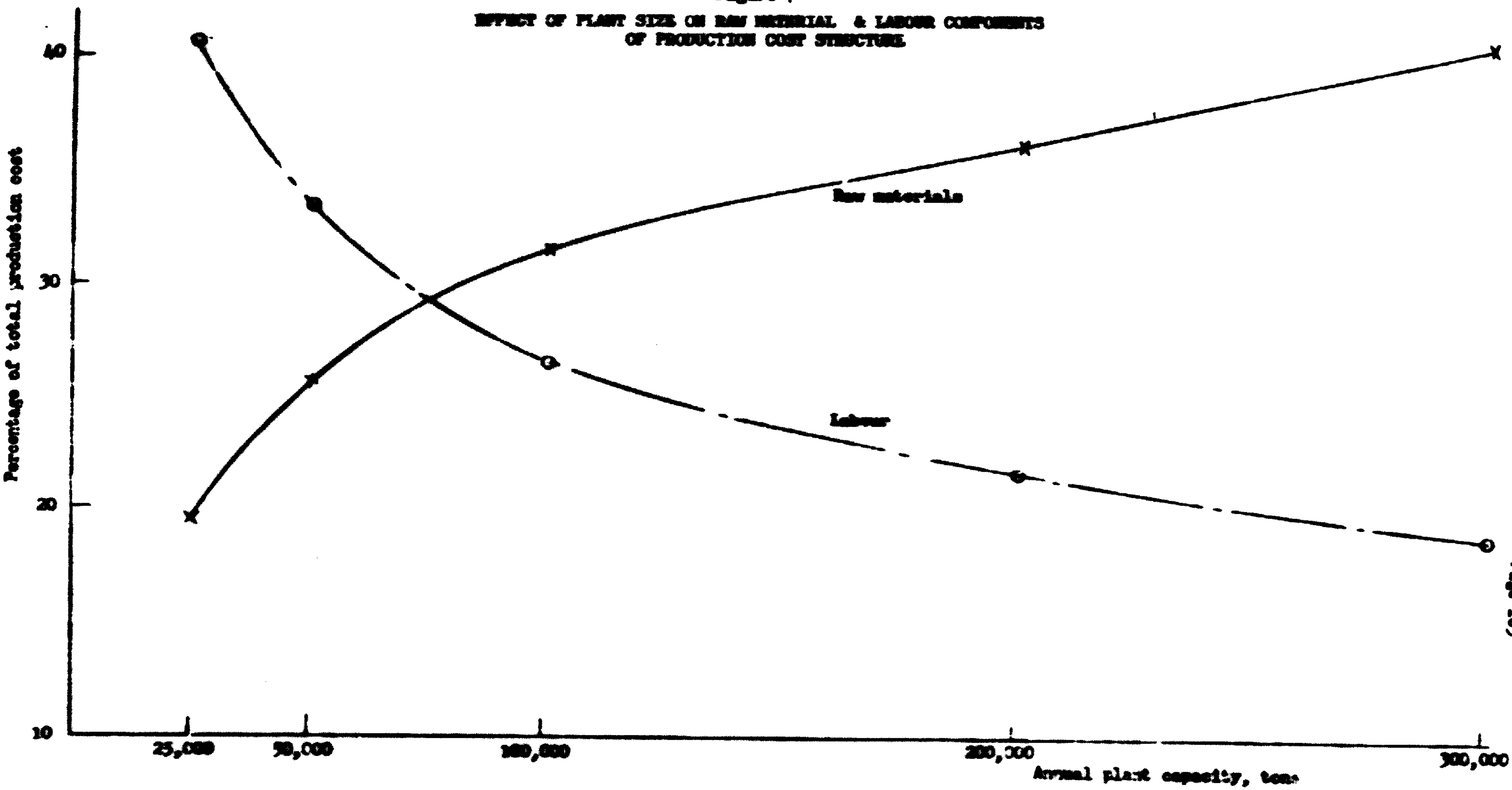
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963

Figure 7

EFFECT OF PLANT SIZE ON RAW MATERIAL & LABOUR COMPONENTS OF PRODUCTION COST STRUCTURE



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Appendix 6-10

ESTIMATE OF COST ABOVE MATERIALS FOR CONCAST BILLETS MADE FROM ELECTRIC ARC FURNACE STEEL CASE II - 50 000 TONS/YEAR

	Concast Billets of electric Arc furnace steel Cost/ton billet (US $)
Cost above materials	
Direct labour	2.50
Indirect labour a/	-
Fuel	0.56
Power	0.16
Utilities	0.31
Repair and maintenance	0.15
Tools, supplies and lubricants	0.21
Copper moulds	0.22
Refractories	2.18
General plant expenses	2.61
Total cost above materials	8.90

a/ Included in Cost Above for Steelmaking.

