The case for 100 000 tonnes/year integrated iron and steel plants for emergent countries

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INTRODUCTION

THE DEVELOPMENT of an iron and steel industry is affected by many factors which vary considerably from country to country, and it is obvious that no overall rules can be laid down which would govern all eventualities. Nevertheless, the problem which faces many countries which are just emerging as iron and steel producers, shows certain similarities which can be summarized as follows:

- (i) in most cases, steelmaking is either non-existent or in comparison with the more developed countries, of extremely low capacity
- (ii) these countries often cover wide territories with under-developed communications systems
- (iii) these countries are usually associated with a relatively low standard of living. The raising of this standard for the greatest number of people is urgent
- (iv) capital for investment and foreign exchange is scarce and the demand on both is heavy.

It has been accepted to date that plants with a capacity of 1 m. tonnes or more have advantages in investment cost per annual tonne and operating cost per product tonne. Several countries planning initial investment in a steel industry have therefore chosen to install plant of this size. If this solution is adopted the initial steel output of a country is concentrated in one area and the technical and social development associated with the steel plant takes place in that area, encouraging further accumulation of secondary industry in the same place. It would undoubtedly be an attractive proposition for such a country to consider the installation of small integrated iron and steelworks, more liberally spread over a large number of areas, if it could be shown that the price to be paid for such decentralization was not too high. There is no doubt that the larger the scale of operation the lower the capital cost per tonne of product and the lower the operating cost. This problem has been faced in this paper and an integrated plant of 100 000 tonnes/a (year) has been developed, at a capital cost per annual ingot tonne similar to that associated with the large plant. The operating cost of the smaller plant is higher and the difference has been measured.

It is shown that the small-scale plant can be increased in capacity and developed technically to reduce the operating cost. Nevertheless, the operating cost can never be brought down to that enjoyed by the large plant. It is obvious that a full range of products cannot be rolled from the 100 000 tonne plant as initially installed and it is suggested that in the first stage these products should be limited to small diameter rod (10–15 mm) and light section material up to about 75 mm. It is suggested that at later stages of development the plant can be made to produce medium sections as local demand for this material grows.

SYNOPSIS

This paper recognizes that advantages can accrue in emergent steel-producing countries by the dispersion of a number of small plants rather than centrally located single large plants. The authors have attempted to compare the cost of these two alternatives, and to measure the extra costs which would be incurred in the development of a number of small plants, in order that these extra costs can be off-set as a measured quantity against the qualitative advantages which could accrue from dispersion of industrial activity. Alternative processes for a small plant are considered, a selection made, and a description given of the plant selected. SR78I

This paper does not set out to prove that there is no case for the large plant. The small plant proposed can be developed in time to cover the medium sections range and all merchant bars. It can never be developed to the stage where it can economically produce either wide flat products or heavy structural sections. These latter products must be made in medium and large tonnage installations as the capital cost of the mill units required to produce them cannot be faced unless they are put to work on large tonnages. These plants may be installed in the early stages of a country's steel development if there is an urgent market demand for such products, but it would seem that they are better left to the later stages of development once the market for the small end products has been satisfied by the output of a number of smaller plants.

Thus it is not suggested in this paper that the right answer for any particular country is the installation of a number of small plants or one large plant or a mixture of the two. The attempt has been made here to present the facts which will allow this political decision to be taken with the full knowledge of the capital cost and economy of operation involved.

Conclusions

1. A small integrated iron and steel plant producing 100 000 tonnes/a of merchant bar and light sections can be established at a capital cost of about £90 per annual ingot tonne, under excellent conditions and up to £130–140 per annual tonne for less ideal conditions of location (*see* Appendix *E*).

2. The equipment actually included in this plant, by virtue of the size factor must of necessity cost more per annual tonne than that same equipment installed in a large-scale plant. Economies of design and layout, along with reduction of equipment to the essentials, have kept this differential as low as possible.

3. The operating cost for such a plant would by virtue of the capital cost economies outlined above be about £3·5 per product tonne more than that of a large plant on the basis of the raw materials prices assumed here.

4. Such plants would allow industrial and social development over a wide area, each area accumulating secondary industry and generally raising the standard of living over a greater territory than would be the case where production was concentrated in one large-scale plant.

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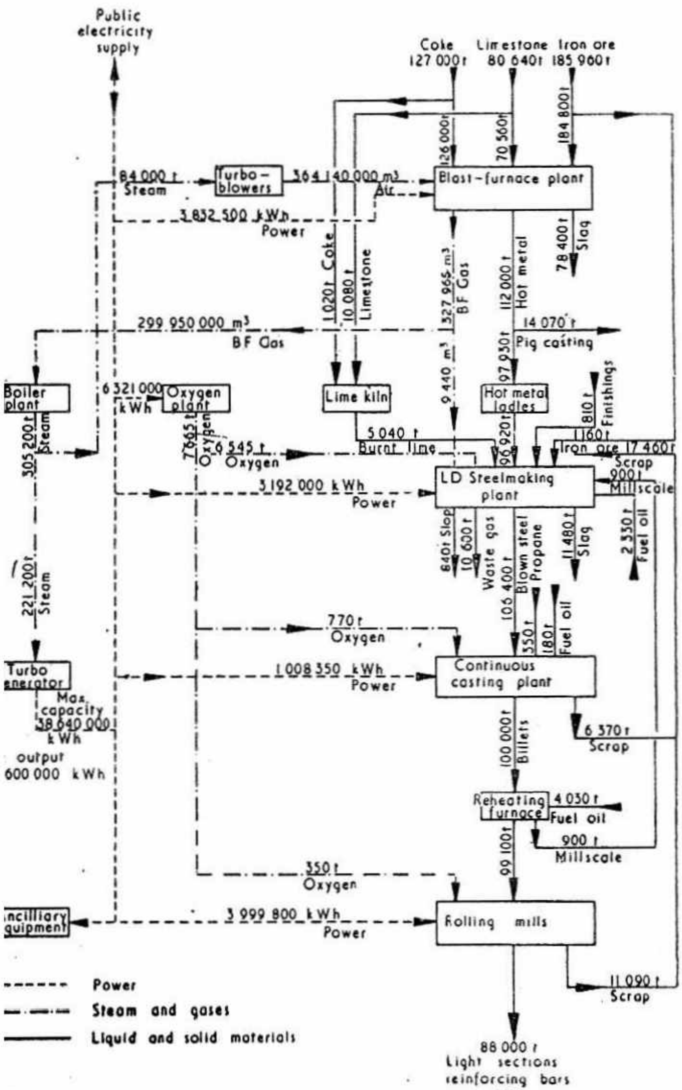


