STEEL IN INDIA
ECONOMIC AND TECHNICAL POSSIBILITIES

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Summary

The growth of agriculture and of consumer goods industries hinges upon the advance made in heavy industry. Taking a long range view of the development process, the proper investment choice is one based on heavy industry which maximizes future benefits rather than one which satisfies some present needs but jeopardizes future growth. As assured supplies of steel are vital to the growth of heavy industry and as installation of steel capacity is a time-taking process, planning for steel has to be done on a long-term basis. A study of steel going into various sectors of the economy, to meet the physical targets laid down by the Planning Commission for the future, indicates that requirements would reach the level of 19 million ingot tons by 1970 and 28 million tons by 1975; the probable steel demand is expected to rise to over 100 million tons by the end of the century. In line with worldwide trends, India would have to rely on large complexes (of up to 10-12 million ingot tons capacity each) for the bulk of the above steel, the balance being met from a large number of widely dispersed smaller plants to meet regional demands.

India is well endowed with the raw materials and other conditions necessary to produce the lowest cost steel in the world, and is therefore well placed for export. Indeed, countries such as Japan and the UK, in spite of having to import the bulk of essential raw materials, still succeed in exporting large tonnages of steel and steel manufactures. For instance, in 1960, the UK produced 24 million tons of ingot steel of which 5.6 million tons (that is, 4.2 million tons finished steel) went into direct exports worth £ 230 million. According to a recent estimate by the U.N. Economic Commission for Europe, by 1972-75, the total world trade in steel for deficit-covering after allowing for steel exchange between countries, would be over 35 million tons; in the Middle-East and the Far-East countries alone, there would be a shortfall of about 11 million tons by that time. Though the steel expansion programme for India indicated earlier does not include any steel for export, it is suggested that serious consideration be given to export, say, 2 million tons of steel (worth about Rs. 1,000 million) by 1970. At this rate, steel could easily become the largest single earner of foreign exchange so vitally required for further development. The steel from the newly created capacity, whether exported or absorbed internally, will help earn or save foreign exchange as the case may be—both very desirable objectives.

The expansion of steel capacity requires urgent attention to ensure continuing supplies of raw materials to the industry. While our iron ore reserves are one of the largest and best, the present supply of coal and flux-grade limestone is critical and allows no ground for complacency. However, the raw materials reserves can support a large expansion of steel

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production by the adoption of new proved technological developments to conserve the known supplies and by sustained and coordinated effort to survey new deposits. Modern methods to improve blast furnace performance include beneficiation and preparation of raw materials, the use of self-fluxing sinter, higher top pressure, higher blast temperatures, and additions of moisture, fuel gas or oil, oxygen, etc. to the blast. Economics of using sinter are so attractive that it is considered even desirable to create fines by further crushing the ore, over and above the natural fines available, in order to have a high proportion of sinter in the burden. Using the above techniques, in modern blast furnaces (2,000-3,000 tons per day), the coke rate could in the future be reduced to about two-thirds of the present requirement. An examination of new developments in steelmaking indicates that the basic oxygen (LD) converter process—due to its lower capital and operating costs and present availability of scrap—could produce 30 to 35% of the total steel in India in the next ten years. However, to maintain a proper overall scrap and fuel balance the open-hearth process, revitalized by recent developments such as bigger unit sizes, the use of oxygen and basic roofs will continue to find an important place. Small-scale ironmaking plants based on electric smelting processes and small blast furnaces would also play a significant role in places remote from coking coal.

The human implications of the steel expansion programme are reviewed. Future steel expansion is to be mainly through the agency of the public sector. To enable the new State undertakings to operate successfully, a reorganization of the management structure, giving it greater administrative and financial autonomy, is necessary. Appointment of technical personnel with requisite plant experience in top management positions is also essential. Facilities for specialized technical education and for practical training—including training in management techniques—need to be greatly expanded. Greater reliance on Indian technical talent will ensure that processes suited to Indian conditions are adopted, equipment standardized to facilitate work of the new machine building plants, and construction programmes scheduled on a continuing basis to make full use of scarce equipment and personnel, thereby appreciably reducing present construction costs.

The objection raised in some quarters against rapid development of the steel industry is a short-term view. Those who doubt India's ability to mobilize its raw materials and manpower resources, and cope with the large expansion visualized, exaggerate our difficulties—and also, do not take into account the bold progress made in the last decade despite heavy odds.

Introduction

'I am greatly honoured by your invitation to deliver the Sir M. Visvesvaraya Lecture in the centenary year of his birth, and I shall take this opportunity to discuss the economic and technological possibilities of the Indian steel industry.

The subject is appropriate to the occasion, because Sir Visvesvaraya has been closely associated with the steel industry, both as a founder of the Mysore Iron and Steel Works at Bhadravati and as a Director of the Tata Iron and Steel Co. from 1927 to 1955. More than that, Sir Visvesvaraya was the first to make out a consistent and well argued case for industrial development in his book 'Planned Economy for India', which appeared in 1934. This book came at a time when India, along with many other countries of the world, was plunged in a severe and sustained economic depression. The rising tide of distress was leading many to turn their face against modern industry and hark back to the idyllic world of self-sufficient village communities. In the prevailing climate of opinion it required both courage and clarity of vision to advocate rapid industrialization, as Sir Visvesvaraya did within the compass of a 10-year national plan. As he said,

> 'A planned economy is required to ensure the rapid advance of industry, agriculture, commerce and finance, and particularly for increasing production and earning power, reducing unemployment, and encouraging greater self-sufficiency and closer interdependence between the various parts of India'.

Today, a quarter of a century later, there is no longer any debate over the merits of industrialization. All sections of opinion, barring certain obscurantist individuals, welcome it. In fact, the choice had been made when we embarked on planned development in 1951 with the idea of 'utilizing more effectively the potential resources available' to raise 'the living standards, and open out to the people new opportunities for a richer and more varied life'.[1]

Economic Considerations

A good beginning with social overheads having been made in the First Plan, the Second Plan was formulated with noticeable greater weightage to industrial development, with about 20% of funds earmarked directly for mining and industry. Of this 20%, almost 80%[2] was claimed by heavy industry projects, marking an important departure in the direction of economic advance. In the proposals made for the Third Plan, there has been an even greater shift towards heavy industry. Since the role of steel in the economy is dependent on the importance we assign to heavy industry, it will be pertinent to examine here the issues arising from the choice made by our planners.

Topmost priority for agriculture

Those favouring priority for the development of consumer goods industries will recognize that by far the largest pressure of consumption is on the supply of foodgrains. Over 90% of our countrymen live on less than a rupee per day, and must, therefore, devote nearly all their disposal income to buying food to keep alive. The development of agriculture will have to proceed at a high rate for many years to come, because we have not merely to provide a sufficiency of cereals to sustain an increasing population but must also aim at improving the standards of nutrition. The present day Indian diet is gravely lacking in calorific content as well as the essential elements needed for the protection of health.

Agriculture depends on industry

Undoubtedly, agriculture must receive top priority in our planning. But to look at the problem of agriculture in isolation would be a mistake. The major increase in food production in future, as in the Second Plan, will have to depend on measures relying heavily upon science and technology, such as improved seeds, major irrigation and fertilizers.

There is also the separate but equally pressing problem of drawing away from the countryside the under-utilized manpower already there. The magnitude of labour surplus in agriculture will be immediately evident if we remember that in the more advanced countries only 12 to 15%[3] of the population is deployed on the farms, as against over 70% in India. While a shift in the occupational pattern will have to be a very gradual process spread over several decades, we cannot even begin to tackle the problem except in terms of such rapid industrial development that makes possible large-scale absorption of manpower in sectors of the economy other than agriculture.

The case for rapid industrialization, therefore, rests not merely on the merits of industrialization *per se*, but also on the patent need to rehabilitate agriculture itself. As the Third Plan outline states, 'It is recognized that beyond a stage, the growth of agriculture and the development of human resources alike hinge upon the advance made in industry. At all times, agriculture and industry must be regarded as integral parts of the same process of development'.[4]

Choice between capital and consumer goods industries

The building up of heavy industry and the development of consumer goods industries to ameliorate the living conditions of the common man, are not mutually exclusive alternatives. Indeed, as the Third Plan visualizes, both must develop side by side. We may note, for instance, that the Third Plan envisages increases of 33 to 40% in foodgrains,[5] 22% in cotton textiles (taking the mill and hand sector together),[6] and 33% in sugar.[6] The whole scheme of development is predicated upon the assumption that consumption will rise by over 4% per annum.[7]

The question really is one of deciding the allocation between consumption and investment in the rising national income. There is no doubt of the real need to raise consumption standards as rapidly as possible. However, should we settle for a strategy of growth that maximizes immediate benefits but jeopardizes the long-term prospects, or, should we opt for a pattern of development which, while not bringing immediate benefits on the same scale, will ultimately make possible much higher rates of economic growth and consumption than otherwise? It is really, therefore, a question of making the right choice between present needs and future hopes.

With miserably low living standards today, and with population growing at over 2%[8] per annum, our pace of development has to be greatly accelerated. If we seek a more rapid growth, we would obviously have to depend on increasing production from the heavy industries generally, which would increase the capacity for capital formation.

Economic development—the upward spiral

As is well known, economic development in India and similarly placed countries is "held back by a series of 'interlocking vicious circles'. Before it starts, economic development is hard to visualize because so many different conditions must be fulfilled simultaneously."[9] But once development gets under way, all the prerequisites and conditions for development are themselves brought into being, and the process becomes an upward spiral.

The choice of investments is decisive in determining this tempo of development, because, as has been said, 'investment is a many-sided actor on the economic scene.'[10]

It not only generates income and creates capacity, but it plays a third role on the top of the other two, *viz.*, setting the pace for additional investment. Our approach should, therefore, be to look for investment that induces the largest amount of investment in subsequent periods. For instance, it has been convincingly argued[11] that an expenditure of Rs. 450 crores with a foreign exchange component of Rs. 300 crores in plants for manufacture of heavy machinery, mining and chemical machinery, machine tools, and other basic industries, will enable us to equip a large complex of industrial units whose annual output will run into hundreds of crores. This will ensure both faster economic growth and greater foreign exchange saving than would be possible if we were to take today the line of least resistance and apply our limited resources to securing the larger immediate benefits available from an emphasis on consumer industries.

Foreign exchange considerations

Quite apart from this strategy of economic development, there is urgent need to press on with heavy industry on the compelling grounds of foreign exchange difficulties. Today, about 50% of the capital goods requirements of the Indian industry are met from imports. Since maintenance imports alone exhaust our foreign exchange earnings,[12] the growing requirements of capital equipment as industrial development proceeds will impose an intolerable pressure on balance of payments. Our traditional exports of plantation crops and other agricultural produce are stagnating, which is evident from the fact that, while the total volume of world trade has increased by two-thirds in the past 30 years, the volume of India's exports has actually declined. Clearly, therefore, the increase in world trade has passed this country by, because the demand for the kind of things we have to sell is not particularly elastic.

