OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

05269

United Nations Industrial Development Organization

ID/WG.146/79
1 June 1973
ORIGINAL: ENGLISH

Third Interregional Symposium
on the Iron and Steel Industry

Brasilia, Brazil, 14 - 21 October 1973

Agenda item [illegible]

THE ECONOMY OF SIZE AND SCALE OF STEEL-MAKING UNITS, WITH PARTICULAR REFERENCE TO THE INDIAN STEEL INDUSTRY[1]

by

A.C. Banerjee
Steel Authority of India Limited
and
M.B. Salgarde
Central Engineering and Design Bureau
Hindustan Steel Limited
India

---

[1] The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.73-4344

SUMMARY

India with its vast resources of iron ore and non-coking coal and its power potential would appear to be an ideal testing ground to determine the scale of operation to which direct-reduction processes using solid reductants can be extended. Mounting transportation costs and limited coking coal reserves, together with the urgent necessity to feed the re-rolling industry, have led to the setting up of scrap-based mini-steel plants for the production of mild steel. In addition to the existing electric arc furnaces which in 1971-72 produced 0.75 million tonne of mild steel, new capacity to the extent of an additional million tonne of steel has been licensed. It is estimated that in 1973-74 these plants could produce 16% of the national requirements of steel. The shaped product demand in the country will increase to nearly 7 million tonnes of finished steel by 1980 and consequently the mini-steel plants could well play a significant role in partially bridging the gap between supply and demand, if conditions are favourable.

The feasibility of setting up sponge-iron plants is being considered seriously and the success of these plants using Indian raw materials could well be established before the end of the decade. Their success would ensure the viability and growth of mini-steel plants regardless of the price and availability of scrap, which is at present restricting the development of mini-steel plants. At present-day costs of scrap, power, electrodes, and refractories, the operating expenses, including fixed charges, would approximate to $ 104.32 per tonne of billets produced in a mini-steel plant of 100,000 tonne capacity.

In spite of the economies of scale, the investment costs of maxi-steel plants are rising steadily and the steel plants to be built in the late seventies are expected to cost nearly $ 500 per tonne of installed ingot capacity. Steps must be taken to improve productivity at the tonnage plants with technological improvements. Concerted efforts must also be made to minimise investment costs of ancillary plant and equipment and to reduce the high costs of indigenous plant and equipment. The fixed-charge element of operating expenses will be as high as 40% for new steel plants and consequently the viability of these plants will be in question except plants producing flat products, whose selling prices are more favourable under the existing pricing system.

INTRODUCTION

In recent years, there has been an abundance of seminars held all over the steel world on the future of direct reduction and its impact on the economy of mini-steel plants. While the success of direct-reduction processes using gaseous reductants has been universally accepted, considerable controversy has been generated by the limited success achieved by processes using solid reductants. A continuous debate has also raged in the technical journals of the developed and developing countries on the merits of pre-reduced material replacing scrap as a raw-material feed for the electric arc furnace-continuous casting route followed by mini-steel plants producing billets, bars, rods, and light structurals.

In no country have these developments been followed with more avid interest than in India, where two seminars, held within the last year by the Indian Institute of Metals and the National Metallurgical Laboratory, have highlighted nationwide interest particularly in direct reduction processes using solid reductants. With its vast resources of iron ore and non-coking coal and its power potential, India would appear to be an ideal testing ground to determine the scale of operation to which direct-reduction processes using solid reductants can be extended. Its limited coking-coal reserves are located in a single region in the States of Bengal and Bihar, while the iron-ore and non-coking coal deposits are spread over different parts of the sub-continent. The mounting costs of inland transportation over the vast distances that have to be traversed for the supply of both raw materials and finished products, together with the urgent necessity to supply an existing re-rolling industry with billets, have led to the setting up of mini-steel plants mainly using scrap as a raw material. These mini-steel plants are intended to serve the local market areas within which they are located. The current shortage of steel in the country together with the inflated prices of steel in the free market have aided the economic viability of these units.

On the opposite side of the steel spectrum, the economies of scale achieved by the maxi-steel plants symbolised by Oita, Kimitsu, Fukuyama, and Mizushima in Japan and Krivoirog and Magnito-Gorsk in the USSR, have attracted equal attention, particularly in view of the rising costs of tonnage steel plants being set up in the country. It is, however, generally recognised that while the relative economics of making shaped products in mini-steel plants and maxi-steel plants could well depend on a host of factors, such as the price and availability of scrap, transportation costs, power and electrode costs, and labour and overhead costs, in the case of flat products there can be no doubt that the capacities of wide strip mill and plate mill presently available establish the favourable economics of steel making by the blast furnace-basic oxygen furnace route. The modern wide strip mills have capacities ranging beyond 5 million tonnes of finished products, while the modern plate mill could have a capacity as high as [illegible] million tonnes of finished plates. Significantly, the individual units of mills producing bars, rods, and light sections have maximum capacities in the region of 500,000 to 1,000,000 tonnes per year and there has been no considerable break-through in recent years increasing the capacities of these mills.

In India's developing economy, the present consumption of shape products constitutes 60% of the national demand and consequently mini-steel plants are destined to play their part in meeting the country's steel requirements. Whether this role will be significant will depend on a number of factors, many of which particularly apply to India, and these are discussed in succeeding paragraphs.

PRESENT STATUS OF PRODUCTION, IMPORTS & EXPORTS

In 1971-72, India imported nearly 1,400,000 tonnes of steel valued at about $ 325 million, of which the mini-steel content was about 1,100,000 tonnes valued at $ 225 million. The import figures for 1972-73 are not yet available, but present indications are that similar figures of imports will have been maintained. The reasons for these large scale imports are not difficult to assess. Figure I shows the production, import, export, and apparent consumption of finished steel from the period 1960-61, when the tonnage steel plants of Hindustan Steel, the first major steel plants built after independence, commenced production, to 1971-72. Steady progress in increasing production together with reduction in imports was achieved till 1965-66, during which financial year 4.6 million tonnes of finished steel corresponding to 6.5 million tonnes of ingot steel were produced. In 1966-67 and 1967-68, the country experienced two years of drought and the industrial recession that followed resulted in a drop in the consumption of steel and a further decline in imports. At about the same time, industrial unrest in the steel plants led to a drop in production which only started picking up in 1968-69. The recession necessitated a certain increase in quantity of exports during the period 1968-69 to 1970-71, but these exports diminished as soon as the conditions of recession lifted. During the recession, there was a "Plan Holiday" on investment in steel (the reference being to the national Five Year Plans) which is largely responsible for the steel shortages being experienced at the present time. The consumption of steel is rising and, although production at the tonnage plants has recently shown signs of improvement, the production during 1972-73 being 5.3 million tonnes corresponding to 7.0 million ingot tonnes, there is still a considerable gap which has to be met by imports. This gap between demand and production is expected to persist even after the Bokaro Steel Plant, a large flat-product plant with a first-stage capacity of 1.7 million tonnes, goes into production at the end of this year.