1 *Overall works materials balance*

5. Such installations would draw on raw materials locally and produce for local requirements. These arrangements would minimize demand on road, rail, and communications services.

6. It is not contended in this paper that either a large-scale plant or a small-scale plant is the answer in every case, but it is suggested that both these alternatives be carefully considered before a decision is taken in planning future production.

DISCUSSION ON INTEGRATED PLANT CAPITAL AND OPERATING COSTS

Capital costs

Later sections of this paper deal with the reasons for the choice of equipment in each of the main producing perimeters. This section summarizes the effect of these decisions on total plant capital and operating cost. The overall works materials balance is given in Fig. 1 and the overall works layout in Fig. 2.

Certain basic assumptions have been made throughout, of which the most important are :

(i) site conditions have been chosen to give as near a zero cost as possible, thus allowing these charges to be added later. To do otherwise would be to guess at these costs and in no two cases will they be comparable. These conditions are listed in Appendix *E*

TABLE I Capital cost breakdown

		£
a	*Items not dependent on location*	
	Ironmaking, steelmaking, and rolling mill equipment (Appendix A, B, and C)	4 556 000
	Power station	1 033 500
b	*Items dependent on location*	
	Civils and co-ordination of producing perimeters	2 778 500
	Transport of equipment (Appendix D and E)	660 000
		£9 028 000

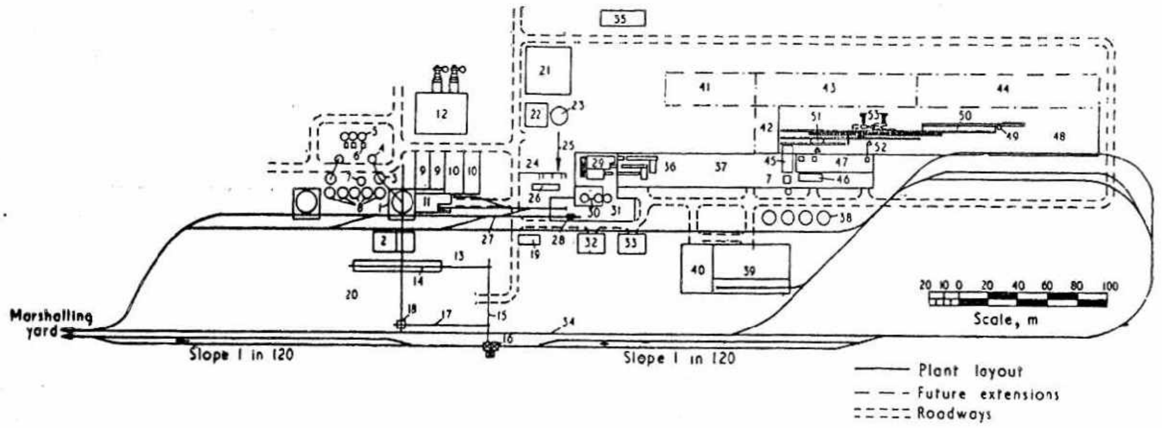
TABLE II Production costs (excluding administration, amortization also credit for gas and slag products)

	100 00 tonnes/a			Comparative* plant *(see below)*		
	£	*s*	*d*	£	*s*	*d*
Ironmaking						
Ore 1·65 tonnes	2	1	3	2	1	3
Coke 1·125 and 0·8 tonnes respectively	5	9	8	3	18	0
Flux 0·63 tonnes		16	4		16	4
Labour		9	6		6	0
Maintenance	1	18	3	1	15	0
Total per tonne of iron	**10**	**15**	**0**	**8**	**16**	**7**
Steelmaking						
Blast-furnace metal 0·9 107 tonnes	9	15	10	8	0	10
Ladle loss 0·0 091 tonnes		2	0		2	0
Steel scrap 0·164 tonnes	2	0	4	2	0	4
Materials additions		17	8		15	0
Operating and maintenance materials etc.	1	1	6		13	6
Labour		4	7		3	6
Total per tonne of steel	**14**	**1**	**11**	**11**	**15**	**2**
Continuous casting						
Liquid steel 1·064 tonnes	15	0	0	12	.10	3
Operating and maintenance materials		12	8		10	2
Labour		1	11		1	6
Sub total	**15**	**14**	**7**	**13**	**1**	**11**
Less scrap credit 0·064 tonnes		15	9		15	9
Total per tonne of cast product	**14**	**18**	**10**	**12**	**6**	**2**
Rolling						
Billet 1·136 tonnes	16	19	6	13	19	8
Production materials		4	5		4	0
Fuel oil		5	6		5	0
Electricity		3	0		2	6
Labour		13	0		10	0
Factory services		4	0		3	6
Maintenance		17	10		15	0
Sub total	**19**	**7**	**3**	**15**	**19**	**8**
Less scrap credit 0·13 tonne	1	12	0	1	12	0
Total per tonne of bar and reinforcing rod	**17**	**15**	**3**	**14**	**7**	**8**
Works Services						
General works service charge	1	0	0		17	6
Total production cost for bars and reinforcing rod etc.	**18**	**15**	**3**	**15**	**5**	**2**