The only viable solution is, therefore, twofold. Firstly, we must diversify our exports, particularly in the direction of new industrial products like metal manufactures, engineering goods, chemicals, etc. in which world trade is rapidly expanding, and secondly, we must cut down our foreign exchange requirements by attempting to manufacture the capital goods ourselves, which in turn require the continuing expansion of the steel industry to provide an assured supply of the basic raw material. This point of view is now widely acknowledged and was given authoritative expression by Shri H. V. R. Iengar, Governor of the Reserve Bank of India, in his Address at the Annual Meeting of the Bureau of Industrial Statistics on November 30, 1959, when he said that 'if a steel plant had been put up during the First Plan period, India would have not only got the plant cheaper, but also saved considerable foreign exchange spent to import steel.'

Exportability

India is well endowed with the raw materials and other conditions necessary to produce steel more cheaply than any other country in the world. Indeed, Japan and the UK which import the bulk of essential raw materials—ore in the case of the UK and both ore and coal in the case of Japan—still succeed in exporting large tonnages of steel and steel manufactures. For instance, in 1960, the UK produced 24.2 million tons of steel, of which 5.6 million tons (that is, 4.2 million tons finished steel) went into direct exports. In value, this represented some £ 230 million, which more than covered the cost of all raw materials imports by their steel industry. In addition, indirect export of steel in manufactured articles was equivalent to another 4 million ingot tons.

Similarly, in 1960, Japan imported two-thirds of its total requirement of iron ore and almost one-half of its coking coal at approximately four times the raw materials costs incurred at Indian steel plants ; however, it still succeeded in exporting about 1.8 million tons of steel (that is, 1.35 million tons finished steel). According to a report by the Government of Japan Economic Deliberation Council, by 1970, Japan plans to import 45 million tons of its requirement of 57 million tons of ore, and 22 million tons of its requirement of 31 million tons of coal, to produce 48 million ingot tons of steel of which 4 million tons would be exported. In addition, another 5 million tons of steel will go into its export of ships, machinery, etc.

Due to the significant role of steel in any country's economy, there is a widespread desire for self-sufficiency in steel, and a large number of new countries are joining the ranks of the steel producers. However, according to a recent estimate by the U.N. Economic Commission for Europe, by 1972-75, the total world exports of steel for deficit-covering after allowing for steel exchange between countries would be over 35 million tons ; in the Middle-East and the Far-East (excluding mainland China and North Korea) alone, there will be a shortfall of over 11 million tons per year by that time.

The steel expansion programme for India indicated later does not visualize any steel for export. It is suggested, however, that serious consideration be given to export, say, 2 million tons of steel (worth over Rs. 1,000 million) by 1970. At this rate, steel could easily become the largest single earner of foreign exchange vitally needed for development of our economy. The steel from the newly created capacity, whether exported or absorbed internally, will help earn or save foreign exchange as the case may be—both very desirable objectives.

It is believed that the cost of Indian steel could be fully competitive in the world market as indicated by the following comparison with foreign home trade prices.[13] In this comparison, 'retention prices' have been used for Indian steel, because these prices are realized by the producers and reflect their production costs plus profits ; thus, they are comparable to the 'home trade prices' in the foreign countries.

Item	Retention price,* Rs. per ton	Home trade price, Rs. per ton		
	India	U.K.	Germany	U.S.A.
Billets	382	430	495	520
Joists	504	518	565	710
Plates	497	585	665	750
Rails	495	540	585	645
Rounds	491	542	590	725

* Prices for tested quality including increases sanctioned in November 1959 and April 1960, less the freight component.

Apart from direct export of steel, India is also in a position to export manufactures of iron and steel. Our export of engineering goods (using iron and steel) has recently risen in value from Rs. 34.7 million in 1959 to Rs. 62.7 million in 1960 and can be further increased substantially in the Third Plan.

Role of Steel in Economic Development

Having discussed why heavy industry should spearhead economic development in India, let us now discuss the role of steel—the first requirement for building up heavy industry itself. As we all broadly know, a correlation can be established between the per capita consumption of steel and energy and the levels of national income. This is only another way of saying that the degree of industrial development, of which the per capita consumption of steel and electricity are good indicators, determines the country's prosperity and the living standards of its people.

Steel and economic growth

In a recent study by the Economic Commission for Europe,[14] the steel consuming countries are divided into three arbitrary groups. The first consists of countries at the

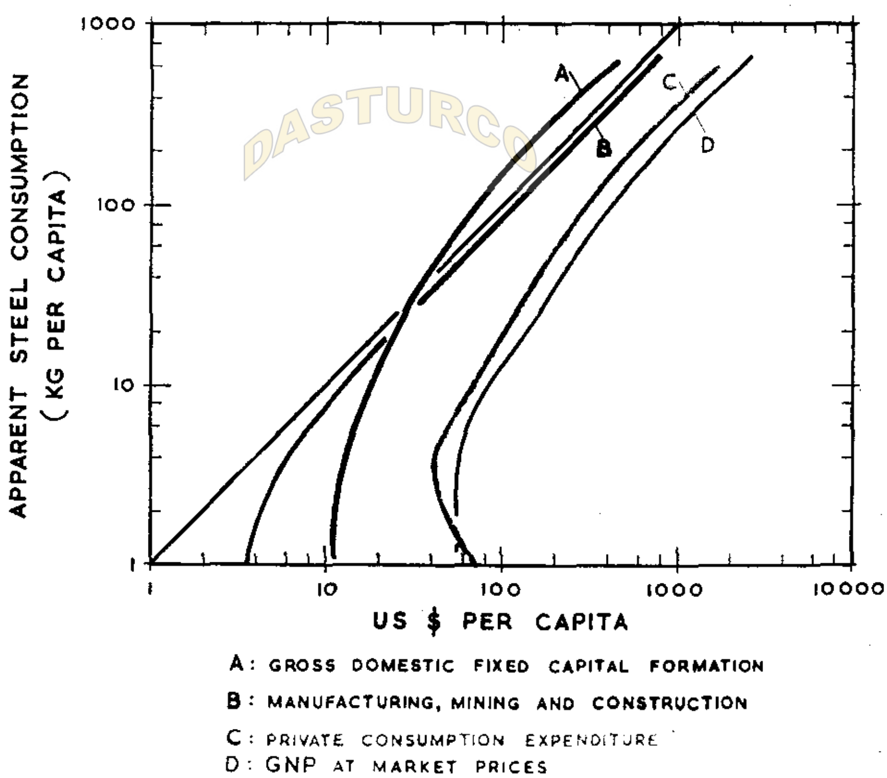

Fig. 1

Relationship between steel consumption and selected macro-economic variables[15]
(All items per capita)

very start of economic development with a per capita steel consumption under 5 kg. The second group, which India has just entered, occupies an intermediate position and has a per capita consumption ranging from 6 to 50 kg. In the last group are highly industrialized countries where the per capita consumption is more than 90 to 110 kg. Statistics collected for 50 countries to show the relationship between steel consumption and four major indicators of economic growth help us to see very clearly the role of steel in development, as given in Fig. 1 above. The indicators chosen are first, the national income per capita, because this by itself is a good index of the degree of economic development attained. The second is the value of industrial production per capita which indicates the degree of industrialization. The third is the per capita gross capital formation within the country which indicates the rate of economic growth. The last criterion is the consumption expenditure per capita, which is a good measure of the standard of living.

It is interesting to note that in the early stages of economic development steel consumption seems to increase at a rate faster than industrial production, because steel is being mainly used at that time for investment in infra-structure projects like bridges, dams and railways, as in India's First Five Year Plan. In fact, in some cases, living standards may actually decline in this initial stage. Once this stage is passed, every increase in steel consumption brings about a larger increase in industrial production and income, until very high levels are reached.

Apart from the generalizations made on the basis of economic correlations, a recent study[16] of the degree of interdependence of industries in Italy, Japan and the USA is of exceptional interest in judging statistically the role of steel in the economy. The degree of interdependence is defined by computing the proportion of total output of each industry that goes to other consuming industries (and not to final demand), and also by computing the proportion of its output that represents purchases from other industries. These measures show the extent to which one industry interlocks with others, indicating the 'forward and backward linkage effects.' It follows that industries with the highest linkage effects provide maximum growth stimuli in relation to industries using their output and also in relation to other industries from which purchases are made.

The conclusions of this study may be summarized thus : 'In any event, it is interesting to note that the industry with the highest combined linkage score is iron and steel. Perhaps, the underdeveloped countries are not so foolish and so exclusively prestige motivated in attributing prime importance to this industry !'[17] This is amply borne out by my own experience in Peru, Colombia and Venezuela where I was associated with the initiation of new steel plant projects. These countries with small populations, and some of them even lacking major raw material resources such as coking coal, still decided to have their own steel industry. Here also, initially, grave doubts were raised from some quarters that it would not be economic. However, they went ahead with their plans, and even before construction was completed it was found necessary to expand the initial plants. Also, in countries such as the Philippines, Indonesia, Ceylon, Pakistan and Iran, indigenous steel manufacture is being developed in spite of severe handicaps.

Employment potential of steel

Some critics of steel expansion take their stand on its low employment potential. If the number of jobs created by each unit of investment was the sole criterion for the choice of projects, the same people should even more vehemently oppose investment in power which calls for a capital outlay of Rs. 250,000 per worker as against Rs. 80,000 in the steel industry. The answer to this argument was very succinctly given by our Finance Minister, Shri Morarji Desai, in an address last year at Jamshedpur when he said:

> 'It should be obvious that the development of secondary industry itself hinges on steel, the basic raw material for all industries. If the emphasis had been on steel production in the First Plan, we would not have to worry now...... As the needs of industry and agriculture are bound to grow in the years to come, the solution lies in increased production of steel.'[18]

Just as the employment benefits of investment in power cannot be measured simply by calculating the returns on the power plant or the employment it provides, we have to look for the employment benefit of the steel industry over the entire chain of developments set in motion by the bringing into being of a steel plant. Indian data on this being lacking, I shall cite here some estimates of employment generated by steel which were worked out by the American Iron & Steel Institute. It is reported that every worker in the steel industry creates factory jobs for another eight in plants which could not come into existence without an assured supply of steel. These factory jobs apart, the steel industry creates additional jobs in non-manufacturing industries like mining, transportation, construction, etc. which are not included in the data presented above. This illustrates the 'backward and forward linkage effect' discussed earlier.

I feel sure you will now agree with me that while the objections against the further development of the Indian steel industry are well taken from the short-term viewpoint, it is difficult to accept their validity taking a longer view of the development process. I suppose, however, that one can only take a long view if one has faith in the country's economic future, and has confidence in planning as an instrument of advance.

Planning for Steel

In the foregoing sections, I attempted to show that heavy industry, which is largely dependent on steel, alone can provide a reliable foundation for rapid and sustained economic growth. In fact, even advance in agriculture will call for increasingly higher industrial outputs. This provides then the rationale for accelerating the development of the steel industry.

Although steel production is known to play a key role in the growth of a country's economy, steel development in India has lagged. At the beginning of the First Plan, based upon the work of the Iron and Steel Major Panel, the future demand seems to have been underestimated, and half-hearted planning for a one-half million ton steel plant initiated. It is now generally recognized that the severe foreign exchange crisis in the Second Plan was largely due to this lapse in comprehending our future needs and providing for them by building a steel plant in the First Plan. The urgency of expanding steel production seems to have been better appreciated in a country such as China which is faced with development problems similar to ours. This is evident from the fact that in the last eight years, while steel output in China multiplied more than twelve-fold, production in India only doubled. While some Chinese statistics may be of doubtful accuracy, I for one have no doubt, after seeing the Chinese industry in 1959, that it is pushing forward boldly and rapidly.