Estimates have recently been made of the total domestic demand for finished steel by 1980 and 1985 respectively. These are indicated in Table 1.

FIG I

PRODUCTION, IMPORT, EXPORT & APPARENT CONSUMPTION OF FINISHED STEEL

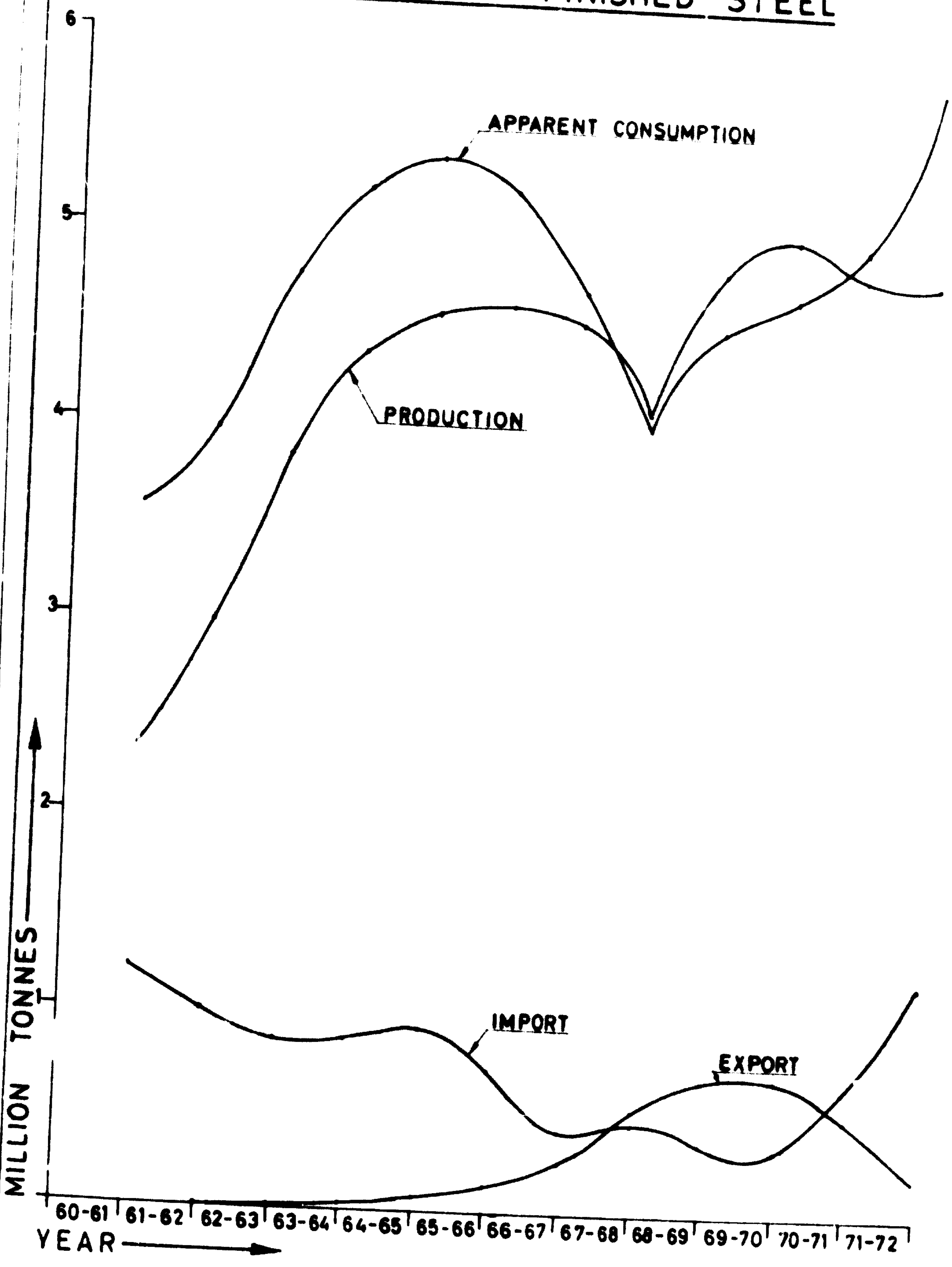


TABLE 1

PLAIN CARBON STEEL DEMAND FOR 1980 & 1985

(in '000 tonnes)

Category		Projections 1980	Growth rate assumed (%)	Projections 1985
DOMESTIC DEMAND				
Shaped products				
Semis for sale	..	444	11.4	762
Bars and rods	..	3,700	9.5	5,825
Wire rods	..	960	11.0	1,620
Structurals	..	1,756	10.0	2,828
Sub-total of shaped products	:	6,860	10.0	11,035
Rails and Railways material		500	5.0	638
Flat products				
Plates	..	1,300	11.0	2,191
CR sheets/strips	..	1,400	11.0	2,359
HR sheets/strips & skelp	..	2,284	11.0	3,849
GP/GC sheets	..	312	5.0	398
Tinplates	..	300	5.1	385
Electrical sheets	..	180	10.0	290
Sub-total of Flat products	:	5,776	10.1	9,472
Total Domestic Demand	..	13,136	10.0	21,145

It will be seen that the total domestic demand for finished steel by 1980 would be of the order of 13 million tonnes, of which 6.8 million tonnes would be of shaped products. The estimated apparent consumption of shaped products during 1972-73 was about 3.8 million tonnes, of which 2.7 million tonnes were met by the tonnage steel plants and 1.1 million tonnes by secondary producers. Imports and exports of shaped products were more or less balanced. The current programme of expansion of steel capacity will not yield any results in terms of enhanced production of shaped products till the end of the decade and consequently the seventies are likely to continue to be a period of shortage of shaped products. It is in this context that mini-steel plants, with their lower investment costs per tonne of finished product manufactured, shorter gestation periods, lower distribution costs, and production flexibility could play a significant role provided conditions are favourable.