Note Costs are based on equal yields for comparison purposes. In practice the larger mill would operate at about 92% rather than 88% yield. There would be similar changes in the steelmaking and casting processes, necessitating adjustment of the works mass balance.

*Comparative plant : 1 m. tonne plant producing medium, light sections. The capital and operating cost difference between (*a*) 100 000 tonne and (*b*) 1m. tonne plant is as follows : .

	(*a*), £	(*b*), £
Capital cost per annual tonne	90–140	80–130
Operating cost per tonne	18–18·75	15·25



1 *Blast-furnace*
2 *Engine house*
3 *Dustcatcher*
4 *Washing tower*
5 *Separators*
6 *Disintegrators*
7 *Chimneys*
8 *Stoves*
9 *Furnace slag pits*
10 *Melting shop slag pits*
11 *Casting house*
12 *Power house and furnace blowers*
13 *Scale car track*
14 *High line bunkers*
15 *Incoming conveyor*
16 *Wagon tippler*
17 *Reclaiming conveyor*
18 *Ground hopper*
19 *Laboratory*
20 *Raw material stockyard*
21 *Incoming water pond*
22 *Pump house*
23 *Water tower*
24 *Lime kiln bunkers*
25 *Ramp to lime kiln*
26 *Lime kiln*
27 *Hot metal line*
28 *Hot metal ladle*
29 *Continuous casting plant*
30 *LD furnaces*
31 *Melting shop*
32 *Gas cleaning plant*
33 *Oxygen plant*
34 *Running track*
35 *Administration block*
36 *Cooling beds*
37 *Billet stockbay*
38 *Oil storage tanks*
39 *Maintenance shop*
40 *General stores*
41 *Future open stockyard*
42 *Future furnace bay extension*
43 *Future medium section bay*
44 *Future coil bay*
45 *Reheat furnace*
46 *Scale pit*
47 *Motor room*
48 *Finishing bay*
49 *Shear*
50 *Cooling bed*
51 *Roughing mill*
52 *Intermediate mill*
53 *Finishing mill*

2 *Overall works layout*

(ii) where possible the initial capital cost has been kept to a minimum (e.g. by increasing the labour force) at the expense of a higher operating cost.

The capital cost is dependent upon (*a*) ex-works 'hardware' cost which is subject to close engineering definition, and relatively accurate measurement irrespective of location of the plant; (*b*) factors which depend entirely on location and vary considerably with location. Table I shows the capital cost breakdown.

It should be noted that of the total of £9·0 m. shown in Table I, only about 60% is reasonably accurate in the context of a general paper of this nature. Quite obviously for any *given* site and *given* location of that site an accurate estimation of total costs can be made. Such an estimation is always open to the criticism that it applies only to the specific, and not the general case.

The authors have, therefore, taken the line that a figure from £9·0 to £14·0 m. although only a broad estimation to allow for differences from assumed location conditions (Appendix *E*) is at least of the correct order of magnitude for the purposes of the proposals contained in this paper.

Operating costs

Everyone will be aware that a reduction of capital cost can be obtained at the expense of operating cost. The plant proposed here has a sound technical basis, but attempts have been made to reduce capital cost purposely at the expense of operating cost. Provided that provision is made for later addition of equipment which would allow a reduction in operating cost, this is a perfectly valid proposition.

Table II attempts to measure the increased operating cost resulting from decreased capital expenditure.

IRONMAKING

Process selection

A considerable amount of effort has been expended in the past decade in the investigation of alternative methods of iron production which would replace the conventional blast-furnace, these methods being somewhat loosely described as direct reduction processes.

Developments of a major nature such as these, invariably take a considerable time before results are obtained, and it is important always to keep in mind the initial reasons for such development because changes in circumstances could alter its basic concept.

Investigation into the possibility of direct reduction processes began primarily for three reasons.

(i) in the late 1940s fears were expressed that good coking coal would become scarce. At the same time blast-furnaces were increasing in size, making even more stringent demands on coke quality. Thus the possibility of direct reduction processes using low grade reductant was attractive

(ii) the possibility of a reduction in capital cost and operating cost by introducing direct reduction process was also attractive

(iii) the possibility of using a solid direct reduction product in open-hearth and electric furnaces at little increase in conversion cost, was also attractive.

Since development work started in the direct reduction field, the essential conditions outlined above have been modified as follows:

(i) new sources of coking coals were developed in the late 1940s and the early 1950s, and further, sintering and other techniques were developed which opened up the possibility of producing iron economically from what was previously considered unsuitable raw materials

(ii) during the past 15 years, the development which has taken place in blast-furnace practice has given a new comparative basis of capital and operating costs

(iii) Equally important, the oxygen steelmaking processes were developed in the period 1950–60. These processes cannot accept a solid direct reduction product. This product must be melted at additional cost before it can be used in oxygen converters. Thus even if the direct reduction process showed some gain in cost over the conventional blast-furnace it would be necessary for this gain to be sufficiently wide:

   (*a*) either to allow for the additional cost of preparing the direct reduction product to make it suitable for oxygen converter raw material.

or

   (*b*) to allow for the higher capital and operating cost of the open-hearth or electric furnaces which can accept the product without further treatment.