Cement/steel imbalance

That the development of the steel industry has so far been very halting in our country is sharply brought out by the unusual ratio obtaining between the output of cement and steel. In most industrialized countries, steel production is considerably higher than that of cement. For instance, during the 1950-59 period, the ratio of cement to steel production in the USA, the USSR and the UK was always between 0.4 to 0.67,[19] that is, the tonnage of cement production was only one-half that of steel. In India, however, the cement/steel ratio has been 2.5 to 3.26. It is not suggested that cement production be curtailed, only that steel output must increase more sharply than hitherto, so that eventually a ratio similar to that found in other industrialized countries begins to obtain.

Here again, it is interesting to see the Chinese performance shown graphically in Fig. 2. A decade ago, China and India were at the same level and both produced twice as much cement compared to steel. However, China has already caught up with the trend prevailing in the highly industrialized countries, and currently produces more steel than cement, but Indian steel production continues to be only one-third as compared with cement.

Long-term planning essential

As installation of new steel capacity together with development of ancillary facilities such as new mines, washeries and railways is a time-taking process, planning for steel has necessarily to be done on a long-term or perspective basis. It has in fact been said that the difficulties faced in the Second Plan period in the expansion of the steel industry are largely the result of inadequate realization of this inherent lag factor, emphasizing the need for planning well ahead in the future. Consequently, while planning for 1965-66, we have to keep in mind the possible requirements of the Fourth, Fifth and succeeding Plan periods, to ensure continuing expansion of existing capacity and initiation of new capacity at appropriate intervals.

Estimating future steel requirement

A number of methods are available for forecasting future steel requirements, for instance, establishing a correlation between steel consumption and macro-economic variables such as national income, industrial output, gross capital formation, or per capita consumption expenditure. These projections are more meaningful in a stabilized economy, but they are not wholly relevant in an underdeveloped country where growth is being accelerated by planned effort, and the components of national income are consequently changing. In fact, economic development is predicted on the assumption that the dynamic industrial sector should yield an increasingly larger share of the national income. Under these circumstances, more reliable estimates can be obtained by the 'end-use' approach.

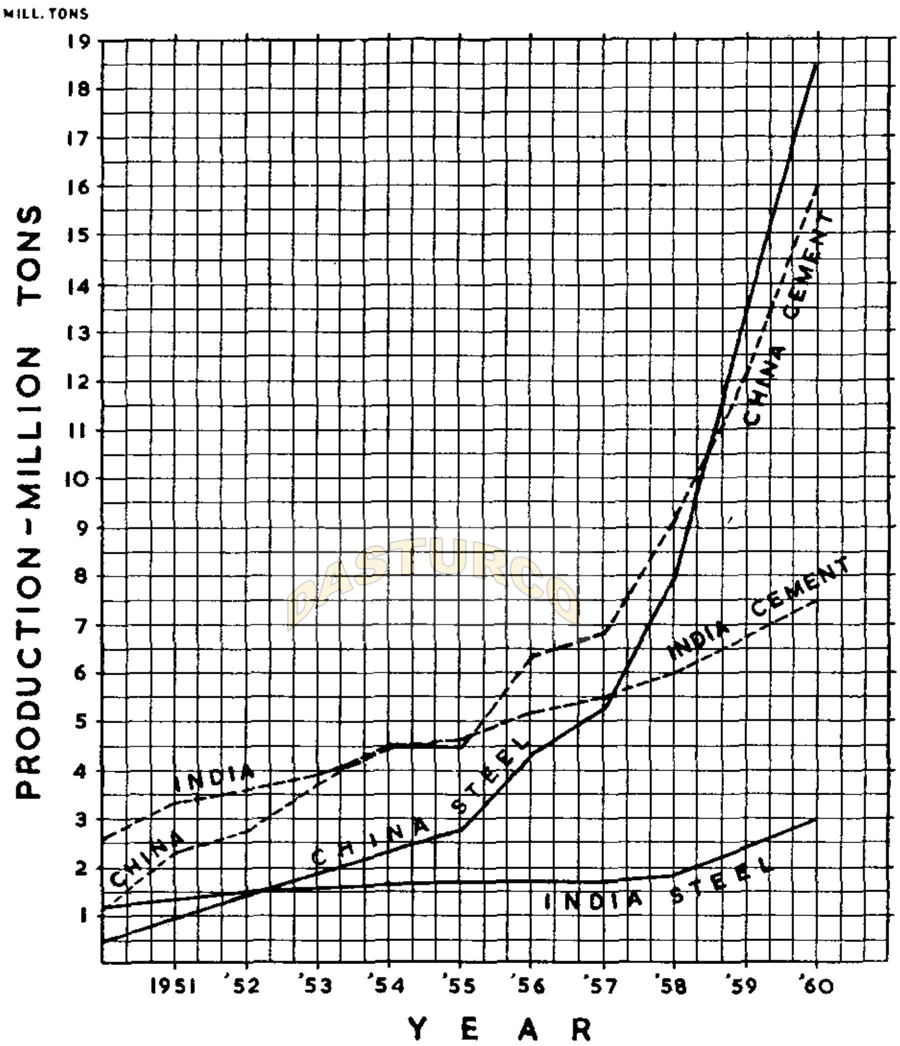

Fig. 2

Production of cement *vs.* steel in China and India, 1950-60

'End-use' approach

The 'end-use' method works out the steel component of various industrial and construction targets laid down by our planners, thus arriving at an aggregate of the demand from various sources. The exercise is based on the use of predetermined norms of steel required per unit of production or construction, the norms themselves having been established as a result of both emperical study in Indian conditions and comparisons with those worked out abroad, chiefly by the American Iron & Steel Institute. After arriving at the requirements under the major heads, additions are made to take care of unspecified consumers and stocks, basing again on past experience.

A recent study made by my colleagues, in connection with a preliminary report on the fourth steel plant at Bokaro, estimated the steel requirements by the 'end-use' method at about 12 million ingot tons by 1965-66, to meet the various production and construction targets as set down in the Plan. This level of production is by no means large when viewed in the light of our vast population. Expansion from 6 to 12 million tons in a five-year period is also well within our capabilities. It should be noted that the USSR accomplished a jump from about 6 million tons of crude steel to 18 million tons in seven years from 1931 to 1938[19] and China attained an even faster rise—from about 3 million tons in 1955 to 18.5 million tons in 1960.[19] There may, however, be ideological objection to the examples cited. It is necessary, therefore, to point out that at the beginning of the century Germany advanced from 6 million tons in 1900 to about 14 million tons in 1910; the USA moved up from about 4 million tons in 1890 to over 10 million tons in 1900 and 26 million tons in 1910.

A consumption of about 12 million ingot tons by 1965-66, when the population is expected to be about 480 millions, would give a per capita consumption of only 25 kg. As against this, the current per capita consumption is 40 to 70 kg in many Latin American countries such as Argentina, Chile, Cuba and Mexico, which also have under-developed, largely agricultural economies.

110 million tons by end of the century

Following the estimate of 12 million tons in 1965-66, we attempted to develop a long-term projection which indicated a probable requirement of about 110 million tons a year at the end of the century, as given in Table 1 below. The object of the exercise was to indicate the scale of effort that will be needed in the future because it has important implications on present day policies.

Table 1

Probable future steel requirements

End of	Year	Population, millions	Per capita consumption, kg	Ingot steel demand, million tons
1st Plan	1955	390	8	3 (actual)
2nd Plan	1960	430	14	6 (actual)
3rd Plan	1965	480	25	12 (estimated)
4th Plan	1970	525	36	19 (estimated)
5th Plan	1975	570	50	28 (estimated)
20th century	2000	840	130	110 (probable)

The above estimates have been arrived at by assuming levels of per capita consumption to be attained in successive periods, corresponding to the degree of industrialization and increase in the national income as envisaged in the long-term perspective plans. At 130 kg per capita, or a consumption of about 110 million tons, by 2000 A.D., we shall barely reach the level of Japan and Italy in 1957.

Expansion of steel capacity

Practically all the existing steel capacity has been installed in the Bengal-Bihar-Orissa-Madhya Pradesh area which possesses the two principal raw materials for the steel industry—the largest reserves of iron ore and the only reserves of coking coal. This area has sufficient reserves to support the expansion of the existing plants and initiation of several large new steelworks, while smaller ore-based plants can be located in other parts of the country. The new steel plants at Rourkela, Bhilai and Durgapur have been designed for future expansion to only 2 to 3 million tons. As there are serious physical limitations to any appreciable expansion beyond the above capacities, it is essential to initiate new capacity on the lines envisaged in order to meet our large future requirements.

Table 2 indicates the possible pattern of development of future steel capacity. It is evident that, as in the Second Plan, at least three major steel plants need to be initiated in each of the succeeding Plan periods.

In addition to planning on a time-scale, the locations of future plants must be decided well in advance. This is necessary in order to enable all facilities such as water, power and transport to be organized ahead of time, and also to avoid the dissipation of time and energy that takes place in 'lobbying' for a project.

Size of future steel plants

As the number of sites available in India for the location of steelworks with large capacities (of the order of 3 million tons and over) are likely to be few, it is necessary that, wherever such sites are available, adequate provision be made in the initial design for the maximum future expansion. Large plants are also indicated on technological considerations to realize possible economics in capital and operating costs. Once the organization and procedures are properly established, the management of a large complex need not present any more difficulty than the running of a smaller plant.

The worldwide trend towards the growth in size of iron and steelworks is brought out by the fact that the USA had 19 plants of over a million tons capacity in 1930, which increased to 26 in 1950 and 48 in 1955. There was only one plant above 4 million tons annual capacity in 1930, the number had increased to four in 1950,[20] and eight in 1960—the figure for the latter year including five plants of over 6 million tons capacity. The same trend is noticeable in the USSR where there were 12 plants of over a million tons in 1958 (including one of over 6 million tons).[21] One may generalize, therefore, that whereas the typical large integrated works of a few decades ago was a million-ton plant, 'the minimum economic size is now likely to be not less

Table 2

Possible timing of future steel capacity
(figures in million ingot tons)

Plan	Year	Estimated requirement	Rourkela	Bhilai	Durgapur	Tisco, Jamshedpur	Iisco, Burnpur	Bokaro	New plants								
									1	2	3	4	5	6	7	8	9
Second	End of period	6	1.0	1.0	1.0	2.0	1.0										
Third	1961																
	1962							✓									
	1963							..									
	1964							..	✓								
	1965	12*	1.8	2.5	1.6	2.0	1.0	..	..	✓							
Fourth	1966																
	1967							1.0			✓						
	1968										..						
	1969										..	✓					
	1970	19*	2.5	3.0	2.5	3.0	2.0	3.0	1.0		..	..	✓				
Fifth	1971																
	1972									1.0	1.0			✓			
	1973													..			
	1974													..	✓		
	1975	28*	2.5	3.0	2.5	3.0	2.5	5.0	2.5	2.0	1.5	1.0	1.0	..	..	✓	

(✓) denotes the 'initiation' of a new plant, *i.e.*, preparation of final project report.