THE ECONOMICS OF INDIAN MINI-STEEL PLANTS

It is generally recognised that the price and availability of scrap and electric power are basic to the setting up of mini-steel plants.

PRICES AND AVAILABILITY OF SCRAP

India has been an exporter of scrap for a number of years and scrap prices in the country have tended to be remarkably stable till the advent of mini-steel plants being set up solely for the manufacture of mild steel. Figure II shows the trend of scrap prices in India. It will be evident that current internal prices are considerably higher than prices prevailing in most developed countries. The internal price of scrap is presently higher by as much as 20% than that of pig iron.

The Steel Furnaces Association of India has conducted studies into the availability of scrap upto 1975-76 and Table 2 indicate its findings regionwise. The availability of scrap has been related to the scrap requirements for a projected increase in liquid metal production from electric arc furnaces and the consequent gaps or surpluses regionwise have been estimated. It will be seen that to achieve by 1976 a liquid metal production of 2.1 million tonnes producing approximately 1.4 million tonnes of finished product, there will be a marginal overall shortage of scrap of about 130,000 tonnes.

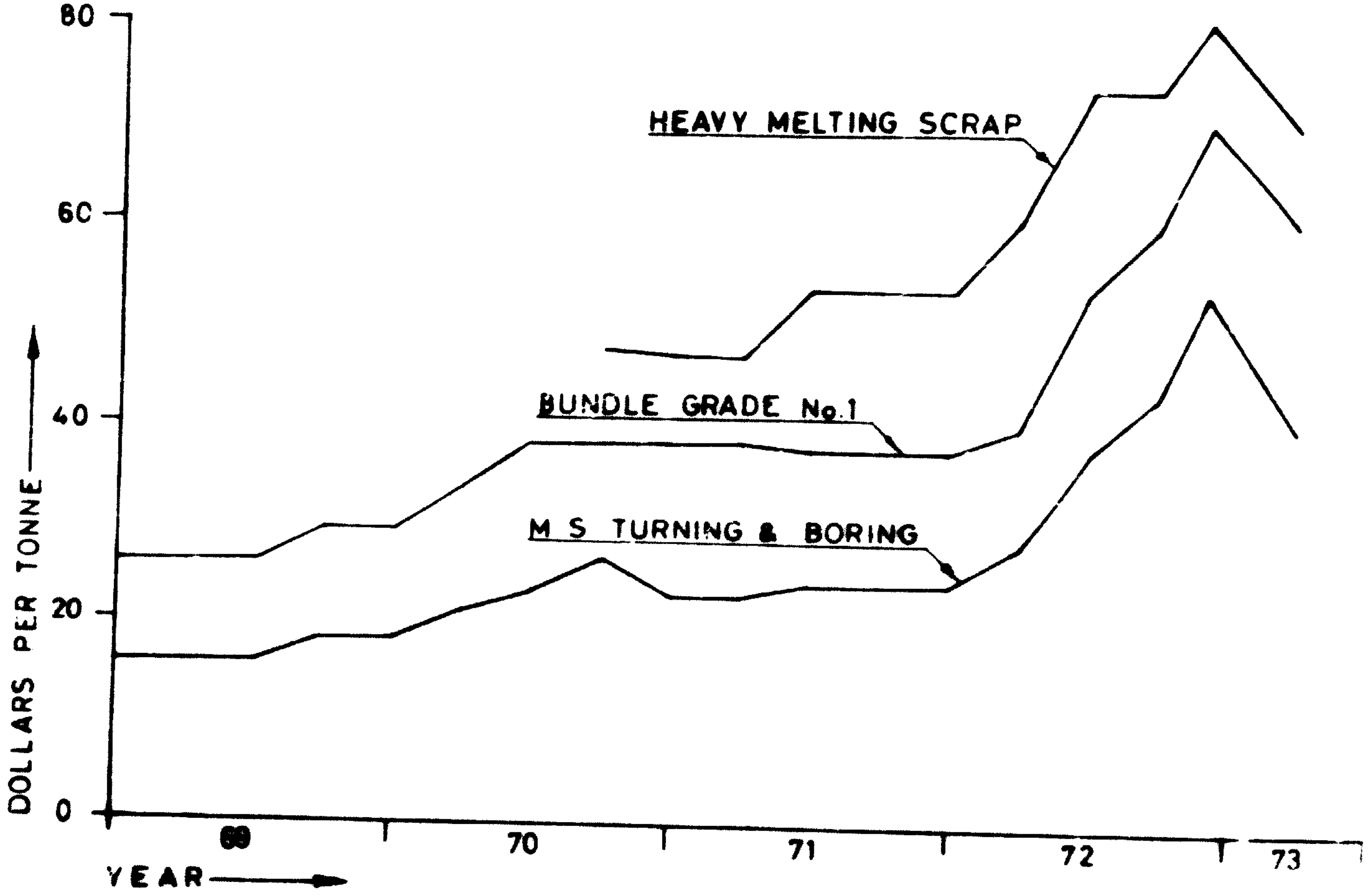
AVAILABILITY AND COST OF ELECTRIC POWER

The availability of electric power is the second major determining factor in the selection of sites for mini-steel plants. To reduce voltage fluctuations arising out of arc furnace operation to within the acceptable limits, the strength of the power system available as expressed in terms of its short-circuit level should have a definite minimum ratio to the furnace transformer capacity proposed. It is generally recommended for satisfactory operation of the plants that the short-circuit level of the power system should be about 50 to 60 times the capacity of the furnace power transformer capacity. Thus, a 20/25 tonnes arc furnace with a transformer capacity of 8 MVA would require a power system having a short-circuit level of about 400 to 500 MVA. The areas where mini-steel plants are presently contemplated to be set up in India are the industrial areas where power systems with short-circuit levels of about 500 MVA are generally available.