Thus it is considered that in the changing conditions which have become effective over recent years, the whole question of direct reduction requires fresh evaluation. Further, as was stated at the outset, development of processes such as these requires a very long-term effort, and to date, only a very small number of direct reduction plants of all types have been installed, mostly in very special circumstances. The number of processes under consideration increases each year and it is obvious that the ultimate stage of this development has not yet been reached.

For these reasons the conventional blast-furnace has been selected for the plant proposed here. This decision in no way rules out direct reduction processes in the future. The next ten years may see this development proceed apace, particularly if a molten product can result at a capital and operating cost equivalent to modern blast-furnace practice.

Plant selection

The blast-furnace is not seriously penalised by a restriction on initial capital expenditure. Basic plans can leave provision for all the elaborations which can result in increased output and efficiency, whilst providing a furnace which may be simply and reliably operated from the start.

The important factor in reducing capital outlay is the decision to forego any ore beneficiation. If the plant was operated without such burden preparation initially, the demands of such preparation could be measured more accurately and a beneficiation planned at a later stage when the total plant output increase would justify such expenditure. Thus it is proposed to use ore as mined, charged direct to the blast-furnace.

The advent of modern reliable refractories and gas-cleaning equipment allows a major saving by installing two rather than three hot blast stoves. The precaution of holding a third stove in reserve because of occasional fouling of the brickwork by dirty gas is no longer justifiable, since these risks have receded almost to vanishing point. Two stoves can raise the blast-furnace temperature to 800–850°C which is more than is required before the introduction of other refinements. When the second blast-furnace is installed, the addition of three stoves at that time would allow one spare stove.

At the present time it is usual to equip a modern blast-furnace with automatic means of screening, weighing, and charging coke. The furnace proposed, however, would be of ample dimensions and would start operations well within its capacity potential. Thus coke, like other materials, could be charged by the scale car. Automatic equipment could be fitted as the demands for increased output arose.

The installation of equipment for high top pressure operation, and automatic stove changing, would be omitted initially. These refinements could follow later, as could a passenger elevator, mechanical slag notch stopper, and power-operated snort valve.

A brief outline of output requirements, raw material requirements, and blast requirements, is as follows :

blast-furnace iron per day	280 tonnes
blast-furnace initial rating per day	320 tonnes
ore per day	528 tonnes
coke consumption (22% ash) per day	360 tonnes
blower capacity (steam driven)	51 000^3/h against 1·4 kg/cm^2 (30 000 ft^3/min against 20 lb/in^2 wg)

To handle about 1 000 tonnes of raw material daily, a system, of furnace bins of one day capacity only, would be connected to railway sidings by conveyor belts. Since raw material supply is expected to be irregular, buffer stockyards are also included into which the balance of materials could be fed by a single high line conveyor with throw-off positions over the stockpiles. A mechanical shovel will be used to spread the stockpiles and to reclaim material, transferring them to a further conveyor which connects with the main incoming conveyor belt to the furnace bins. The capacity for this inexpensive substitute for the conventional stocking transporter bridge would be sufficient to meet initial requirements, working on a two-shift basis. As output demands increase, three-shift operation could later be introduced.

The electrically propelled scale car will withdraw material from the furnace bins to feed the furnace hoist. Operation of the skip by the scale car driver would be automatically interlocked with the bell opening and closing and distributor rotation, to ensure a proper sequence.

Iron would be cast five times a day into rail-mounted 60 tonne ladles fitted with lids to conserve the heat, which would be locomotive hauled to the steel melting shop. Surplus iron would be sand-cast into pigs. Later, equipment for granulation would be installed to allow easier handling and re-melting.

It is recognized that the iron production would have to be interrupted during furnace relining. A furnace campaign normally lasts anywhere from 4 to 10 years. By meticulous planning, and an abundant supply of labour, a relining process could if necessary be completed in three weeks. This period of three weeks could be used for general works maintenance.

STEELMAKING AND CASTING PLANT

Process selection

The choice of steelmaking and casting plant will be substantially influenced by local conditions ; nevertheless two broad classifications exist. The process may be based upon the use of hot blast-furnace metal, or alternatively, upon steel scrap. In the case of an integrated iron and steelworks as outlined here, it has been assumed to operate on a closed scrap balance.

Steel may be cast either by conventional methods into ingots which are then reduced to billets in a primary mill, or by continuous casting directly to billet size. These alternatives have been compared in conjunction with each steelmaking process. The choice of steelmaking and casting methods for an emergent country

TABLE III Furnace units required to produce 100 000 tonnes of cast product per year

Steel-making process	Furnace capacity, tonnes	Av. cycle time, min	Minimum cycle time, min	No. of furnaces installed	Method of operation
OH (normal)	60	480	450	2	Both working simultaneously on 84% furnace availability
LD	10	47	25	2	1 working whilst the other is being relined
Kaldo	13	62	45	2	1 working whilst the other is being relined

must be based primarily upon low capital cost. Operating costs have also been evaluated to establish that the basis is economically realistic.