Appendix 6-11

ALTERNATIVE IRON AND STEEL MAKING PROCESSES: CASE II - 50 000 T/YR

PRODUCTION COST OF LIQUID STEEL AND CONTINUOUS CAST BILLET FOR FIVE ALTERNATIVES

	Case II - Blast furnace - LD converter a/			Case II - Blast furnace - Arc furnace b/			Case II - Electric smelting (with pre-reduction) - Arc furnace c/			Case II - Electric smelting (without pre-reduction) - Arc furnace d/			Case II - Arc furnace - 100% scrap charge e/		
	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)	Price/ton material (US$)	Qty/ton (Kgs)	Cost/ton (US$)
Liquid steel															
Hot metal	48.14	898	43.23	58.52	492	28.79	68.01	492	33.46	80.04	492	39.38	-	Nil	-
Scrap	30.00	224	6.72	30.00	492	14.76	30.00	492	14.76	30.00	492	14.76	30.00	1 064	31.92
Iron ore (63% Fe)	-	-	-	9.50	135	1.27	9.50	135	1.27	9.50	135	1.27	-	-	-
Fe-alloys - Fe-Mn	210.00	9	1.89	210.00	9	1.89	210.00	9	1.89	210.00	9	1.89	210.00	9	1.89
- Fe-Si	180.00	5	0.90	180.00	5	0.90	180.00	5	0.90	180.00	5	0.90	180.00	5	0.90
Total cost of metallics			52.74			47.61			52.28			58.20			34.71
Less credit for scrap	30.00	20	0.60	30.00	20	0.60	30.00	20	0.60	30.00	20	0.60	30.00	20	0.60
Net cost of metallics			52.14			47.01			51.68			57.60			34.11
Fluxes - burnt lime	30.00	60	1.80	30.00	40	1.20	30.00	40	1.20	30.00	40	1.20	30.00	20	0.60
- fluorspar	150.00	3	0.45	150.00	3	0.45	150.00	3	0.45	150.00	3	0.45	150.00	3	0.45
Total cost of materials			54.39			48.66			53.33			59.25			35.16
Cost above materials for liquid steel f/			31.37			30.40			30.40			30.40			32.50
Total works cost of liquid steel			85.76			79.06			83.73			89.65			67.66
Fixed charges g/ at 5%			17.00			13.18			12.52			11.99			6.60
Total ex-works cost of liquid steel (incl. fixed charges)			102.76			92.24			96.25			101.64			74.26
Continuous cast billet															
Liquid steel	85.76	1 040	89.19	79.06	1 040	82.22	83.73	1 040	87.08	89.65	1 040	93.24	67.64	1 040	70.35
Less credit for scrap	30.00	25	0.75	30.00	25	0.75	30.00	25	0.75	30.00	25	0.75	30.00	25	0.75
Total cost of materials			88.44			81.47			86.33			92.49			69.60
Cost above materials f/			9.89			8.90			8.90			8.90			8.90
Total works cost of billet			98.33			90.37			95.23			101.39			78.50
Fixed charges h/ at 5%			21.10			16.76			16.07			15.51			10.19
Total ex-works cost of billet (incl. fixed charges)			119.43			107.13			111.30			116.90			88.69

a/ Iron making in blast furnace and steel making in LD converter, the process considered for all cases in this report.
b/ Iron making in blast furnace and steel making in electric arc furnace with 50% hot metal - 50% scrap charge.
c/ Iron making in electric smelting furnace with pre-reduction and steel making in electric arc furnace with 50% hot metal - 50% scrap charge.
d/ Iron making in electric smelting furnace without pre-reduction and steel making in electric arc furnace with 50% hot metal - 50% scrap charge.
e/ Steel making in electric arc furnace with 100% scrap charge.
f/ Cost above materials for liquid steel and cement billet for the first alternative are as given in Appendices 6-5 and 6-6 and for the other alternatives as given in Appendices 6-9 and 6-10.
g/ Fixed charges calculated on total capital cost of iron and steel making plants, including allocations for auxiliaries.
h/ Fixed charges calculated on the total capital cost for iron making, steel making and continuous casting plants, including allocation for auxiliaries.