The energy consumption of the electric steel making industry has increased from 0.645 billion KWHr in 1970-71 to 0.935 billion KWHr in 1972-73, an increase of nearly 50%. Even so, the requirements of energy for electric steel-making are estimated to be only 2 to 2.5% of the total energy requirements and in view of the vital role that

FIG. II

SCRAP PRICES IN INDIA



NOTE:- HEAVY MELTING SCRAP FIGURES FOR [illegible]-70 NOT AVAILABLE

TABLE 2

Regional Scrap Requirements vis-à-vis Availability

(i) (a) Liquid Metal Production and (b) Scrap Requirements: (All in million tonnes)

Regions	71-72 (a)	71-72 (b)	72-73 (a)	72-73 (b)	73-74 (a)	73-74 (b)	74-75 (a)	74-75 (b)	75-76 (a)	75-76 (b)
North	0.25	0.28	0.55	0.60	0.61	0.67	0.64	0.70	0.69	0.75
East	0.52	0.56	0.53	0.57	0.59	0.64	0.64	0.70	0.69	0.75
West	0.19	0.21	0.30	0.32	0.33	0.36	0.37	0.40	0.40	0.44
South	0.14	0.15	0.23	0.25	0.25	0.29	0.30	0.32	0.33	0.36
All Regions	1.10	1.20	1.61*	1.74	1.78	1.96	1.95	2.12	2.10	2.30

(ii) Scrap Availability Region-wise, (b) Requirements, (c) Availability and (d) Surplus/Deficit:

(All in million tonnes)

Regions	71-72 (b)	71-72 (c)	71-72 (d)	72-73 (b)	72-73 (c)	72-73 (d)	73-74 (b)	73-74 (c)	73-74 (d)	74-75 (b)	74-75 (c)	74-75 (d)	75-76 (b)	75-76 (c)	75-76 (d)
North	0.28	0.21	-0.07	0.60	0.29	- .31	0.67	0.31	- .36	0.70	0.34	-.36	0.75	0.37	-.38
East	0.56	0.70	+0.14	0.57	0.72	+ .15	0.64	0.85	+0.21	0.70	1.05	+.35	0.75	1.15	+.40
West	0.21	0.20	+0.05	0.32	0.29	- .03	0.36	0.38	+0.02	0.46	0.42	-.04	0.44	0.48	+.04
South	0.15	0.10	-0.05	0.25	0.12	- .13	0.29	0.16	- .13	0.32	0.18	-.14	0.36	0.19	-0.17
All Regions	1.20	1.27	+0.07	1.71	1.38	-0.33	1.96	1.30	- .13	2.12	1.99	-.13	2.30	2.17	-0.13

* This figure was estimated in October, 1972 but the current power shortage has lowered this figure by 25%.

[illegible] plays in the national economy, [illegible] made for the demand [illegible] to be met. With the power development programme envisaged for the country, the strength of the various power grids and their short-circuit levels are likely to increase and in course of time high power transformers may be considered. The techno-economics of the installation of these transformers, however, will have to be worked out in detail weighing the additional capital outlay and power costs involved against the increase in production achievable.

Table 3 indicates the electricity tariffs in various States in India. It will be seen that cost of electric power varies between 10 to 15 mills per KWHr. Corresponding figures in some foreign countries are also indicated for purposes of comparison.

TABLE-3

ELECTRICITY TARIFF IN VARIOUS STATES OF INDIA

Supplier	Rate in Mills/KWHr - Annual production of 100,000 T with 2 x 20 / 25 T arc furnaces Annual load factor 50% Mills/KWHr
State Electricity Boards	
1. Andhra Pradesh	15.42
2. Assam	11.26
3. Bihar	13.60
4. Gujarat	13.28
5. Kerala	9.68
6. Mysore	12.67
7. Madhya Pradesh	13.60
8. Maharashtra	14.00
9. Orissa	14.93
10. Punjab	9.92
11. Uttar Pradesh	10.35
12. Damodar Valley Corporation	12.53
Foreign Countries	
1. U. S. A.	8.7
2. Sweden	6.4

PROGRAMME FOR THE SETTING UP OF MINI-STEEL PLANTS

In 1971-72 there were about 170 electric arc furnaces of various sizes producing 1.2 million tonnes of liquid steel corresponding to about 0.8 million tonnes of finished steel. Of the above tonnage of liquid steel, about 0.75 million tonne was plain carbon steel, while the rest was alloy steels and steel castings. Most of the liquid steel produced in the electric arc furnaces was cast into small ingots which were subsequently rolled in re-rolling mills, there being in existence in the country only four continuous-casting plants based on electric steel-making. Estimated figures of production for 1972-73 and 1973-74 are given below in Table 4 :

TABLE-4

STEEL PRODUCTION BY ELECTRIC ARC FURNACES

(in million tonnes)

Year	Liquid	Alloy steel	Steel casting	Plain carbon steel	Finished steel (A)	Steel requirement as per NCAER (B)	% (A) of (B)
Actuals 1970-71	0.86 =	0.31 +	0.16 +	0.39	0.56	5.2	10.8
Actuals 1971-72	1.22 =	0.31 +	0.16 +	0.75	0.79	5.9	13.4
Estimate 1972-73	1.20 =	0.39 +	0.14 +	0.67	0.78	6.7	11.6
Estimate 1973-74	1.78 =	0.48 +	0.20 +	1.10	1.16	7.2	16.1

21 new plants having a total capacity of over 1.0 million tonne have been recently licensed for the production of mild steel and five of these units have gone into production. Most of these units are 50,000 tonnes units having arc-furnace capacities of 10/12 tonnes and have plans to instal continuous-casting machines for the casting of billets of sizes 80 mm sq. to 100 mm sq.

SIZE OF MINI-STEEL PLANTS

The capacity of the furnaces or the heat size for a continuous-casting plant depends upon the casting speed of sections to be cast, the permissible casting time, and the number of strands of the continuous-casting machines. At the present stage of development of continuous-casting technology in India, it has been considered advisable to go in for twin-strand machines casting smaller-size billets, 80 mm sq. to 100 mm sq. For such machines casting billets of sizes mentioned above, the capacity of the furnace would be limited to about 15 tonnes. Depending upon the size availability in the country, the capacity of the electric arc furnace has been fixed at 10/12 tonnes in all the seven mini-steel plants presently under construction and planned for the electric arc furnace-continuous casting route. These 10/12 tonnes capacity furnaces are manufactured in the country and the delivery period is relatively short. The production capacity of a furnace of 10/12 tonnes capacity is 25,000/27,000 tonnes of liquid steel per annum. Since a single twin-strand billet-casting machine, casting sections of sizes mentioned above, can handle the entire quantity of steel produced from two such furnaces, a number of mini-steel plants being set up are installing two 10/12 tonnes electric arc furnaces and a single billet-casting machine. The rated capacity of these plants is about 50,000 tonnes of billets per annum.