The alternative steelmaking processes using a feed of hot metal are reviewed as follows :

Bessemer process

This process is thermally deficient with blast-furnace iron of low silicon or phosphorus content and may result in a scrap build-up within the works. Furthermore, an inferior product is obtained which, whilst being suitable for reinforcing bar and small structural sections, could hinder the development of a wider range of products. The use of oxygen steam blast overcomes this problem of quality but a scrap balance could only be maintained by installing an electric melting furnace at extra cost.

LD process

This method of steelmaking has developed rapidly in recent years because of its simplicity, low capital cost, and high production rate. Normally sufficient heat is derived from oxidation to permit the melting of scrap arising from a steelworks based on continuous casting. Modifications such as lime injection allow a wide range of blast-furnace metals to be treated. Oxygen is supplied to the converter which, in an integrated works without a piped supply, would be made in tonnage oxygen plant on the site.

Kaldo process

This oxygen process is in some ways a more versatile method of steelmaking than the LD process. Much of the carbon monoxide is burnt within the converter and this results in high thermal efficiencies. Thus comparatively larger amounts of scrap or ore may be consumed. However, the furnace is mechanically more complex and refractory consumption is higher than in the equivalent LD plant.

Open-hearth process

This is the most flexible process which accepts a wide range of charge mix. The slow driving rate and heat input affords good metallurgical control. However, the furnace units are comparatively large and expensive. Cheap fuel is essential for economic operation and although oxygen can be used to increase output from a given furnace size, the cost of suitable oxygen plant is likely to be at least equivalent to any reductions achieved on the steelmaking plant.

Comparison of processes

Within the confines of the assumed emergent conditions, capital and operating costs have been worked out for the open hearth, Kaldo, and LD processes, each operating with the alternatives of continuous casting and conventional casting into 20 cm (8in) square ingots. The basis of the comparison has been upon an initial output of 100 000 tonnes/a of cast product and the capital costs shown include all mechanical and electrical equipment, fully erected, together with the necessary ancillaries, i.e. lime kilns, tonnage oxygen plant etc. Services and transport costs are not included since they have been covered in a separate section. Information about the furnaces is shown in Table III, from which it will be seen that in each case a margin has been left on the theoretical minimum cycle time. This is in order to make an allowance both for future expansion and for the use initially of unskilled labour. A minimum heat size of 10 tonnes has been chosen to give a reasonable production yield per cast and a simplified casting operation.

TABLE IV Comparison of capital and operating costs of alternative steelmaking and casting plants

	Index of capital cost	Index of operating cost
OH + conventional casting + primary mill	188	148
OH + continuous casting	134	101
Kaldo furnace + conventional casting + primary mill	184	146
Kaldo furnace + continuous casting	108	98
LD furnace + conventional casting + primary mill	175	150
LD furnace + continuous casting	100	100

Note Operating costs include the cost of hot metal but exclude amortization and administration. Capital costs exclude civils.

In order that the comparison of the different processes may be based upon similar products, in the case of conventional casting the cost of a primary mill has been included. The results of this comparison investigation are shown in Table IV.

The main factor in selecting a suitable steelmaking process for an emergent country must be the initial investment cost. Under the particular conditions chosen, the LD/continuous casting combination has been selected and the reasons are shown below.

(i) the combination represents the lowest capital investment per tonne of productive capacity
(ii) the grades of steel required can be produced at low cost with adequate metallurgical control
(iii) the relatively simple expedient of lime blowing enables high phosphorus irons to be treated
(iv) the furnace works on a short cycle time producing small quantities of steel regularly
(v) a closed scrap balance can be maintained
(vi) refractory consumption is low
(vii) a high yield of saleable product results.

Factors influencing the choice of steelmaking process

The choice of steelmaking plant will change if conditions other than those assumed exist. For example, if some quantity of external scrap is available at a favourable cost, then careful consideration must be given to the Kaldo and OH processes. Fuel lances can be used to increase the scrap melting capacity of an LD furnace, but this must be assessed in the light of the inherent low thermal efficiency of this operation. Such lances could, however, be used on the proposed plant when the blast-furnace is being relined as during this limited period lower efficiency operation would be acceptable.

TABLE V Typical rolling schedule

Stand no.	Pass no.	Area mm² (in²)	Reduction, %	Dimensions, mm (in)	Length, m (ft)	Speed, m/s (ft/s)	Time, s
...	Billet	8 100 (12·55)	...	90 sq. (3·54)	5 (16·4)	...	...
1	1	6 310 (9·78)	22	...	6·44 (21·1)	2·6 (8·53)	2·48
1	2	4 540 (7·04)	28	...	8·94 (29·3)	2·6 (8·53)	3·44
1	3	3 320 (5·14)	27	57·6 sq. (2·26)	12·2 (40·0)	2·6 (8·53)	4·68
1	4	2 160 (3·34)	35	...	18·8 (61·6)	2·6 (8·53)	7·23
2	5	1 555 (2·41)	28	39·4 sq. (1·55)	26·1 (85·6)	2·6 (8·53)	10
1	6	1 025 (1·59)	34	...	39·6 (130)	2·6 (8·53)	15·2
2	7	746 (1·15)	27	27·3 sq. (1·07)	54·4 (178)	2·6 (8·53)	20·9
2	8	522 (0·809)	30	...	78 (256)	2·6 (8·53)	30
3	9	397 (0·615)	24	19·9 sq. (0·78)	102 (334)	3·4 (11·15)	30
3	10	294 (0·456)	26	...	138 (452)	3·4 (11·15)	40·6
4	11	235 (0·364)	20	15·3 sq. (0·60)	173 (567)	3·6 (11·8)	48
4	12	191 (0·296)	19	...	213 (698)	3·6 (11·8)	59
5	13	164 (0·254)	14	14·5 dia. (0·57)	248 (813)	4 (13·1)	62
6	14	132 (0·205)	19	...	308 (1 010)	4·9 (16·1)	62
7	15	113 (0·175)	14·7	12·0 dia. (0·47)	359 (1 177)	5·6 (18·4)	64
8	16	91·6 (0·142)	18·8	...	442 (1 449)	6·9 (22·6)	64
9	17	78·5 (0·122)	14·3	10·0 dia. (0·39)	517 (1 695)	7·85 (25·7)	65