* This total is *not* attained on the basis of expansion shown. Therefore, it is essential to initiate more plants in each Plan. Part of the shortfall will be met by small plants.

than 3 to 4 million tons of steel per year.'[22] Indeed, recent technological advances and economic considerations have already made a 10- to 12- million-ton steelworks a desirable proposition wherever the raw materials and other conditions permit it.

Planning steelworks layout

To enable a steel plant to grow rationally to a large future capacity, its initial layout must be planned with great care. The provision of space should be such as to allow additional coke ovens, blast furnaces, meltshops and rolling mill complexes to be added without interfering with the operations of the existing units. At the same time, utilities such as tracks, power and water should be designed so that they can be expanded with minimum alterations to existing facilities. Such provision adds only a negligible amount to the initial plant cost but pays off handsomely in the future. This is even more true in a country like ours where rising steel demand inevitably requires that plants be expanded even before their installation has been completed. At Bokaro, which has a strong raw materials base, we have designed for expansion of the initial capacity to 10-12 million tons in the future when required.

The importance of providing ample facility for future expansion was well expressed by the British Productivity Team that studied the U.S. steel industry a decade ago, as follows :[23]

> 'In new works it is mainly a question of having the courage to look far enough ahead and provide a basic layout which can increase in size beyond anything which may be contemplated at the time or during the life of the people immediately concerned.'

In this connection, it is interesting to note that some plants installed in the USA over 60 years ago with very small initial capacities have, today, due to the foresight of their early planners, reached capacities of some 6 to 8 million tons, *i.e.* 20 to 30 times the initial capacity.

Large plants essential

The necessity of having large plants in India is also dictated by the sheer arithmetic of trying to provide a sufficient number of plants of varying sizes to total up to a capacity of over 100 million tons in the next 40 years. As in other steel producing countries, the bulk of our capacity will have to come from a few large steel complexes, while, at the same time, a large number of smaller plants will be required to serve as nuclei for future growth, and also to disperse the steel capacity to meet regional demands. To illustrate, a hypothetical pattern of size distribution of the future steel industry is attempted in Table 3. It is seen that although less than 10 large integrated plants (over 3 million tons each) produce one-half the total steel required, more than 100 smaller plants (under 0.5 million ton each) are also necessary. These small plants, though serving a useful function, make a comparatively minor contribution to the total capacity.

Table 3

Possible size pattern of steel industry in future (2000 A.D.)

Plant capacity, million tons	Number of plants	Total capacity, million tons
8-12	2-3	20
3-8	5-7	32
1-3	14-16	30
0.5-1	22-24	14
Under 0.5 (including non-integrated plants)	100-110	14
Total	125-142	110

Equipment manufacture

By the end of the Third Plan, the heavy machine building plant at Ranchi is expected to be completed to provide the main equipment for metallurgical industries. It will have an annual output of 80,000 tons of equipment which will enable it to meet the bulk of the requirements for establishing a million-ton steel plant each year. Similarly, the development of other machine building industries envisaged in the Third Plan, *e.g.*, heavy electricals, heavy plate and pressure vessels, heavy structurals and mining machinery, should enable us to rely more and more upon indigenously produced capital equipment.

In order, however, to insulate the 'steel expansion' programme from the uncertainties of foreign credits and aid, it is necessary that progress of heavy machine building industries should not be needlessly checkmated by indecision and executive delays. Another point to be noted is that a steel plant requires such a large variety of plant and machinery that the task of equipping it must necessarily be spread over a very large number of engineering units. For instance, equipment for Bhilai has come from 400 different sources in the Soviet Union. It follows, therefore, that a serious quest for self-sufficiency requires an imaginative policy of looking ahead not merely to create new equipment capacity but also to mobilize and develop the productive potential already existing in the country.

Outlook on Raw Materials

The expansion of steel capacity requires urgent consideration of the raw materials base of the industry. While iron ore reserves are one of the largest and best in the world, the known reserves of good coking coal are comparatively low and the ash content is high. The present supply of suitable fluxes with low insolubles for steel-making is even more critical.

Table 4 below indicates the estimated reserves of the principal raw materials and the probable period these will last assuming the successive production targets listed in Table 1 earlier. It should be noted that the figures in Table 4 are only approximate.

Table 4

Available raw materials

Raw material	Estimated reserve, million tons	Duration of production from known resources (approximate)
Iron ore	20,000	100 years
Manganese ore (marketable grade)	60	50 years
Coking coal (washed)	1,600	35 years
Flux limestone (up to 6% insolubles)	100	15 years

The figure for limestone reserves covers only the good flux-grade material (up to 6% insolubles) occurring in the Sundargarh District of Orissa, the Jabalpur, Durg and Bilaspur Districts of Madhya Pradesh, the Shimoga and Tumkur Districts of Mysore, and the Salem and Madura Districts of Madras. When the steel industry is forced to accept limestone with higher insolubles and over longer distances, this reserve figure would increase.

Coal and limestone supply critical

The above figures emphasize the urgency of stretching out the supplies through the upgrading of high ash coals by washing, by petrographic preparation to permit large mixture of non-coking coals in the blend, by the use of self-fluxing sinter in the blast furnace burden and other technological improvements to reduce specific coke consumption.

It cannot be too strongly emphasized that the coal and limestone positions allow absolutely no ground for complacency, and that the large investments being made in steel plant facilities are likely to be idle unless, taking a lesson from the Second Plan, there is a sustained and coordinated effort to survey, investigate, raise and transport these materials to the steel plants.

Some of our main raw materials problems are indicated below in order of their importance.

Coking coal

The Second Plan target of 60 million tons coal production capacity is likely to be reached, although supplies may be hampered due to transport bottlenecks. During this Plan period, the problem was to mainly expand the existing operations, while, in the Third Plan, it will be essential to open a greater number of new mines. To achieve the 97 million tons coal target by 1965-66, requires a 'massive' programme and a long-term policy, including adequate subsidies for stowing and deep mining operations, arrangement of finance for development work, new washeries and better movement of coal away from the pithead.

While the steel industry's coal requirement is only a sixth of the total coal consumed by the country, this requirement is very discriminating, and therefore, the problem is not only that of raising the required quantity but also one of ash content and coking quality.

Problem of high ash coal

During the last 20 years the average ash content of Indian coal has increased from about 16 to over 24% and is likely to go up further with larger future production by mechanized bulk mining methods. The inferior quality of the majority of our coking coals forces the Indian blast furnace operator to accept coke with 22 to 23% ash, which is twice the proportion of ash in coke used by the majority of works in other parts of the world. Increase of ash in the coke charge to the blast furnace is known to decrease production and increase the overall production cost. It also increases the phosphorus content of the iron, requiring higher flux consumption for steelmaking.

It will, therefore, be essential to wash practically all Indian coal supplies to the steel plants in order to reduce the ash content and thus bring down the ash in the coke produced. But it is necessary to arrive at a compromise between the yield of usable washed coal and the maximum ash content that may be tolerated in the coal. Each one percent reduction of ash in the coal through washing entails proportionately a much higher increase in the quantity of the middlings and rejects produced. The utilization of these high ash middlings and lower yields of washed coal pose serious problems.

To achieve a fair quantitative yield of clean coal from the washery, and at the same time, to ensure reasonably economic operations at the blast furnace, it may be necessary to limit the maximum ash in the coal charged to the oven to 16 to 17%, which would produce blast furnace coke with ash content of about 22%.

The poor planning and consequent delays in setting up of washeries in the Second Plan has contributed substantially to the production bottlenecks at our steel plants. Washery capacity to produce about 9 million tons of clean coal should have been ready by 1960-61, but actually only one-half of this capacity is ready at present and the other half is either still under construction or the equipment is yet to be ordered. Even after these washeries are completed, there will be a severe shortage of washed coal in the Third Plan, unless detailed coal blending and washing investigations are immediately initiated, new washeries started, and existing ones expanded to meet the 1965-requirement of about 18 million tons of clean coal.

Conservation of coking coal

In order to conserve our limited low volatile coking coal resources, the larger use of higher proportion of high volatile coals in the blend at Indian steelworks is desirable. Pilot plant investigations at the Central Fuel Research Institute, Dhanbad, indicate that it is possible to blend poorly coking coals to the extent of 20% or more, thus reducing the requirement of good coking coals.

Petrographic preparation

To produce metallurgical coke of adequate strength from such a blend, the selective crushing process, based on the separation of the petrographic constituents of coking coals, needs to be considered.

The different coals which make up the coal blend, as well as the various petrographic constituents of each coal, vary in hardness and grain size as well as in coking properties. For instance, constituents such as vitrain and clarain are easier to coke and are also more easily crushed, as compared with the relatively inert materials such as durain and shale.

In conventional coal preparation practice, coal is subject to indiscriminate crushing in a hammer mill, which reduces the softer materials to a very fine size and leaves the harder constituents too coarse for satisfactory coke production. The principle of petrographic preparation process is to avoid indiscriminate size reduction, and, by means of various combinations of screens and disintegraters, ensure that vitrain/clarain is not crushed too fine, but the infusible constituents are crushed to a narrow size range. The process is also reported to increase bulk density, which results in increased production from the ovens due to increased charge weight and higher conductivity.

Also, in the interest of coal conservation, the minimum size of coke for the blast furnaces should be reduced to about 25 mm, with 25 to 40 mm and 40 to 100 mm fractions being charged in separate layers. The undersize pearl coke and breeze should be rationally allocated to electric pig iron and ferro-alloy plants, etc.

Decrease in coke rate

The present consumption of coke per ton of iron in Indian blast furnaces is about 900 kg. By the use of techniques suggested later—such as burden preparation, self-fluxing sinter, high top pressures, high blast temperatures, etc., it is considered possible to bring the coke rate down to 650 kg. This figure could be even further reduced as technology advances, and the injection of hydrocarbons such as oil or coke oven gas proves successful.

In this connection, it is interesting to note that, according to factual maximum results reported[24] on furnaces in the U.S. and Canada, the coke rate per net ton of iron has declined from 1,750 lb (800 kg) in 1930 to 1,250 lb (570 kg) in 1959, and is expected to drop further with the addition of hydrocarbons, etc., as indicated in Fig. 3. It should be noted that the above coke rates are based on about 85% fixed carbon and 10 to 12% ash in the coke, whereas Indian coke has 75% fixed carbon and 22 to 23% ash.

If, using Indian raw materials, it is possible in the future to reduce the coke rate to about 600 kg, it means that iron production from the known coking coal reserves could be extended by more than 50%. This is the objective towards which our steel plants and research laboratories should urgently apply their efforts. There are before us the examples of the USA cited above, of the USSR which reduced specific coke consumption by 35% between 1930 and 1958, and of other countries.