Figure 1

STUDY ON ECONOMIES OF SCALE AT SMALL INTEGRATED STEELWORKS PLANT GENERAL LAYOUT CASE - V

(300.000 tons/year)

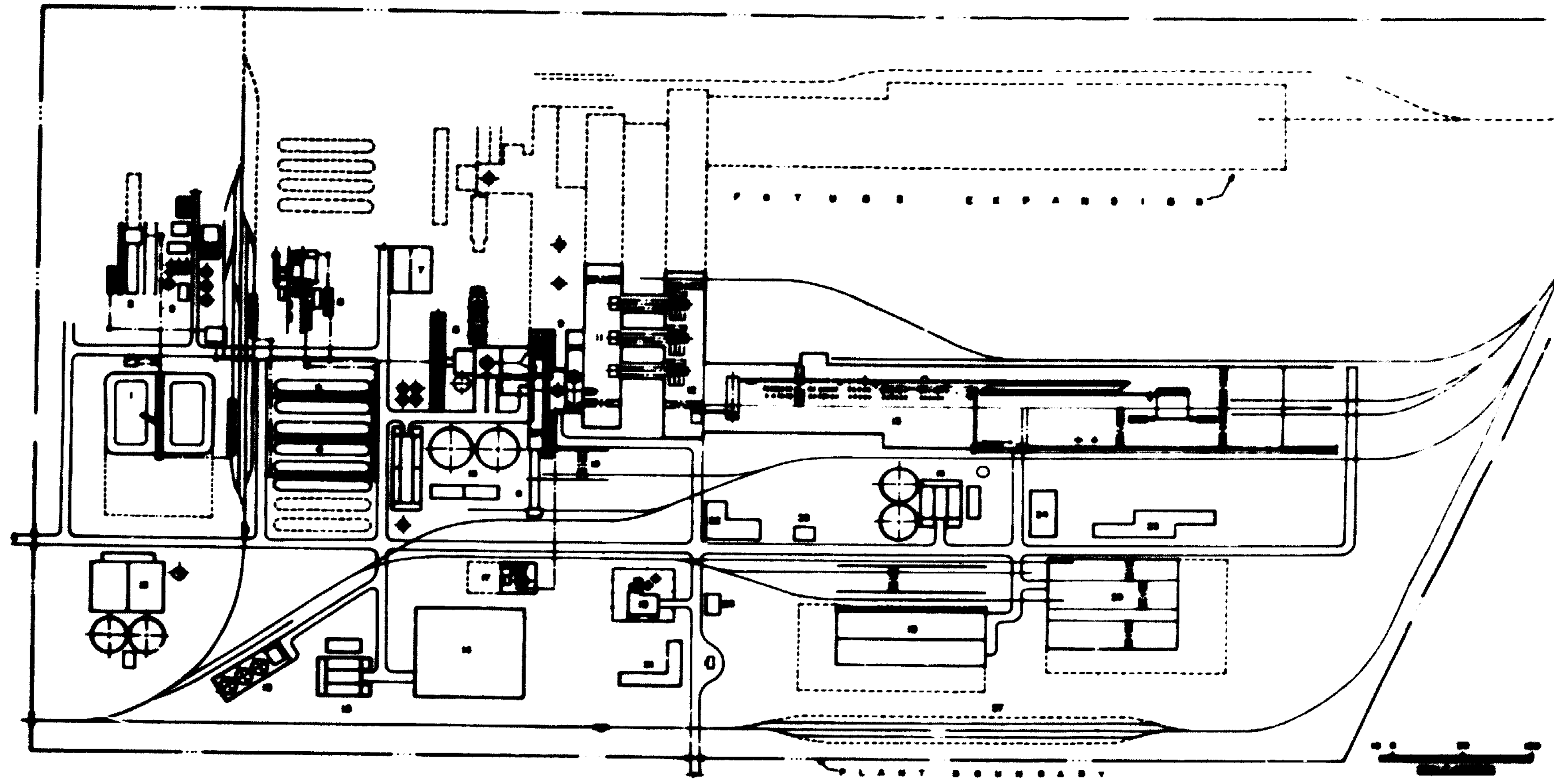