Note : Gear ratio for stands 1 and 2 is 6·8 : 1 with 1 200 kW installed power (ac)
Gear ratio for stands 3, 4, and 5 is 3·54 : 1 with 800 kW installed power (dc)
Gear ratio for stands 6 and 7 is 2·5 : 1 with 350 kW installed power (dc)
Gear ratio for stands 8 and 9 is 1·82 : 1 with 350 kW installed power (dc)

Plant selection

The layout scheme (Fig. 2) shows a typical steelmaking and casting plant of this nature to produce 100 000 tonnes/a of 90–120 mm billets (3½–4½in). Only one of the two 10-tonne converters shown would be operated at a given time whilst the second is being relined. The continuous casting plant consists of two simple machines each employing a triple mould with space for a third machine. Expansion to 140 000 tonnes/a output can easily be achieved by operating the converters on the minimum cycle time of 32 min. In the layout, additional space has been allowed for a third 10-tonne converter which would be needed after the installation of a second blast-furnace. The steelmaking and casting plant consists of three bays : a hot metal and scrap charging bay, furnace bay, and the continuous casting bay. There is a separate material stockyard together with adjacent lime kiln and tonnage oxygen plant. Scrap boxes are filled in the mill area and transferred to the melting shop by road and to the converter by crane. The converters are slagged into pots in this bay which is served by a 20-ton ladle crane and a 5-ton scrap charging crane.

The furnace and tapping bay contains the two converters, waste gas stacks, lances and control gear. Steel is tapped into a ladle from the furnaces and transferred by car into the continuous casting bay.

The continuous casting bay is parallel and adjacent to the furnace tapping bay and is served by a 20-ton high-level crane. Steel is teemed via a stopper rod controlled tundish into the water-cooled triple mould of the Weybridge continuous casting machines. The billets are withdrawn horizontally from the machine on to roller tables where cut-off and parting torches prepare them before delivery to the billet stockyard.

A simple raw materials handling system is proposed and the conventional overhead bunker system eliminated. Boxes of the various additions are filled and weighed in an adjacent yard before transfer to the hot metal and scrap bay of the steel plant. From here they are lifted to the converter platform and charged by one of the overhead cranes.

ROLLING MILL

Process selection

The background development of the mill chosen for this installation is one which would initially produce rounds, squares, and hexagons from 10 mm to 15 mm, sections and angles, channels, joists and flats up to 75 mm. This can be produced from a nine-stand combination bar and light section mill, with a plant capacity of 100 000 billet tonnes/a. As the product requirement develops, the first need which could be satisfied could be for coiled rod of 6–10 mm (0·24–0·41in) section, the smaller size being suitable for wire drawing. At this stage, two-strand rolling could be introduced in the intermediate and finishing stands which would increase the total output by between 25% and 30%. The smaller sections could then be passed to a six-stand rod mill for further reduction.

As the plant developed further, heavier sections could be produced. A three-stand, three-high medium section mill would roll 15 m (50 ft) long channels and beams up to 175 mm (7in) section, as well as 150 mm (6in) angles, rails, and fishplates. The output of this medium section mill would be so dependent upon programme, that output rates cannot be pre-judged accurately, but the mill could fit into almost any overall integrated plant development programme.

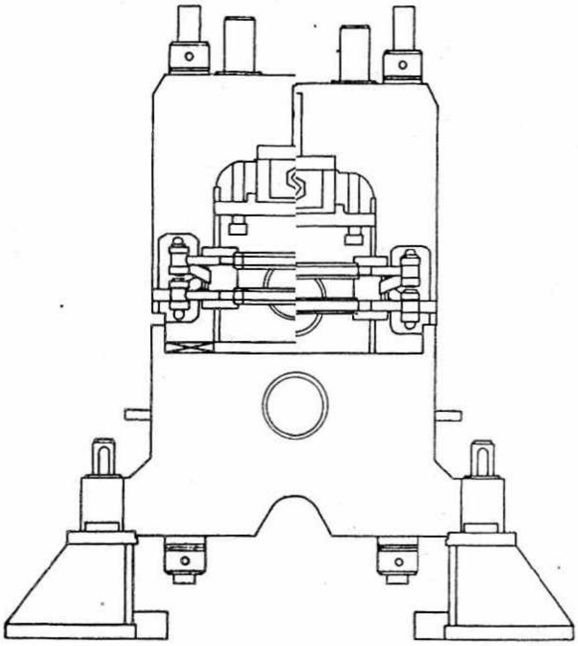
By using a continuous casting process, the capital and operating expense of a breakdown mill would be saved. The billets for the bar mill would therefore arrive in the rolling mill perimeters in 90–120 mm (3½–4½in) square size of 3 or 5 m (10–16½ ft) lengths. The second stage development of a medium section mill will accept 120, 150, and 180 mm square billets of the same alternative lengths. The 10 mm (0·4in) dia. rods can be rolled in the proposed mill at the rate of about 12 tonnes/h. With sections over 18·5 mm (0·73in) the limit on output would be that of a furnace capacity, i.e. 35 tonnes/h.