An equal production of billets could also be achieved from a 20/25 tonnes arc furnace and four-strand billet-casting machine, as has been set up in one of the plants in South India. The continuous-casting machine will, however, have a reserve capacity which could be utilised with the expansion of steel-making capacity at a later date.

CAPITAL COSTS OF ELECTRIC ARC FURNACES/ CONTINUOUS-CASTING PLANT.

A study on the estimated cost of electric arc furnace/continuous casting installations has been made for plants of capacities 50,000 tonnes, 100,000 tonnes, and 150,000 tonnes of billets per annum based on electric furnace steel-making. The size of the billets to be cast has been assumed to be within the range of 80 mm sq. and 120 mm sq. The major facilities required for such a production and the estimated costs are given in Table 5.

TABLE-5

Billet production per year	No.& capacity of the electric arc furnace	No.of continuous casting machines and its strand	Estimated installed cost of continuous casting plant and electric arc furnace complex.
50,000 T	2 x 10/12 T	1 - 2-strand	$ 4.67 million
100,000 T	2 x 20/25 T	1 - 4-strand	$ 8.0 million
150,000 T	3 x 20/25 T	2 - 4-strand	$ 13.33 million

The above costs do not include the costs for auxiliary service departments, like stores, repair shops, calcining plants, external power supply system, etc. Generally, private entrepreneurs in India avail the services of outside agencies for these facilities. The estimated costs for such 'captive' facilities could be $ 3.33 to 4.0 million for a 100,000 tonnes per year plant. The capital costs also do not include interest during construction.

From the above, it will be observed that the capital cost of electric arc furnace/continuous casting complex (excluding the service facilities mentioned above) per tonne of annual capacity for the 150,000 tonnes plant is comparatively higher than that of the 100,000 tonnes plant. This can be attributed mainly to the surplus capacity of the continuous-casting plant.

PRODUCTION COST OF BILLETS

The estimated production cost of raw steel billets for an output of 100,000 tonnes per year is presented in Table 6. The assumed yields are as shown and fixed charges are calculated at 15% of an estimated investment cost of $ 8.0 million.

In working out the production cost of billets, a scrap-mix price of $ 53.87 per tonne has been assumed on the basis of scrap prices prevailing in April 1973. The scrap cost represents 59% of the continuous-cast billets and 65% of the raw-steel production cost. These are very high proportions by international standards.

The cost of power has been assumed to be 13.3 mills per KWHr. With an estimated power consumption of 570 KWHr per tonne, the power cost works out to 29% of the operating cost. With one mill reduction in the rate of power, the total power cost would be reduced from 29% to 26.8%.

The cost of electrodes in India is of the order of $ 1,070 per tonne. With an estimated electrodes consumption of 6 Kg., the cost of electrode per tonne of billet works out to about 25% of operating cost.

While furnace roofs in India are generally lined with silica bricks, the lining of the shell varies in different furnaces. Some steel makers use magnesite bricks, while others use steel-clad magnesite bricks. Silica bricks are used by some manufacturers for walls above sill level. The cost of silica, magnesite, and steel-clad magnesite bricks is approximately $ 106.67 to $ 120.0, $ 160.0 to $ 166.67 and $ 166.67 to $ 173.33 per tonne respectively. The refractories component represents about 13 per cent of operating cost.

The above exercise would indicate that the estimated cost of billets per tonne produced in a 100,000 tonnes mini-steel plant using scrap as a basis and at present-day prices of scrap, power, electrodes, and refractories would be $ 104.32 per tonne, including the fixed charges. This figure would appear to be high but, as has been indicated earlier, reflects the present abnormally higher price of scrap and the high cost of indigenous power.

MAXI-STEEL PLANTS

INVESTMENT COSTS OF TONNAGE STEEL PLANTS IN INDIA

The investment costs of tonnage steel plants have been steadily rising since the country embarked on its programme for steel development shortly after independence. This increase in investment cost per tonne of installed ingot capacity has occurred notwithstanding the fact that the plants presently being built or in the planning stage are considerably larger in size than the three steel plants set up at

TABLE (

Estimated Production cost for scrap-based mini-plant with annual output of 100,000 tonnes of billets

		£	£	$
1. **Raw Steel** (Yield 93%)				
Metallics :	Purchased scrap ..	53.33		
	Plant scrap ..	1.07		
	Additions ..	3.28		
			57.68	
Cost above :	Power (electrical energy)	7.60		
	Electrodes ..	6.56		
	Fluxes & refractories	3.89		
	Fuel, utilities, & supplies. ..	1.85		
	Repair and maintenance	1.07		
	Labour and supervision	1.33		
	overhead ..	3.49		
			25.79	
Cost per tonne of raw steel excluding fixed charges ..				83.47
2. **Continuous Cast Billets** (Yield 95%)				
Metallics :	83.47 ÷ 0.95 ..		87.88	
Cost above :	Power (electrical energy)	0.15		
	Refractories ..	1.02		
	Fuel, utilities, & supplies	1.39		
	Repair & Maintenance	1.50		
	Labour and supervision	0.70		
	Overhead ..	0.75		
			5.51	
Cost per tonne of billets excluding fixed charges ..				93.39
	Less credit for recoverable scrap ..	1.07		
	Net cost per tonne of billets excl. fixed charges ..			92.32
3. **Fixed Charges**				
Fixed charges at 15 per cent on $ 8.0 million, per tonne			12.00	
4. Total cost of billets per tonne ..				104.32

Rourkela, Durgapur, and Bhilai, in the [illegible] as part of the country's Second Five Year Plan. Table 7 shows the investment cost of these three steel plants at their initial and expansion stages and the investment cost of Bokaro Steel Plant, a flat-product plant which is presently under construction. The investment cost of a new steel plant to produce shaped products based on 1972 costs is also shown in the table. It will be evident that the investment cost per tonne of installed capacity has risen from approximately $ 250 pertonne of installed capacity (in terms of ingot steel) to nearly $ 500 per tonne of installed capacity. A certain element of this increase can be attributed to escalation, but there are certain basic reasons why the economies of scale have not resulted in lowering of investment costs per tonne of installed ingot capacity. The present investment costs of Indian steel plants are inordinately high in comparison to European and Japanese steel plants, but are comparable to U.S. costs. The three basic factors contributing to the high cost of Indian steel plants are the lower productivity (pro rata), the cost of additional facilities that have to be provided at Indian steel plants to suit local conditions, and the higher costs of indigenous plant and equipment.