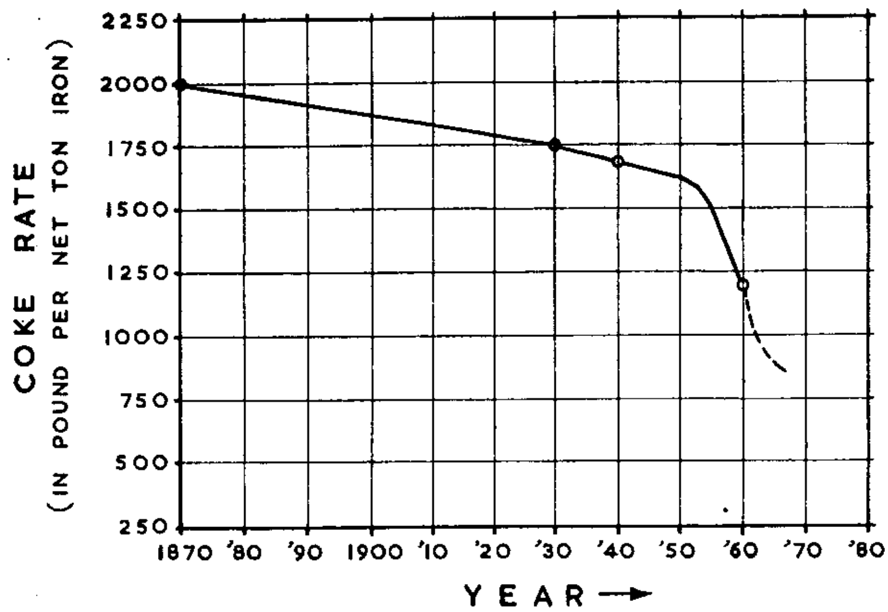

Fig. 3

U.S. coke rates — past and predicted[24]

Limestone

Known reserves of high grade limestone in proximity to the steel belt are very limited. The increased demand created by new plants will require that the steel industry get its stone over larger distances, which will slightly increase the cost of the iron produced. At the same time, the use of stone with higher insolubles may be necessary, which would result in higher flux consumption—each one percent of SiO_2 requires more than 2.5% of lime to flux it and adversely affects the performance of the blast furnace. It is, therefore, necessary to undertake extensive prospecting to locate new deposits of good flux-grade stone and investigations to wash the stone to reduce the insolubles. This beneficiated limestone, in its crushed form, could be used in making self-fluxing sinter for the blast furnace.

Iron ore

Unfavourable alumina content

The quality of ore for iron and steelmaking is not determined by the iron content alone; other factors such as physical characteristics and reducibility, association of undesirable elements like phosphorus and sulphur, and the chemical nature of the gangue must also be considered. Many Indian ores have comparatively high alumina content in the gangue material, producing an unfavourable alumina/silica ratio. This together with the high ash in the coke produces blast furnace slag high in alumina (about 26 to 28%). This slag has a poor desulphurizing quality and is more refractory, requiring a higher range of temperature for operation which increases the coke rate in the blast furnace. There is the possibility of beneficiating the iron ore by methods such as washing and heavy-media separation with the object of lowering the alumina content preferentially to silica.

Use of siliceous material (quartzite) also helps to lower the alumina percentage in the slag and, as in the case of addition of dolomite, increases the fluidity of the slag. The lower coke rate by the use of dolomite may offset the increased cost of flux.

Fines in Indian ores

Another factor which determines the quality of ore is its physical characteristic. The parent rock for most of the hematite ores in India is banded hematite-quartzite. However, hard compact ore for the blast furnace and as charge ore for the open-hearth is limited to certain areas only. The rest of the hematite deposits are generally soft and produce considerable quantities of fines (minus 12 mm about 30 to 50%) during mining and sizing operations. In order to improve the usefulness of the available ore, it is necessary to prepare the burden for the blast furnace. Adoption of sintering becomes essential as increased mechanized mining methods are adopted. These techniques, as applicable to Indian conditions, are discussed later.

Manganese ore

Need to conserve manganese

Metallurgically, there is no substitute for manganese in steelmaking. Steel—no matter what grade or type—cannot be made and rolled into the required shape without the proper amount of manganese in it. Most other alloying elements used in steelmaking can be substituted to a lesser or greater degree, as shown during the last two World Wars, but not manganese. It is, therefore, necessary to sound a note of warning regarding the indiscriminate export of this vital raw material. A mistaken notion seems to prevail that our reserves of good manganese ore are practically inexhaustible, and therefore, it has been and continues to be exported at a rate of a million tons a year for the last several decades. However, a look at Table 4 indicates that, for the magnitude of steel production visualized, the better grade ores must be conserved. Already our growing ferro-alloys industry is experiencing shortage of high grade ores. It is, therefore, imperative that the present rate of export of such ores should be reduced drastically, if not completely stopped. This also emphasizes the necessity of beneficiating low grade ores.

Long-term outlook on raw materials

The raw materials outlook is likely to be improved by new discoveries and large-scale beneficiation. Although geological surveys for minerals have been carried out since the middle of the last century, the programme has lacked an overall long-term approach, and large areas have yet to be intensively studied. For instance, at the beginning of the Second Plan, only one-fifth of the country had been covered by detailed maps. Also, most of the prospecting has been confined to surface observations. We will have to use modern techniques such as geophysical methods in order to adequately cover larger areas, so as to extend our known reserves and also discover new minerals which have so far eluded us.

Therefore, it is imperative that an intensified and coordinated long-term geological investigation programme be initiated. This in turn requires a large increase in our present strength of geologists by an expansion of their education and training facilities.

However, between finding new deposits and delivering them to steel plants, there is a long preparatory period, six to eight years, say, in the case of coal. This requires forward planning to open up the known reserves, and provide transport, beneficiation and other facilities for their exploitation.

Technological Possibilities

Problems of high insolubles in our fluxes, high ash in coke, unfavourable alumina/silica ratio in some of our ores, together with bottlenecks of transport are plaguing our steel industry at a time when it is already hard pressed by the difficulties of running in new plants with inexperienced personnel. Undoubtedly, the problems posed by our raw materials are major ones, but these can be solved by proper planning and more intensive use of all available technical facilities, together with the adoption of proved new developments in the metallurgical field.

I would, therefore, like to review some of the major technological trends, and how these could be utilized to conserve our critical resources and enable the Indian steel industry to expand rapidly at low investment costs. It may be emphasized that the discussion that follows relates specifically to Indian conditions, and it is believed that the suggestions made are such as can be effectively applied.

Ironmaking

The blast furnace is the starting point of metallurgical processes in a steel plant, and also the source of many of its troubles. The present method for the extraction of iron from its ores is a very old pyrochemical process, which only recently attained its present high state of engineering development. Essentially, the blast furnace is a large chemical reactor (vertical shaft) in which, under our conditions, about 1.7 tons iron ore, 0.9 ton of coke and 0.4 ton of limestone are charged at the top, and about 4 tons of heated air (blast) blown at the bottom, per ton of iron produced. Gases from the combustion of coke reduce the iron oxide in the ore to iron, while the limestone fluxes the gangue materials in the ore and the ash from the coke to form slag.

Evolution of blast furnace

Without belittling the efforts of the metallurgical engineer, it is fair to point out that the blast furnace owes a large part of its present day efficiency to the contribution made by his electrical and mechanical colleagues. The hand-charging of the early blast furnace has been replaced by automated scale cars and skips, the old reciprocating blowing engine has given way to the more efficient turbo-blower and may perhaps, in time, be replaced by the gas turbine. Such improvements have made the coke blast furnace the only feasible method for the commercial production of iron on a large scale.

Basic technology unaltered

However, the basic technology of ironmaking in the blast furnace has remained practically the same for almost 100 years. This technology has some major disadvantages. For instance, from a metallurgical point of view, the blast furnace gives only an impure product containing impurities such as carbon, silicon and phosphorus, which must be subsequently refined to make rollable steel. From the heat economy point of view, it needs to be remembered that the blast furnace takes more than twice the heat that is theoretically required to convert iron oxide to pure molten iron.

During the last ten years, engineers and scientists have taken a close, critical look at the technology and economics of ironmaking, and have achieved a substantial increase in blast furnace productivity and a consequent decline in the coke rates. The main techniques being used or proposed to improve furnace performance include preparation and beneficiation of the burden, use of fluxed sinter, high top pressures, high blast temperatures, and additions of moisture, fuel gas or oil, and oxygen.

Burden preparation

The reduction of iron oxide in the ore to iron takes place mainly in the stack of the furnace and is a gas-solid reaction. The presence in the blast furnace burden of materials of varying size allows the gases to escape up the stack without effective use of their heat content or reducing ability. Consequently, coke consumption is increased and iron output decreased. Therefore, burden preparation to ensure uniformity in size and composition is the first step in raising blast furnace performance.

Bedding and ore drying

This calls for an ore blending system to homogenize the ore arriving from a number of mines or even from various seams in the same mine. The Messiter system together with a stockyard may be used for stocking, bedding and reclaiming the ore. To facilitate screening-out of fines below 8 to 12 mm under Indian monsoon conditions, the provision of ore drying facilities may be necessary together with dust extraction equipment at all crushing and screening points. Alternatively, wet screening may have to be adopted.

Self-fluxing sinter

The attempt to utilize iron ore fines led to their agglomeration by sintering. Soon it came to be realized that the use of sinter has also other far greater advantages. Today sintering is recognized all over the world as the most important recent development for increasing iron production at low cost and also conserving raw materials. Unfortunately, while there is much talk about conserving our critical materials such as coking coal, one of the most useful conservation measures, *viz.*, use of self-fluxing sinter, has not received the attention it fully merits at the Indian steel plants.

The advantages of sinter in improving blast furnace performance have now been amply demonstrated. At a Swedish blast furnace plant,[25] the sinter in the burden was raised progressively to 100% over a 20-year period, resulting in a 90% increase in iron production. Recent tests at the Steel Co. of Canada[26] show that the coke rate was reduced by 26% from 1,700 lb (775 kg) per net ton with 40% unfluxed sinter in burden to 1,254 lb (570 kg) with 100% fluxed sinter. At the same time, daily iron production increased by 43% and flue dust losses decreased from 132 lb (60 kg) to 28 lb (13 kg) per ton iron. Similar work done in Japan with 100% self-fluxing sinter burden in blast furnaces over a 1½-year period showed that the furnaces operated efficiently on a coke rate as low as 550 kg per ton iron.