This type of mill and mill development has been chosen because of the scale of plant contemplated initially. Such a plant would have the first essential of rolling small quantities of a wide range of products to reasonably close tolerances, at the same time, laying plans for future stage-by-stage expansion. Such a mill would not be dependent on highly skilled operators for general manning. It is recognized that there will also be a national demand for galvanized sheet, but it is suggested that this area of production is uneconomic in small-scale operation, as is the production of plate and heavy section. It is suggested, therefore, that the small-scale plants installed concentrate on the production outlined above, developing into the medium section range whilst the production of sheet, plate and heavy section, be concentrated in large-scale integrated installations.

Plant selection

Billet reception

After dressing and inspection, billets will be charged

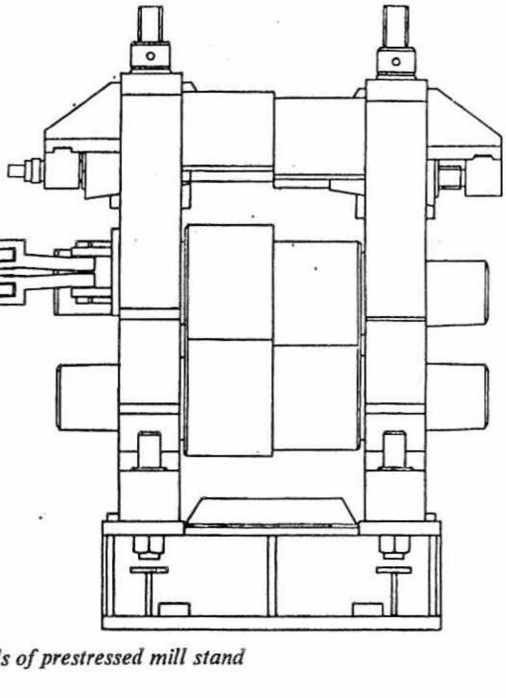


3 *Details of prestressed mill stand*

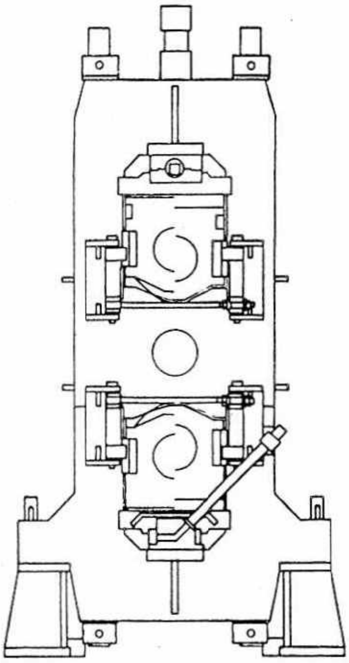
into a two-zone oil-fired re-heat furnace. Use of end charging and discharging can lead to appreciable cost saving, thus this method has been adopted. It would, however, be necessary to separate the billets manually. An adjustable hydraulic pusher would feed and discharge the billets into the furnace singly.

Roughing stands

Billets leaving the furnace area pass to a two-stand three-high roughing mill with roll size 470 mm dia. × 1 400 long (18·5in × 55in). The billet enters the lower roll gap on the first stand and is raised to return in the upper roll gap by an automatic tilting table. It is then returned and positioned in the lower gap by an automatic drop guide. After four passes, the billet is sufficiently small to be guided by repeaters to the second stand.



4 *Details of prestressed mill stand*



5 *Axial adjustment of mill by winged chock and stud arrangement*

Intermediate stands

From the roughing stands the bar is driven by pinch rolls through a transfer tube. The front and rear ends are trimmed by a photoelectric controlled crop and cobble shear during transfer. Heavier sections which are too big to repeat are transferred by roller table. The intermediate mills, which for large sections would complete the finishing pass, consist of two 370 mm dia. × 900 mm long (14·6in × 35·4in) three-high stands, and one 430 mm × 600 mm long (16·9in × 23·6in) two-high stand, each fitted with repeaters for the smaller sections.

Bar finishing mill

Sections below 14½ mm (0·57in) are finished in two pairs of 288 mm × 480 mm (11·3in × 18·9in) two-high stands fitted with repeaters. A typical rolling schedule is shown for the mill in Table V.

Cooling bed

Finished material either from the intermediate or bar finishing mill is carried to the cooling bed on a high-speed roller table fitted with electronically controlled flying shear for cutting to lengths suitable for the 50 m (164 ft) bed. At the end of the roller table the bars are pushed off on to a chain conveyor and transferred slowly across stationary skids to be discharged by gravity and collected in batches for shearing to length by a 250-tonne shear. In order that the shear may keep up with production, some multiple cutting will be essential but it is felt that this would be acceptable in order to save initial capital cost.

Development to produce small-section rod

From the bar finishing mill 10 mm (0·4in) sizes would be further reduced to 6 mm (0·25in) in a six-stand 280 mm dia. × 480 mm long (11·0in × 18·9in) rod mill train driven through a multiple gearbox from one motor. With the installation of coilers at this stage, rods up to 30 mm (1·2in) dia. could then be coiled on one of four hydraulically stripped pouring reels capable of coiling up to 0·48 tonne. The coils would discharge on to a high-speed flat conveyor which would deliver them in the horizontal position to a hook conveyor.