LOWER PRODUCTIVITY

It has been estimated that, with an additional investment of about 10%, the facilities provided in an Indian steel plant of 2.0 million tonne capacity would be adequate to produce 3.0 million tonnes in a foreign location. The factors contributing to higher production in foreign plants are the superior quality of raw materials, superior quality and easier availability of refractories, the ready availability of spares and consumables, and fuller utilisation of built-in technological improvements.

The average ash content of coke made from Indian coal is about 24% and the coke requirement per tonne of iron is 690 to 700 Kg (dry). In European countries and in Japan, this requirement is as low as 500 Kg per tonne of iron, mainly due to the low ash content of their coke and the use of fuel oil and industrial oil for the blast furnaces. Further, while coking times of 14 hours are easily attainable abroad, the same coke ovens under conditions prevailing in India are rated for a coking time of about 17 hours. These factors result in greater coke-oven capacity having to be provided at Indian plants.

Indian iron ore though high in Fe has an unfavourable Al_2O_3/SiO_2 ratio, which presents problems to the blast-furnace operator. These problems are further aggravated by the high ash content in coke and high-gangue flux available in India which produce slag volumes of the order of 600 to 800 Kg per tonne of hot metal with Al_2O_3 content of 20-27%. The production of hot metal per cubic metere of blast-furnace volume in Japan and other developed countries with prepared burden, low-ash coke, oil injection, oxygen enrichment, and other technological innovations, is about 2.4 tonnes per day. The present production of hot metal at Bhilai, where blast furnaces are considered to be running

TABLE 7

I N D I A

INVESTMENT COST PER TONNE OF INGOT STEEL

Sl. No.	Item	Durgapur		Rourkela		Bhilai		Bokaro		New Steel Plant
		Stage-I	Stage-II	Stage-I	Stage-II	Stage-I	Stage-II	Stage-I	Stage-II	
1.	Total capital cost in million $	268.4	358.8	310.9	534.1	269.7	471.3	1,013.3	1,609.1	1,087.3
2.	Capital cost of the plant proper (excluding township, interest duting construction and mines, etc.) in million $	238.8	326.5	250.0	440.9	227.1	413.7	946.1	1,541.9	983.5
3.	Ingot steel capacity in million tonnes	1.0	1.6	1.0	1.8	1.0	2.5	1.7	4.0	2.2
4.	Investment cost per tonne of ingot steel in $	238.8	204.1	250.0	244.9	227.1	165.5	556.5	385.5	447.0

satisfactorily, is about 1.1 tonne per cubic metre of blast-furnace volume per day. With the limitations of Indian raw materials, it would not be safe to assume a figure higher than 1.4 tonne per cubic metre of blast-furnace volume for blast furnaces being erected in the near future which will be operated with prepared burden and other technological improvements.

Under Indian conditions, it would be extremely difficult if not impossible to emulate the tap-to-tap times of LD converters being obtained in the countries like Japan, where the national average tap-to-tap time has been stated as 35 minutes. For Bokaro, the tap-to-tap time for 250 tonnes converters has been assumed as 80 minutes and for Vijayanagar, one of the new steel plants, a tap-to-tap time to 68 minutes has been assumed. It is anticipated that the tap-to-tap times for 250 tonne capacity LD converters will gradually come down to 60 minutes or even less, but at the present time this cannot be assumed and consequently the rated capacities of these converter shops are only 2/3rds that of similar shops abroad. A major contributory factor to lower productivity in the converter shops is the poor quality of refractories, which results in converter lining life being as low as 150 heats.

ADDITIONAL FACILITIES AT INDIAN PLANTS

Foreign steel plants are not generally designed to provide ancillary facilities that are generally part of an Indian steel plant. A number of shops, like refractory-materials plant, repair and maintenance shops, and ingot-mould foundry, would not generally form a part of the steel plant in developed countries, since the engineering industry is well established there. Even the oxygen plant does not exist in certain foreign steel plants, where oxygen is bought from regular suppliers, who establish oxygen plants in the vicinity of the steel plant. Power-plant capacities are substantially lower in foreign steel plants, in view of the stability of the power system and the availability of bulk power from the power grid. There are also reductions in capital costs for other services, such as transport, tracks, construction facilities, water supply, etc. Since equipment manufacturers in developed countries are normally responsible for both equipment design and engineering of the project, there would also be reduction in engineering costs. The administration during construction of Indian steel plants, because of the essentially complicated nature of non-turnkey operations involving a large number of agencies, tends to be more expensive than is normally the case in European plant construction. The overall period of construction for a foreign plant is of the order of 4 years as against 7-8 years envisaged for an Indian steel plant, and this enhances the interest during construction. The above factors contribute 25% to the higher capital cost of Indian steel plants in comparison to foreign steel plants.

COST OF INDIGENOUS PLANT AND EQUIPMENT

The cost of indigenous plant is generally equivalent to the landed cost for corresponding imported plant. This cost is approximately 50% more than the current FOB prices based on present-day rates of ocean freight and customs duty. Since plant and equipment forms nearly 60% of the total cost of the plant and every effort is being made to maximise indigenous supplies, the resultant effect on the overall capital costs can easily be evaluated.

EFFECT OF HIGH INVESTMENT COST ON PROFITABILITY

The high investment costs to which reference has been made in preceding paragraphs have naturally a considerable effect on the profitability of Indian steel plants. Figure III shows the effect of fixed and variable expenses on the total operating expenses of the Hindustan Steel plants, Rourkela, Durgapur, and Bhilai, for a period from 1961-62 to 1971-72. For comparison purposes, the figures for the Tata Iron & Steel Company (TISCO), where the investment block is considerably lower since it was constructed much earlier, and the projected figures for a new steel plant to be set up in South India are also shown. It will be apparent that, while in Hindustan Steel plants the fixed charges constitute over 20%, at TISCO this figure is of the order of 10% and in steel plants to come this figure may go up to as high as 40%. Inspite of the fact that Indian steel plants employ a large number of personnel, salaries and wages as a percentage of total operating expenses are generally of the order of only 15%.