Coke rate and iron output

Fig. 4 summarizes the impressive effects of sintering on iron output. Blast furnace production is raised by 45 to 60% and coke rate is lowered by 25 to 40% when

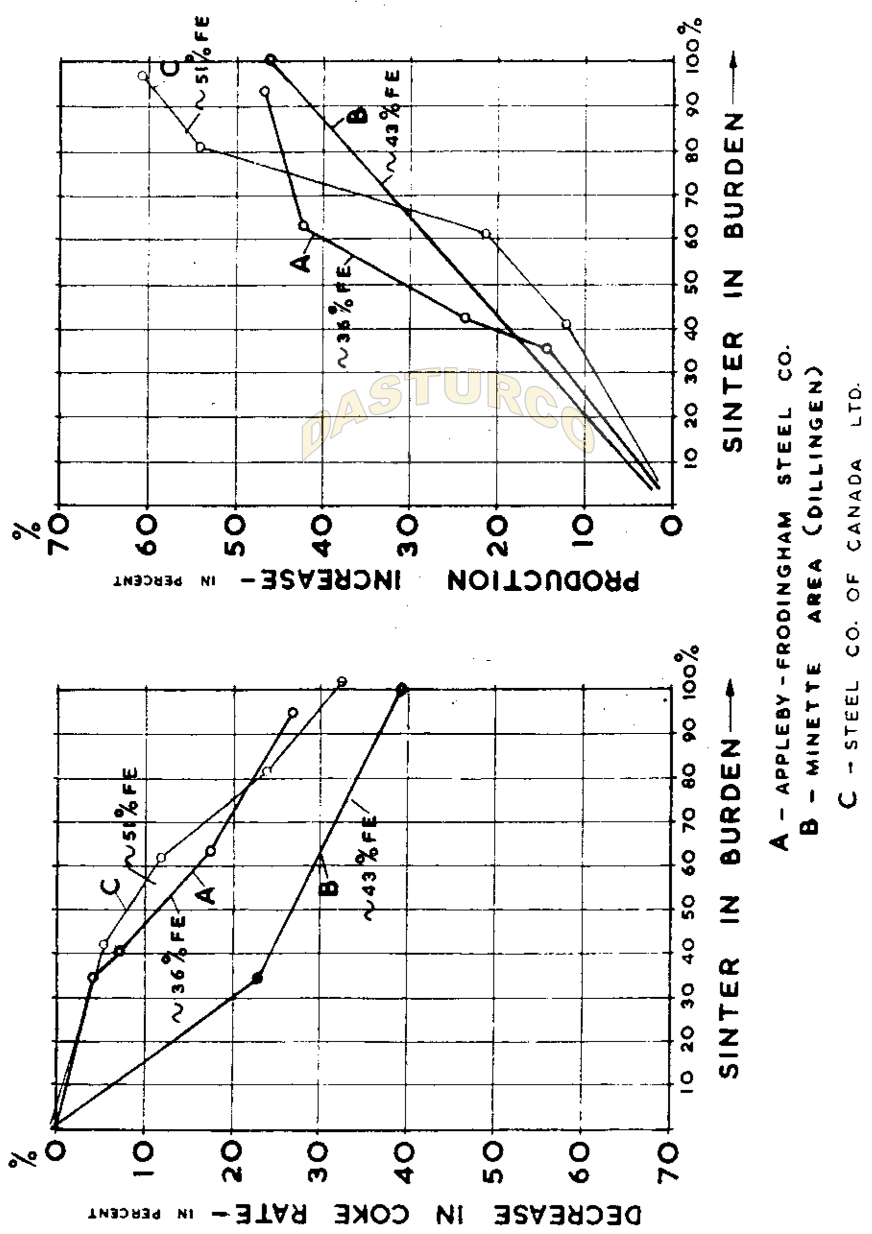

Fig. 4
Effect of sinter on coke rate and iron production[27]

using 100% sinter in the burden. It may be noted that best results are obtained when sinter as a proportion of the burden exceeds 60%.

World trend

The success of the early work on sintering at Domnarvet in Sweden, and subsequently at the Appleby-Frodingham works in England and at Russian steel plants, has led to an upsurge in sinter production all over the world. The steeper rise in sinter production as compared with the rise in pig iron output in three of the largest steel producing countries of the world, the USA, the USSR and the UK, is shown in Fig. 5. It is seen that in the USSR the tonnage of sinter production now exceeds pig iron production.

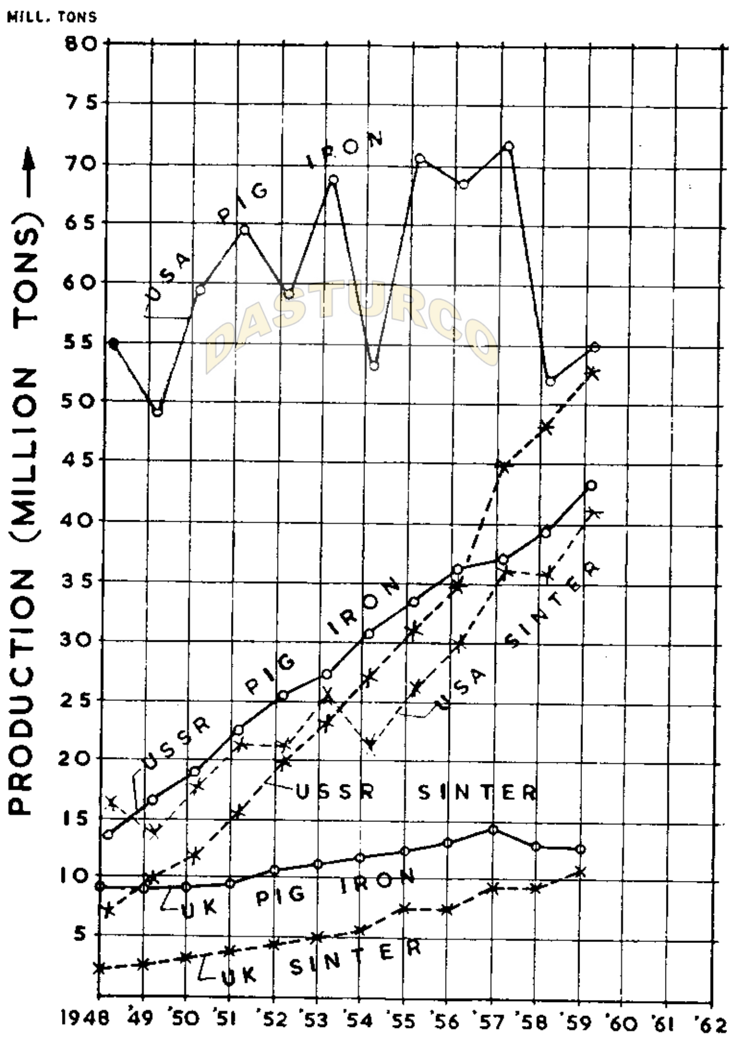

Fig. 5

Pig iron and sinter production in USA, USSR and UK, 1948-59[28]

Superfluxed sinter

The extent to which a sintered burden is used in blast furnaces in different countries is brought out in Fig. 6. Blast furnace operators are aiming at still higher share of sinter, with the ultimate aim of an ideal two-component burden—superfluxed sinter and coke. Judging from the present trends, it would seem that 100% use of sinter or a position close to that will be reached in many steelworks in different parts of the world.

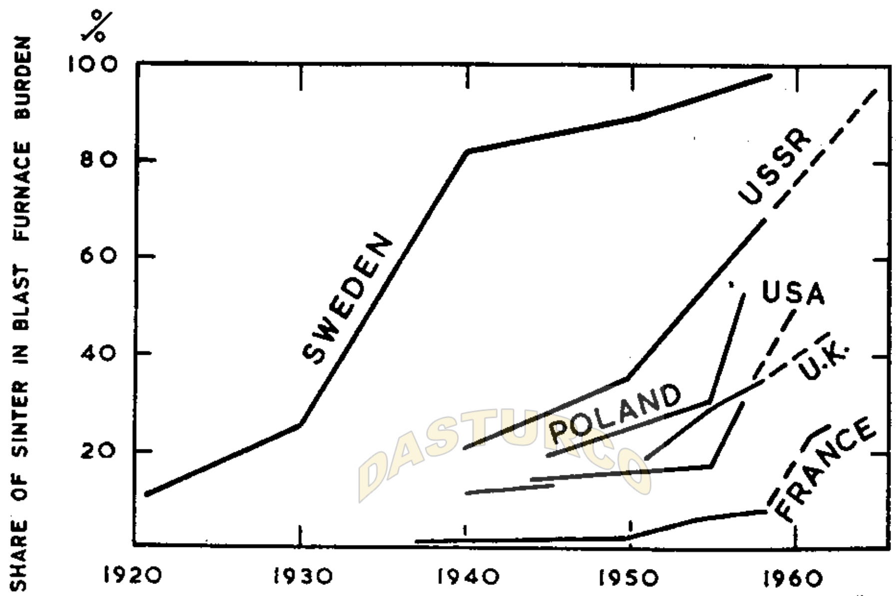

Fig. 6

Share of sinter in blast furnace burden[29]

Economics of using sinter

The economics of sinter are so attractive that it is even desirable to create fines by further crushing the ore, over and above the natural fines available, in order to have a high proportion of sinter in the burden. With Indian ores and coke, it is considered possible by using 100% self-fluxing sinter to increase production by over 40% and reduce coke rate by 30% from the present average of about 900 kg per ton iron to about 650 kg. This would have a major impact on the economics of ironmaking, besides helping tremendously in conserving our limited stock of coking coal.

Utilization of iron ore and coke fines, reduced coke rate, lower conversion cost, and increase in the productivity of a blast furnace make the use of sinter a very economic proposition. Table 5 gives a comparison under Indian conditions of blast furnace economics, operating on raw iron ore without sinter and operating with 100% superfluxed sinter. For the purpose of this exercise, it is conservatively assumed that with an all-sinter burden the production would be about 30% higher and the coke rate 28% lower. It is seen that the production cost (including fixed charges) would be

Table 5

Economics of ironmaking with 100% sinter and without sinter

(Basis: one million ton of iron production in an integrated steelworks)

(a) **Production Costs**

Item	Cost per ton of material, Rs.	No sinter		100% self-fluxing sinter	
		Quantity per ton of iron, tons	Cost per ton of iron, Rs.	Quantity per ton of iron, tons	Cost per ton of iron, Rs.
Iron ore (lump)	20	1.60	32.00	..	..
Sinter (self-fluxing)	26	..	..	1.90	49.40
Coke	45	0.90	40.50	0.65	29.25
Flux	24	0.40	9.60	..	..
Cost above materials			12.00		9.50
Less credit for gas at Rs. 4 per million kcal.	..	..	−7.40	..	−5.30
Production cost excluding fixed charges		..	86.70	..	82.85
Advantage due to lower production cost		..	..	..	3.85
Advantage due to lower fixed charges at 13% on investment in coke ovens, sinter and blast furnace plants		..	..	..	3.25
Total advantage in prodn. cost		..	..	..	7.10

(b) **Capital Costs**

Item	Investment per ton of material, Rs.	No sinter		100% self-fluxing sinter	
		Installed capacity per ton of material, tons	Investment per ton of iron, Rs.	Installed capacity per ton of material, tons	Investment per ton of iron, Rs.
Coal mining	45	2.22	100.00	1.58	71.00
Coal washing (60% yield)	25	1.34	33.50	0.97	24.20
Ore mining (lump and fines)	20	2.70	54.00	1.50	30.00
Coking (67% yield)	150	0.90	135.00	0.65	97.50
Sinter	30	..	..	1.90	57.00
Ironmaking	120	1.00	120.00	0.75	90.00
Total		..	442.50	..	369.70
Advantage in capital cost per ton of iron capacity		..	..	..	72.80

about Rs. 7 per ton lower with the use of sinter burden. The capital cost of all facilities (such as coal mining, washing and carbonizing, ore mining, sinter plant and blast furnace) for ironmaking with sinter is about Rs. 72 per ton lower. This saving is achieved in spite of providing additional sintering facilities because (i) the production capacity of an equivalent furnace goes up when using 100% self-fluxing sinter, and (ii) the reduced coke rate requires lower investment in mining, washing and carbonizing coal. Thus, there is a saving in the initial capital investment of about Rs. 72 millions and a recurring annual saving in operating cost of Rs. 7 millions for every million tons of iron production. In addition, there is a significant saving of a quarter million tons of good metallurgical coking coal per year.