Figure 2

EFFECT OF PLANT SIZE ON CAPITAL COSTS OF BLAST FURNACE, STEELMELT SHOP, CONTINUOUS CASTING & ROLLING MILLS

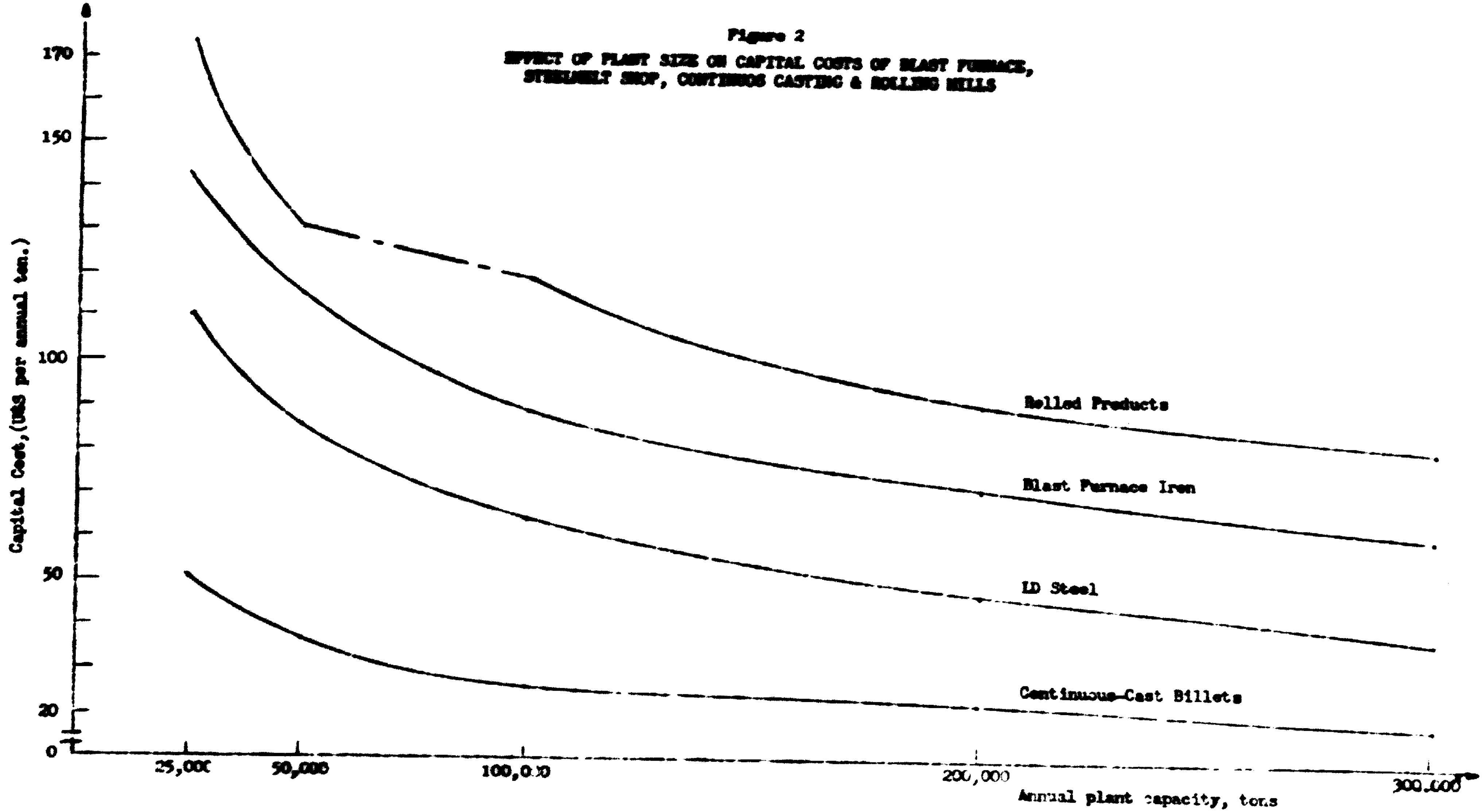