Mill for heavier structural sections

The heavier structural sections would be rolled in a medium section mill of two three-high stands 550 mm dia. × 1 600 mm long (21·7in × 63·0in) and one two-high stand 520 mm × 1 000 mm long (20·5in × 39·4in).

Pre-stressed stand design

The first prerequisite of accurate tolerance control is a stiff, rigid mill structure. The best way of achieving this whilst retaining reasonable mill dimensions and accessibility is to pre-stress the load-carrying members. Figures 3–5 show a mill design with this feature which has been simplified to the point where it can be fabricated from oxygen-cut steel plate. All three-high stands in the proposed mill area would be of this pre-stressed design, with a fixed middle roll and hydraulically balanced top roll, the top and bottom rolls being adjusted by wedges. The wedges themselves are driven by screws designed to have very small backlash so that the roll adjustment is positive and precise whether the rolls are being lifted or lowered An advantage of this type of stand is that it permits the use of roller bearings. The stand components are bolted firmly together, giving a minimum of free surfaces in contact, hence mill spring is not increased unnecessarily as components bear down under load. It is felt that these advantages are most relevant in a mill which is to be operated by unskilled crews. Two-high stands would be designed similarly so as to have identical bearings and chocks, thus leading to simplification of the spares provision. In this case wedge adjustment would be provided on the bottom roll. Both the wedges on any one roll are operated simultaneously by a single screw, which in turn can be adjusted to level the rolls. Axial adjustment is provided by a winged chock and stud arrangement which can be seen in Fig. 5.

APPENDIX A

Plant items included in base capital cost, ironmaking plant

- Blast-furnace
- Refractories
- Three 60-tonne ladles
- Concrete bin system
- Gas cleaning plant
- Materials handling
- Plant erection
- Spares

APPENDIX B

Plant items included in base capital cost, steelmaking plant

- LD steelmaking plant
- Continuous casting plant
- Lime burning plant
- Tonnage oxygen plant
- Refractories
- Ladles, cars, stands, etc.
- Electrical engineering
- Buildings
- Services
- Erection
- Spares

APPENDIX C

Plant items included in base capital cost, rolling mills plant

- Mill mechanical equipment (erected)
- Mill electric drives (erected)
- Buildings
- Amenities
- Reheating furnaces
- Oil storage
- Cranes for rolling mills and billet stock yard
- Electricity distribution
- Cables
- Lighting
- Miscellaneous mill operating equipment
- Rail and guide shop equipment
- General maintenance equipment
- Interconnecting services and pipe work
- Spares

APPENDIX D

Plant items and services included in base capital cost, overall integrated plant co-ordinating

- Site survey and overall site co-ordination
- Earth moving and site clearance (this is a minimum charge for a flat site)
- Boundary wall and gate house
- Roads
- Railways
- Drainage (minimum charge for a flat site)
- Water services
- Administration block
- Civil engineering maintenance, shop and stores
- Laboratory
- Transport equipment
- Blast-furnace gas and air main
- Spares

(*Note* The above is based on specified general site conditions given in Appendix E, and is therefore a minimum cost.)

APPENDIX E

Summary of assumed site conditions

1*a* The chosen site is adjacent to a main road and railway, is flat and there is no space restriction.

2*a* Soil bearing pressure is 2 tons/ft

3*aaa* The supply of iron ore from a local site is ungraded but contains no lumps over 20 cm (8in) major dimension.

4*aa* The ore analysis on a dry basis is as follows:

Iron	60%	Manganese	0·1 %
Silica	0·8%	Phosphorus	0·12%
Alumina	1·8%	Sulphur	0·05%.

The raw ore contains 5% moisture.

5*a* Dolomite blocks can be delivered to site. No burning plant is necessary.

6*aa* Sufficient electricity supply is available to supplement works generated power.

7*aa* There is a township available in the district, where living accommodation for employees can be found.

8 The mean temperature on site will be 25°C. Maximum temperature 45°C, minimum temperature 5°C.

9 There is sufficient piped supply of settled unfiltered water from a local river which can accept effluent downstream. Incoming water solids content not greater than 25 ppm.

10*a* Coke is available delivered to site to the following analysis:

C	76%	S	0·55%
SiO_2	11·31%	Fe	2·10%
Al_2O_3	6·03%	P	0·18%
CaO	0·64%	Ash	22%
MgO	0·33%		

11*a* Limestone to the following specification is available locally:

CaO	48% (85·7% CO_3)	Fe_2O_3	1%
MgO	3% (6·27% Mg CO_3)	$S{\cdot}O_2$	2%
Al_2O_3	1·5%	Moisture	3·53%.

12 Product specification:

C	0·1–0·15%	P	0·06% max.
Si	0·1% max.	S	0·06% max.
Mn	1·2% max.		

APPENDIX F

Assumed labour and materials costs

Labour	Engineers and commercial staff	£135/month
	Assistant engineers	£86/month
	Junior engineers	£45/month
	Site supervising staff Grade 1	£47/month
	Site supervising staff Grade 2	£35/month
	Site supervising staff Grade 3	£25/month
	Site supervising staff Grade 4	£15/month
	Skilled labour Grade 1	15*s*/day
	Skilled labour Grade 2	8*s*6*d*/day
	Skilled labour Grade 3	5*s*6*d*/day
	Unskilled labour	3*s*6*d*/day

Materials	£	*s*	*d*/ton
Iron ore	1	5	0
Boiler oil	8	10	0
Coke	4	17	6
Scrap	12	6	0
Limestone	1	6	0
Burnt dolomite	10	11	0
Electricity	0·8*d*/kWh		