Advantages of sinter

I should like to recommend strongly the use of sinter in the context of our conditions, because of the significant advantages summarized below:

1. Conservation of our limited coking coal by
   - (i) lowering the coke rate due to reduction in thermal load inside the blast furnace, as fluxed sinter does not need the heat that would be required in an unsintered burden for the calcination of limestone and the coke for the reduction of carbon dioxide from the stone,
   - (ii) better burden permeability, permitting more efficient heat utilization, and
   - (iii) utilization of coke fines in the sinter mix, helping to stretch out coke supplies.
2. Utilization of the large quantities of iron ore fines produced in mining and crushing operations. We have been improvident and wasteful in dumping vast quantities of such fines (containing 60% Fe) at the mines over the last 50 years. These fines in our ores, which in the past were a major problem, can now be used to our advantage by converting them into sinter.
3. Sinter in the blast furnace burden permits the use of weaker coke from inferior coals which could not be used otherwise. Sintering permits installation of larger blast furnaces, resulting in further economies.
4. Increase in blast furnace productivity; this in turn means saving in production cost and on fixed capital charges per ton of output.
5. Lower capital investments in coal mining, washing and carbonizing due to greatly reduced coke consumption.
6. Utilization of the iron content of flue dust and mill scale in the sinter mix, and reduction in the dust losses from the blast furnace.
7. Better regulation of analyses of charge materials and furnace operation, resulting in the better control of iron analysis.

Trend in blast furnace size

The trend in ironmaking is towards larger blast furnaces. During the last 60 years, the blast furnace has grown steadily from a small unit producing about 100 tons per day to the modern giant with outputs of over 3,000 tons per day. For instance, in the USA, in 1918, a total of 455 blast furnaces produced 53 million tons, while today only 265 furnaces produce almost twice as much iron. In Russia, about 70% of the total iron is currently produced in furnaces with a working volume of over 1,100 m^3 and furnaces of 2,133 m^3 (output 4,000 tons per day) have gone into operation. Similar furnaces are being planned in the USA also. The majority of Indian blast furnaces have a working volume of about 1,000 m^3, the largest being about 1,300 m^3.

The increase in average blast furnace size in selected countries is shown in Fig. 7.[30] The reasons for building a large blast furnace are that its larger output reduces unit operating costs, and also gives a small but significant saving in coke. Further, there is a considerable reduction in the capital cost per ton annual capacity. In view of these technological trends, it would be desirable for large integrated steelworks in India to standardize on blast furnaces of, say, 1,600 to 1,800 m^3 working volume. There is nothing inherent in our raw materials which could prevent us from using furnaces of this size to advantage. Moreover, our blast furnace men, who have successfully run medium-size furnaces under difficult conditions, can now handle large blast furnaces.

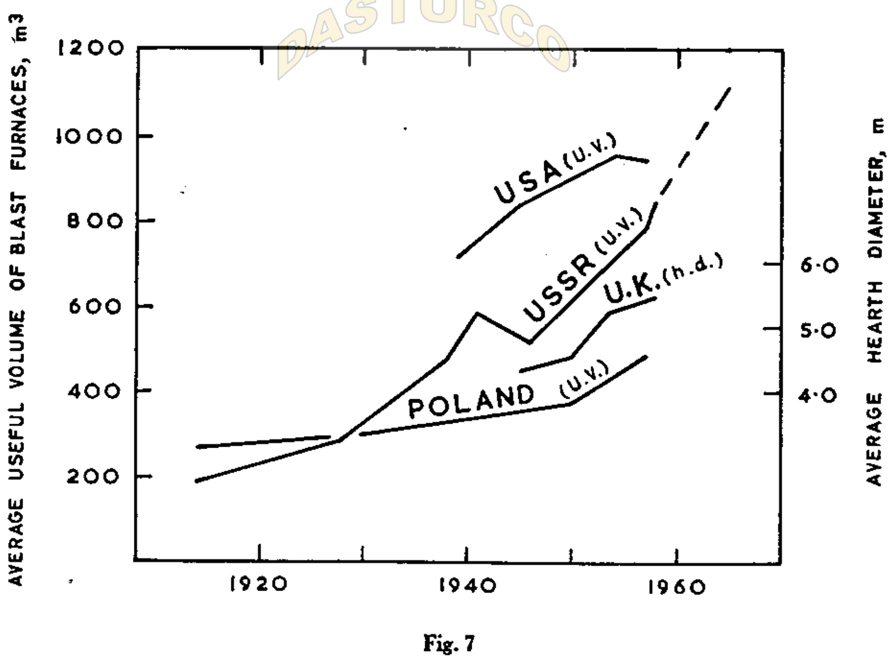

Fig. 7

Average size of blast furnaces[30]

Blast furnace operation with high top pressure

The use of high pressure inside the blast furnace has a sound technical basis, resulting in economic advantages such as increase in productivity and substantial decrease in flue dust. The theory behind top pressure operation is that putting a blast furnace (which is essentially a closed chemical reactor) under increased static pressure by a throttling valve in the discharge gas main permits more wind to be blown without increasing the upgoing gas velocity. The supply of additional oxygen in the air blast enables more carbon to be burnt at the tuyeres, *i.e.*, provides more CO gas to reduce the iron ore. Longer retention time of the gas in the stack with correspondingly longer gas-solid contact increases the amount of gaseous reduction of iron oxides and minimizes the reduction by solid carbon. The less this reduction by solid carbon the more efficient the blast furnace becomes since this reaction absorbs rather than liberating heat as in the case of gaseous reduction.

At the Ore Research Laboratory of H. A. Brassert & Company, New York, during my work on 'direct gaseous reduction' processes for ironmaking, some investigations were made on the effect of pressure on the time of reduction of iron oxide with hydrogen at about 700°C. As can be seen from Fig. 8, increase in pressure from 1 to 2 atmospheres reduced the time for 90% reduction from 85 to 45 minutes. A pressure of 5 atmospheres further lowered the reduction time to only about 20 minutes.

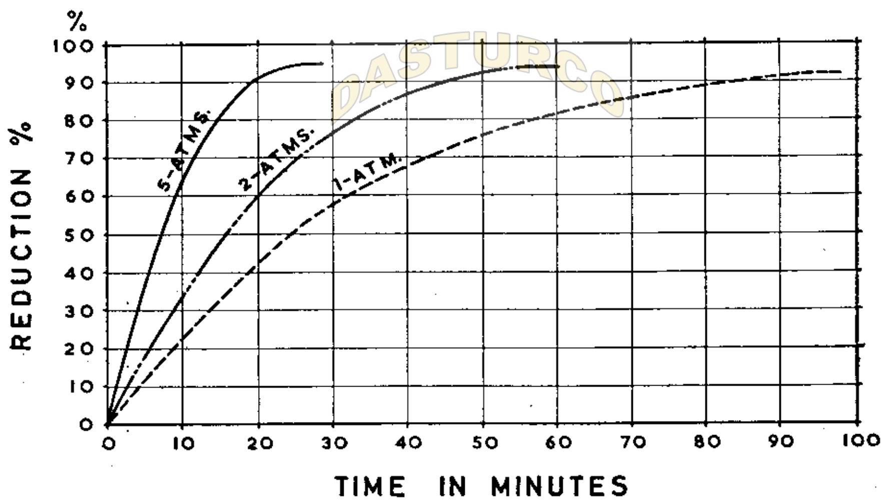

Fig. 8

Effect of pressure on reduction time of iron ore pellets with hydrogen

In summary, the operation of blast furnaces at elevated top pressure increases iron production, reduces dust losses, and consequently reduces the production cost of iron. The objections to the use of high top pressure, such as increase in maintenance and blower costs, are more than compensated by better performance. Although this idea was patented in 1938 in the USA, it was fully implemented on a commercial scale first in the USSR, so that today more than 80% iron in the USSR is from blast furnaces operating on pressures up to 2 atmospheres.

Blast preparation

The supply of additional external heat in the blast has been known to decrease the carbon consumed at the tuyeres per ton of iron, and consequently increase the iron production rate. It would be desirable for Indian blast furnaces to operate on 950 to 1,050°C to realize this benefit. Currently, blast temperatures of 1,100 to 1,200° C are being contemplated abroad., Further, fluctuations in humidity under Indian conditions and the trend towards high blast temperatures call for the use of steam for controlled humidification of air. Although the dissociation of steam is endothermic, the gases produced perform useful functions—the hydrogen is a useful reducing agent, and the oxygen serves to enrich the blast.

Auxiliary gases

Another interesting development is the injection of natural gas into the smelting zone of a blast furnace. The Colorado Fuel and Iron Corporation has been injecting up to 5% natural gas in the hot blast at one of its furnaces for the last two years, with a coke saving of about 35 kg per ton iron for each 30 m^3 of natural gas used. Recent investigations by the U.S. Bureau of Mines on an experimental blast furnace showed a reduction in coke consumption by about one-third over the base period. This caused a 30% increase in pig iron production. The results are summarized in Table 6.

Table 6

Injection of natural gas in tuyere zone[31]

Item	Base period (average)	Period of 7% gas injection (average)	Period of high wind rate
Natural gas, cft per ton of iron	—	4,560	3,975
% of wind blown	—	7.08	7.5
Coke rate, lb per ton of iron	1,484	1,116	938
Wind blown, standard cft per min.	844	741	810
Blast temperature °F	1,518	1,938	2,450
Products			
Pig iron, net tons	15.5	16.6	22.0
Slag, lb per net ton of iron	723	669	590
Flue dust, lb per net ton of iron	3.2	3.2	3.9

Similar work is also being done in the USSR where the Petrovskii works has increased productivity by 3 to 5% and reduced coke rate by 12 to 15% by using natural gas and higher blast temperatures. The injection into the blast furnace of hydrocarbons in the form of heavy oil is being investigated by an USA oil company with promising results. In India, where natural gas and heavy oils are not likely to be abundant, the injection of coke oven gas into the blast furnace needs consideration.

Summarizing, it may be said that with the use of the techniques suggested above the production from a blast furnace with a specified working volume can be increased by 100%. This means that Indian furnaces currently rated at 1,000 to 1,200 tons per day could produce about 2,000 tons using self-fluxing sinter, high top pressure, prepared blast, high blast temperatures, and other advanced techniques.

Steelmaking

We turn now to steelmaking, *i.e.*, the refining process by which iron is converted to steel. The molten iron from the blast furnace contains numerous elements such as carbon, manganese, phosphorus, sulphur and silicon, which must be reduced to the desired levels by oxidizing them out of the bath ; the oxidized impurities then combine with the flux to form slag.

Effect of raw materials

The quality of available raw materials, particularly their phosphorus content, has a major influence on the selection of the appropriate steelmaking process. If the phosphorus in the iron is low (below 0.09%), the acid Bessemer process is feasible, whereas if the phosphorus is high enough (over 1.8%), the basic Bessemer (Thomas) process is indicated. The use of oxygen with steam or carbon dioxide is extending the usefulness of the Bessemer processes which produce steel at a low cost. However, the phosphorus content of Indian coal and ore result in an iron containing 0.3 to 0.4% phosphorus, which rules out both acid and basic Bessemer operations.