Figure 3

EFFECT OF PLANT SIZE ON CAPITAL COST OF AUXILIARY DEPARTMENTS

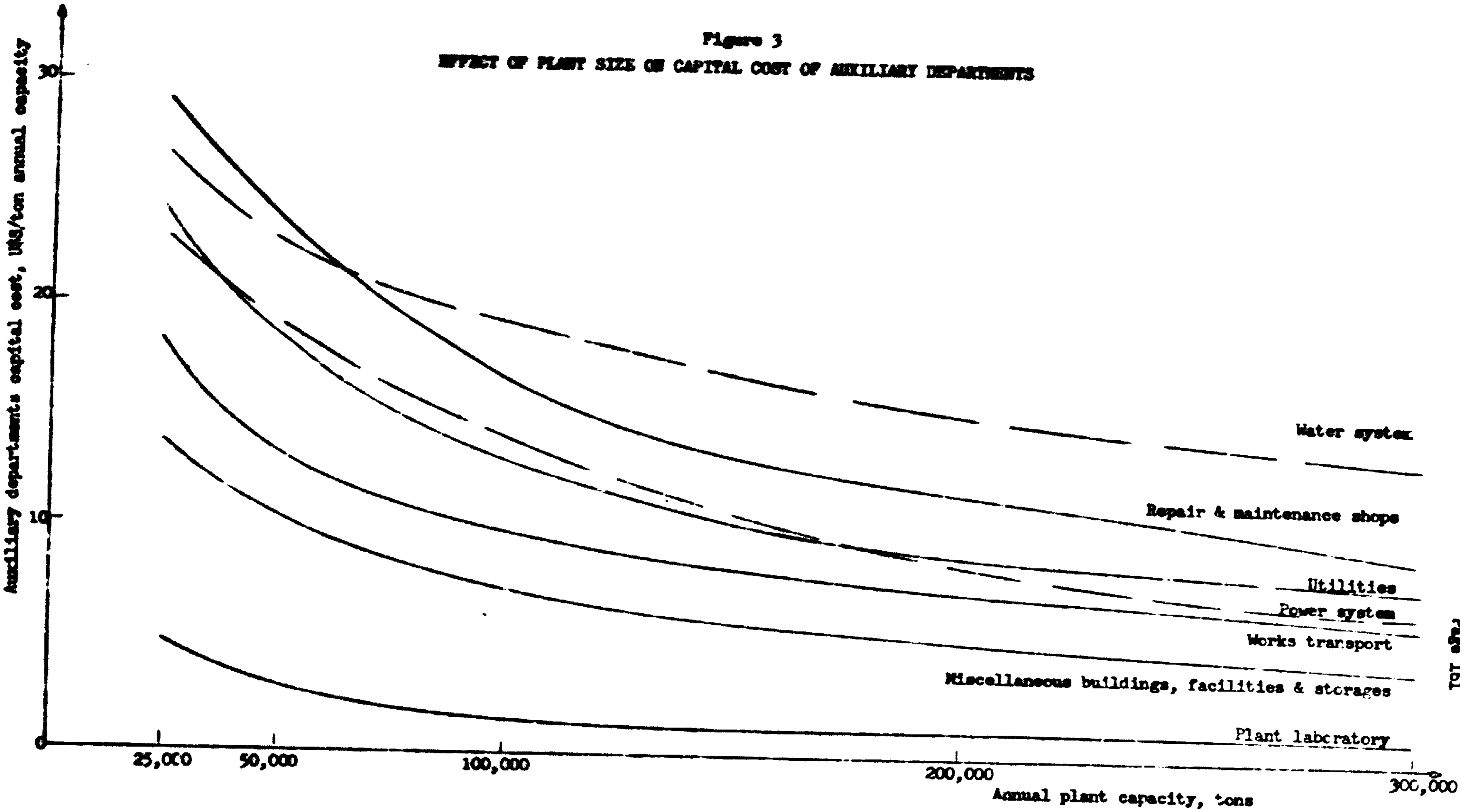

Figure 4