EFFECT OF THE PRESENT INTERNAL PRICING SYSTEM ON PROFITABILITY

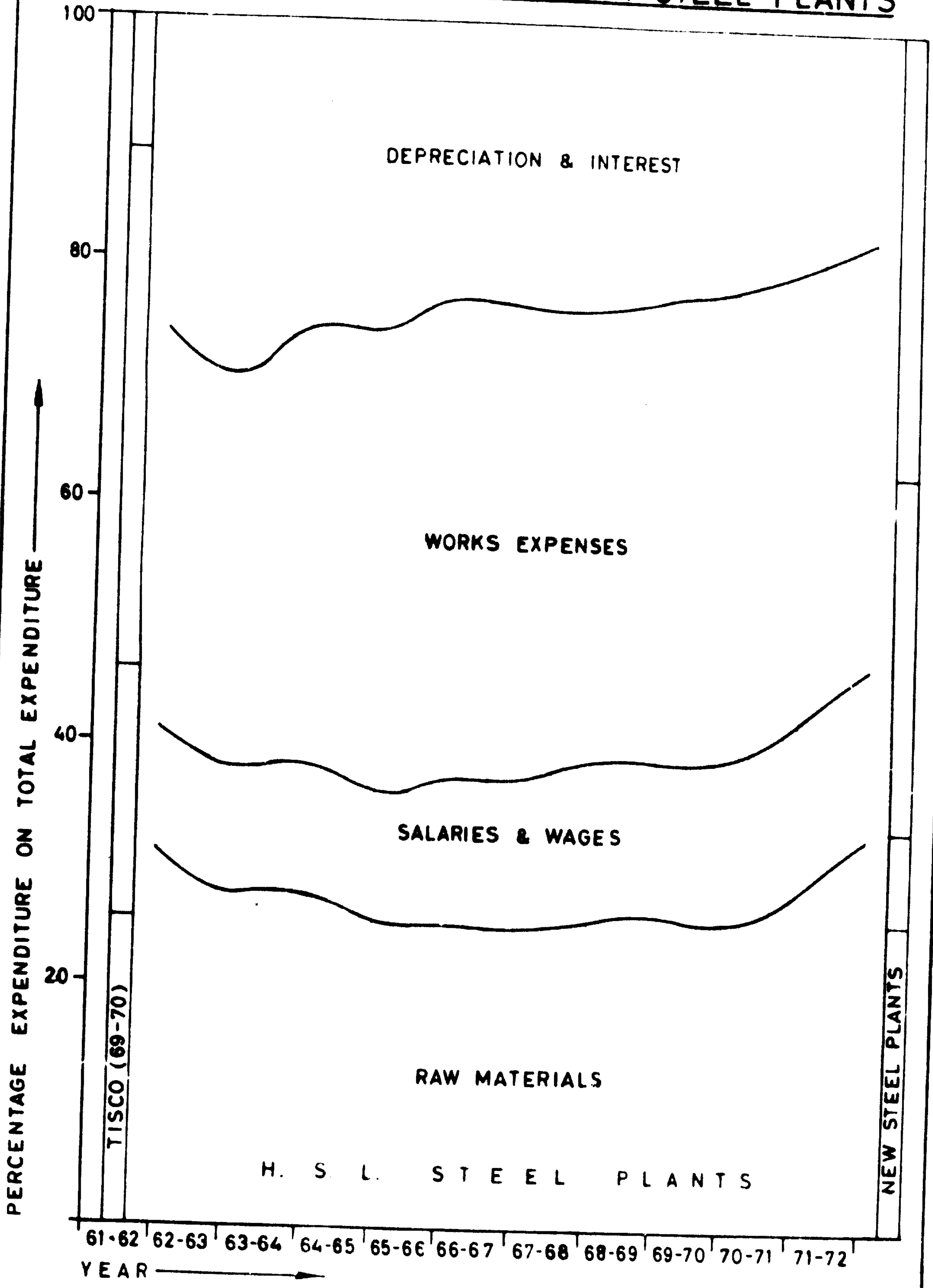
Table 8 indicates the current JPC (Joint Plant Committee) controlled prices for certain items of shaped and flat products.

TABLE-8

Products	Net prices for standard/tested quality (ex-steel plant realisation) effective from 1.3.1973 $ / Tonne
I. Shaped Products	
1. Billet	77.2
2. Bars & rods (excluding flats) 14 mm & below in straight lengths	98.2
3. Bars & rods (excluding flats) 14 mm and below in coils	96.7
4. Structurals (angles, channels, etc)	97.9
II. Flat Products	
1. Plates	114.5
2. HR coils - 14 G & thicker	110.5
3. HR sheets - 14 G & thicker	120.5
16-20 G	152.5
Thinner than 20 G	159.2
4. CR coils - 14 G and thicker	137.3
16 - 20 G	169.3
Thinner than 20 G	175.9
5. CR sheets - 14 G & thicker	143.9
16 - 20 G	175.9
Thinner than 20 G	182.6

FIG III

OPERATING EXPENSES OF INDIAN STEEL PLANTS



The disparity in the price structure in favour of flat products has a considerable effect on the relative economic viability of plants producing shaped and flat products respectively. Table 2 shows the relative economics of two such plants of similar capacities based on 1972 costs.