EFFECT OF PLANT SIZE ON TOTAL CAPITAL COST

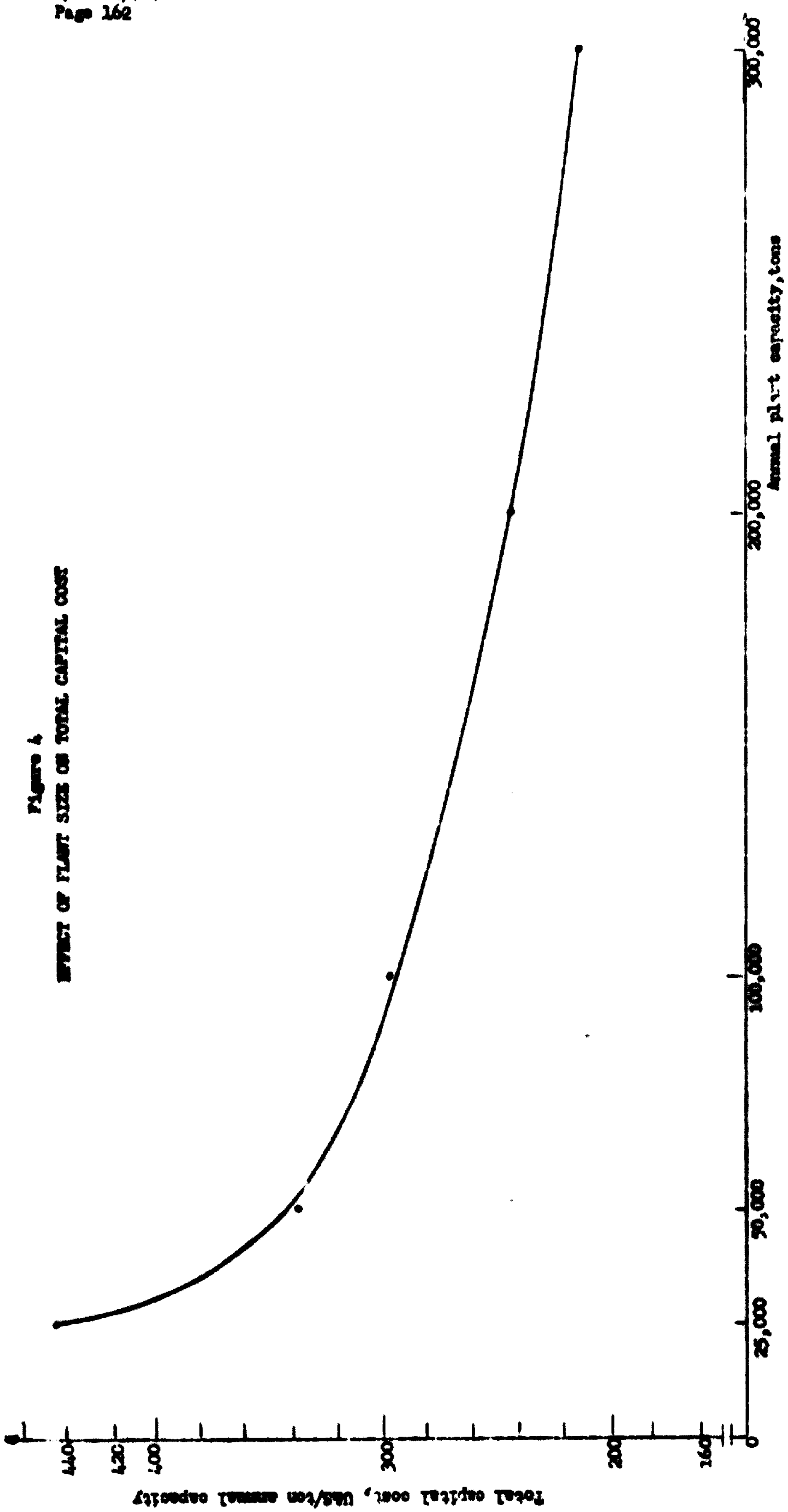

Figure 5

EFFECT OF PLANT SIZE ON PRODUCTION COSTS OF BLAST FURNACE IRON, LD STEEL, CONTINUOUS-CAST BILLETS & ROLLED PRODUCTS

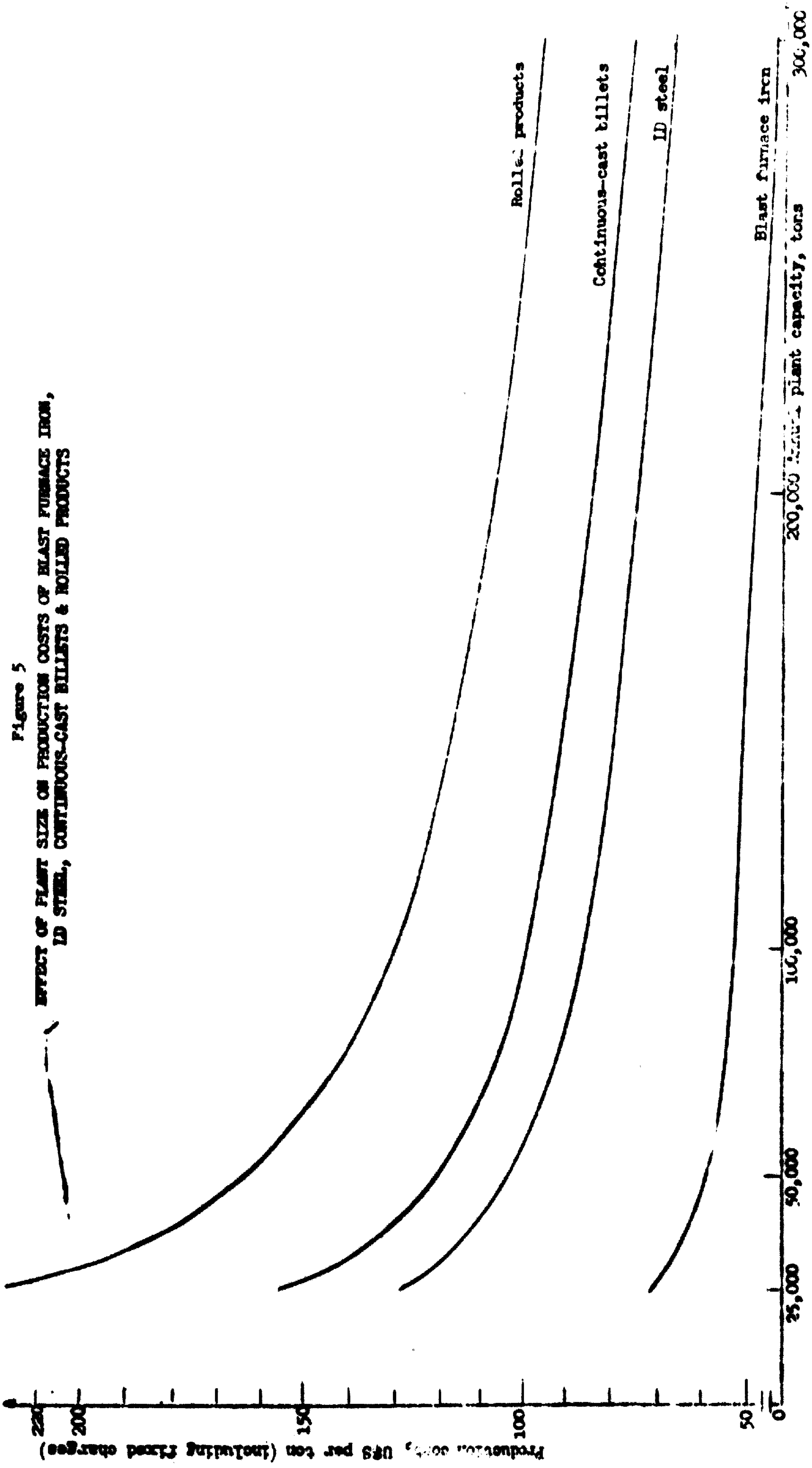

Figure 6

EFFECT OF PLANT SIZE ON LABOUR PRODUCTIVITY & INVESTMENT PER HEAD