TABLE 2

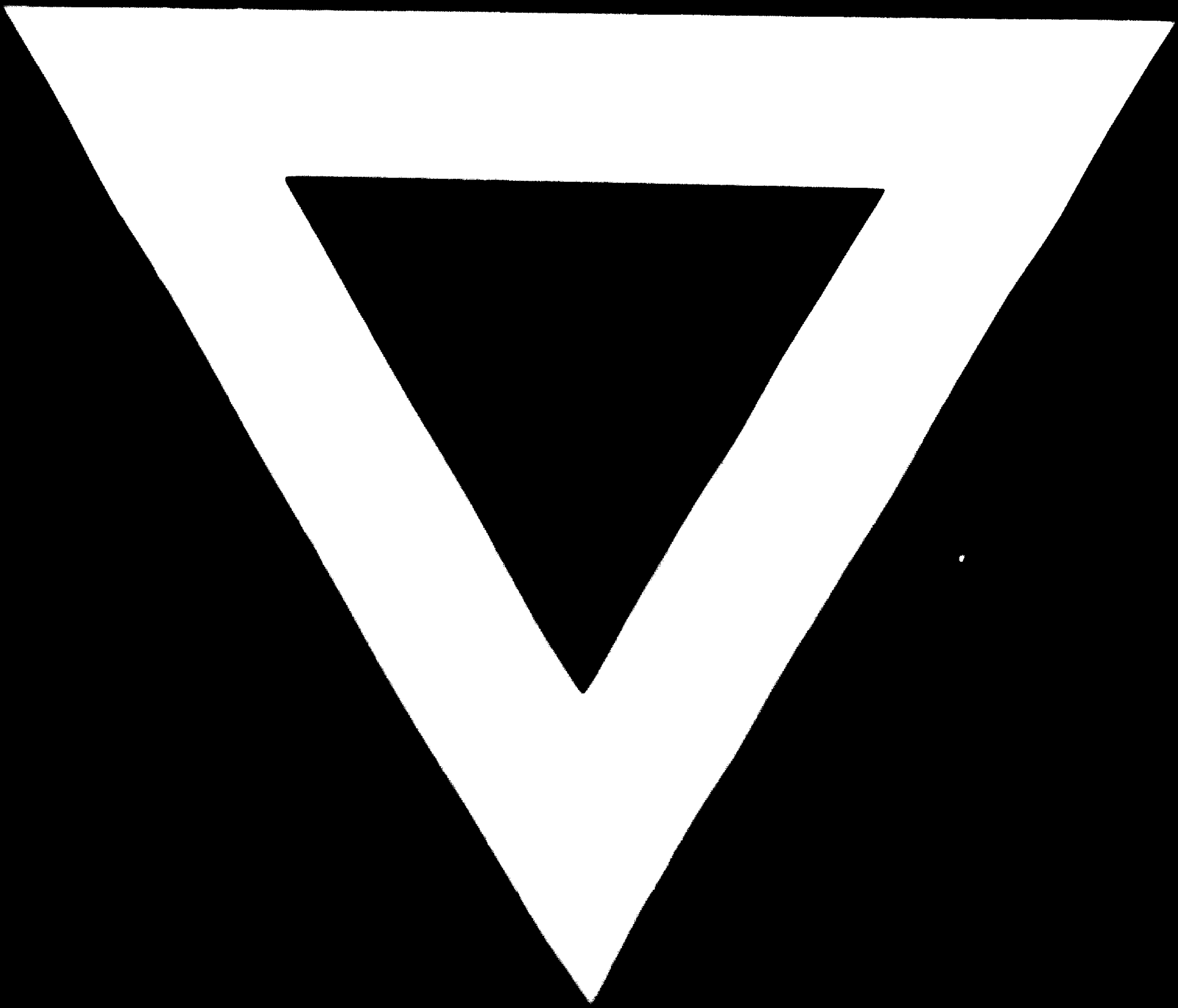
Particulars	PLANT-A Shaped products.	PLANT-B Flat products
A. **Facilities**		
Coke ovens ..	4x65 ovens (5 m)	4x65 ovens (5 m)
Sintering machine ..	2x252/312 m²	2x252/312 m²
Blast furnaces ..	3 x 1719 m³	3 x 1719 m³
Converters ..	4 x 150 tonne	4 x 150 tonne
Continuous casting ..	--	6 m/c of double strand slab casters
Rolling mills ..	Blooming & Billet mill; Med. Sec. mill; Merchant mill; Wire rod mill.	Hot strip mill
B. **Production** (Unit/thousand tonnes)		
Steel (liquid/ingot)	2,500 (ingot)	2,600 (liquid)
Finished products (T) :-		
Medium sections ..	500	-
Light merchant sections	400	-
Wire-rod coils ..	400	-
HR sheets/coils ..	-	2,310
Saleable billets ..	666.5	-
Total saleable steel :-	1,266.5	2,310
Saleable pig iron ..	37,000 tonnes	72,000 tonnes
Granulated slag ..	905,500 "	905,000 "
C. **Financial Indices** (in millions of $)		
1. **Capital expenditure**		
Fixed capital ..	1,091.73	969.18
Working capital ..	39.47	43.60
Total :	1,131.20	1,012.78
Fixed capital cost per tonne of installed capacity. ..	$ 436.7	$ 372.8
2. **Net Margin** (after depreciation & interest) (operating at 100% capacity)	(-) 75.50	(+) 14.53
3. **Return on capital** (after depreciation and interest)	(-) 6.7%	(+) 1.4%

The production cost of billets [illegible] and depreciation and at 100% capacity [illegible] per tonne. This does not bear favourable comparison [illegible] billets produced from electric steel in the mini-steel [illegible]. At Bhilai, an existing plant, the present production [illegible] approximately $ 86 per tonne. The above figures indicate [illegible] certain manner the effect of increasing investment [illegible] economic viability of the maxi-steel plants.

CONCLUSION

Mini-steel plants presently operating or under construction in India are scrap-based. These plants are proving economically viable, in spite of rising scrap prices and high electricity tariffs, mainly because of the current steel shortage in the country and the fact that their products do not come within the purview of price control. This position will obviously not prevail indefinitely and consequently the future of these plants will largely depend on the success of pre-reduction using solid reductants and the percentage charge of sponge iron that can be accepted by the electric furnace under Indian conditions. Plans are under way for setting up of direct-reduction plants and it is expected that the success of these plants will be known by the end of the seventies. Should direct reduction in these plants prove technically and commercially viable, the eighties could well see a reduction in shaped products being produced by maxi-steel plants and the percentage of electric steel rise as high as 30% of the national figures. The savings in foreign exchange annually may amount to $ 120 million when the million tonnes of steel-making capacity licensed for mini-steel plants goes into production in the mid-seventies.

India has not been in a position to maximise the economies of scale as exemplified by the maxi-steel plants of Japan and the USSR for reasons which have been earlier indicated in this paper. While the idea of coastal-based plants using low-ash imported coal has been considered for a number of years, this matter may well warrant urgent re-examination, particularly for plants coming up in the eighties. Improvements in blast-furnace productivity using prepared burden, high top pressure, high blast temperature, etc. must be maximised. Every effort must also be made to reduce the high costs of indigenous plant and equipment and to minimise investment costs on ancillary plants. All these measures are essential if the economies of size and scale are to be taken advantage of, in India.



13. 8. 74