Of the remaining processes, three technically feasible alternatives could be considered for large scale steelmaking :

(a) Duplex process (acid Bessemer-basic open hearth),

(b) Basic open-hearth, and

(c) Basic top-blown oxygen LD process.

Duplex process

The conventional Duplex process, using acid converters and basic open-hearths, requires higher capital investment and operating costs, and gives lower yields than one-stage refining operations. With the advent of faster pneumatic processes and improved open-hearths, the Duplex method is becoming obsolete except under very special circumstances.

Basic open-hearth

The basic open-hearth today produces the bulk of the world's steel. One of its major advantages is its technical flexibility ; it can produce quality products from a wide variety of raw materials. Also, the metallic charge to the furnace can vary from all-cold scrap to 80% hot metal from the blast furnaces.

Oxygen in open-hearth

In the last decade, while there has been spectacular progress in the LD and other pneumatic processes such as 'Kaldo' and 'Rotor', a number of significant improvements have also been made in the open-hearth process. The most important of these is the increasing use of oxygen both for flame enrichment to accelerate heating and melting, and for oxidation of the steel by direct insertion through roof lances. The combination of the two methods, *i.e.*, flame enrichment and direct oxidation, can increase productivity by 40 to 50% and at the same time, decrease the fuel consumption. The Appleby-Frodingham works has developed the Ajax furnace[32] for using oxygen whereby productivity has increased by some 30%. With an oxygen input of about 40 m^3 per ton, the fuel consumption is decreased to one-fifth of good British practice, and the cost of fuel plus oxygen is one-half the total fuel cost. The Ford Motor Co. has reported the use of two oxygen-fuel lances along with the standard end-burners to give production rates of up to 100 tons per hour on a 360-ton open-hearth furnace.

Another important application of oxygen is for the pretreatment of iron to lower the metalloid content and thus reduce the metallurgical load on the open-hearth furnace. This ladle desiliconization has been provided at the Durgapur steel project.

In view of the developments indicated above, it is not surprising that the use of oxygen in open-hearth steelmaking is spreading rapidly. In the USSR, the share of open-hearth steel made with oxygen increased from about 1% in 1950 to over 25% in 1958.

Basic roofs

One of the important consequences of the use of oxygen is that the higher temperatures inside the furnace call for the use of the more refractory basic bricks in open-hearth roofs. In order to maintain their competitive position, the existing and future open-hearths in India will have to use oxygen requiring basic roofs, which, in turn, will call for a change in the pattern of refractories production in India, as indeed everywhere else. According to present indications, the total brick capacity in India will be about one million tons by 1962, of which only 65,000 tons will be in basic bricks. It is appropriate, therefore, that basic refractories projects are under consideration to help redress the shortfall.

Increase in open-hearth size

Another line of development which is improving open-hearth economics is the increase in furnace size from about 40 tons per heat in the twenties to an average of about 200 tons per heat in the USA and the USSR today. The largest furnaces are those of 500- and 600-ton capacity in the USSR and China, which are capable of production rates of over 100 tons per hour. Furnaces with heat size of 850 to 950 tons are now being designed, each furnace to produce about three-fourths of a million tons of ingot steel annually. This increase in heat size not only improves output but also lowers fuel and refractories consumption. The overall effects of these improvements may be gauged from the fact that annual steel production per open-hearth shop worker rose in the USSR from 524 tons in 1940 to 1,163 tons in 1957.[33] I have no doubt that large furnaces of 500 tons capacity or more will also have to be adopted in India. Indeed, a welcome trend in this direction is the decision to instal 500-ton furnaces in the Bhilai expansion, though, unfortunately, the other plants will continue with smaller furnaces.

The open-hearth process revitalized by these recent improvements is thus better able to meet the challenge of the LD converter and other pneumatic processes which have made very big headway in the last few years.

LD process

Rapid growth

Although the first commercial LD plant came into operation in Austria only in 1952, there were 46 converters with an annual capacity of 12.5 million tons by 1957, and another 50 vessels will soon have been brought into operation, taking the total LD capacity to some 26 million tons.

In the LD process, oxygen of 99.5% purity is blown vertically through a water cooled lance on the surface of liquid iron in a closed bottom vessel. Scrap, iron ore or cold pig iron are added to regulate the heat. Burnt lime and limestone are added during the oxygen blow which lasts from 18 to 24 minutes. The high temperature created by the oxygen jet and the eddying of the bath result in a very brisk refining action. The rapid formation of a reactive slag enables satisfactory dephosphorization.

Advantages of LD process

The process combines the advantages (comparatively lower capital investment and rapid refining rate) of a pneumatic converter operation with the flexibility of an open-hearth to some extent (use up to 35% scrap), and produces a variety of steels of open-hearth quality. Steel can be finished to the desired analysis and contains very low nitrogen. The process is well-suited for the production of all sections, and is particularly suited for deep drawing quality sheets.

Size of converters

While a few years ago the average LD converter size was only about 40 tons—such as the converters installed at Rourkela—today, converters of up to 300-ton capacity are being designed, which will give production rates of over 200 tons per hour per vessel. The Great Lakes Steel Corporation in the USA is installing two 270-ton vessels to produce 1.8 million tons per year, while the Colorado Fuel & Iron and McLouth Steel in the U.S., the Ijmuiden works in Holland, and a number of other companies are installing vessels with capacities of 100 tons or more.

The development of large converters has increased the attractiveness of the LD process in comparison with the conventional open-hearths. A recent study made by us indicates that the capital cost of a two-million ingot ton per year meltshop using three 120/150-ton LD vessels (including oxygen plant) would be about Rs. 200 millions as compared with a cost of about Rs. 350 millions for an open-hearth shop of equivalent capacity with six 500-ton furnaces with desiliconizing, that is, the LD plant would cost only about 60% that of the open-hearth shop. The LD process in this case was advantageous not only in terms of capital cost, but also was lower by about Rs. 20 per ingot ton in production cost.

Share of LD in total steel

In view of the above considerations — lower capital and operating costs, and suitability in the context of our iron analysis and scrap available — it is believed that the LD process should produce 30 to 35% of the total steel in India in the next 10 years. Indeed, the share of the LD process all over the world is expected to rise from under 10% at present to 20 to 25% of the world's steel production. However, to maintain a proper overall scrap and fuel balance inside an integrated steel plant, the open-hearth will continue to find an important place.

Other steelmaking processes

Other oxygen steelmaking processes of great interest are the 'Kaldo' process developed in Sweden, and the 'Rotor' process developed in West Germany. Until recently, both these processes have been operated on a small scale, but the Kaldo plants at Sollac in France, Oxelosunds in Sweden, and Consett in the UK, and the Rotor plants at Iscor in South Africa and Richard Thomas & Baldwins in the UK are now coming into production, bringing the combined annual capacity to about 3 million ingot tons. These new developments must be watched with interest by Indian steelmakers, as they promise to combine the speed of the LD process with the versatility of the open-hearth.

Small Scale Iron and Steelmaking

Alternative ironmaking processes

The preceding discussion of technological alternatives has been based on the assumption that the mode of iron production is the blast furnace using coke, with the subsequent steelmaking operations being carried out by either the dominant open-hearth or the fast growing LD process. This, however, limits the economic location of the steel industry to sites at which metallurgical coking coal and ore can be cheaply and conveniently assembled. In Indian conditions where the relatively meagre reserves of such coal are concentrated in a small area on the Bengal-Bihar border, but the iron ore deposits are widely dispersed, there is a strong case for investigating methods of production which either eliminate or substantially reduce reliance on coking coal. However, it must be remembered that, in spite of worldwide developments in new smelting and direct reduction techniques, the blast furnace still remains the most economical mass producer of iron, and that the pursuit of alternatives is mainly dictated by lack of resources needed in conventional technology.

Scope for small plants

While, as discussed in an earlier section, the bulk of our future steel must come from large integrated plants, there is ample scope for a great number of smaller plants in widely dispersed locations away from coking coals. These small plants could meet a part of the regional demands and, as we have already discussed, open the door to a variety of processing industries, which in turn would further accelerate the industrial development of the region. Such plants could be installed with much less dependence on foreign supplies of equipment, and could, as observed in China, create the enthusiasm and technical skills for evolution of the small units into larger, more complex plants.

Small scale ironmaking

Turning again to ironmaking, it is well known that the heat efficiency and the reduction of iron oxide by carbon monoxide improves as the height of the shaft increases. However, this has the disadvantageous corollary that a high shaft furnace requires a strong coke to support the burden and a sized ore free of fines. It is also known that by reducing the particle size of the burden the same thermal efficiency can be achieved with lower shaft heights. The lowering of the shaft height then opens the possibilities of using substitute materials such as a weaker coke from poorly coking coals.

'Low shaft' furnace

Furnaces with low shafts have been used successfully at Calbe in East Germany to produce a quarter-million tons of foundry iron per year. The Calbe furnaces use coke made from lignite, which is similar in analysis to the Neyveli lignite in South India. It is understood that this lignite coke is to be tried out at the pilot-scale furnace set up by the National Metallurgical Laboratory in Jamshedpur. Since good lignite deposits are also available in other parts of India, notably Kutch and Bikaner, the trials will have a wide national interest.

The attempt to use raw coal, either as lump or as ore-coal-flux briquettes, in shaft furnaces has not met with much success, although considerable amount of research work has been done in this direction.

Electric smelting furnace for ironmaking

One of the most useful devices for substantially reducing the requirement of coking coal—at the same time making small scale ironmaking possible—is the electric smelting furnace. This substitutes electric energy for the purpose of heating and a low grade carbonaceous material as reducing agent. The electric furnace needs only one-half as much fuel/reductant per ton of iron as a blast furnace. Of this smaller requirement, only a part need be coke and the rest can be low volatile coal or coke breeze which cannot be used in conventional blast furnaces. However, conventional electric smelting requires about 2,400 kWh of energy per ton of iron, and its commercial feasibility, therefore, depends on the availability of cheap power.

Here also, considerable amount of development work is being done on preheating and prereducing the burden in rotary or shaft kilns using the byproduct gas from the furnace itself, thus reducing the power consumption by almost 50%. The new Strategic-Udy and the Dwight-Lloyd-McWane processes are examples of this type of development. At the same time, the size of electric smelting furnaces has been increasing, and a 500-ton per day furnace using prereduction techniques and having a power consumption of only 1,000-1,200 kWh per ton now appears to be on the horizon.

Direct reduction processes

The search for ironmaking processes which can produce small tonnages at low investment costs, and at the same time use a wider range of available raw materials, has created widespread interest in direct reduction techniques. Sponge iron or a powder (later briquetted) is produced for use as metallic charge to cupola, open-hearth, or electric furnace. These processes utilize a reaction vessel (Hojalata y Lamina and

Madaras processes), a shaft furnace (Wiberg process), rotary kilns (Krupp-Renn, R-N and Basset processes), and fluidized beds (Esso-Little, H-iron, NU-iron and Stelling processes). Although some semi-commercial units are now in operation abroad, the economics are yet to be proved for large scale application. The availability of very high grade iron ore and the limited reserves of blast furnace fuel are factors favouring the development of 'direct reduction' processes in India.

Small scale steelmaking

Steelmaking on a small scale does not present the same problems as ironmaking. The LD converter process, which has already been discussed earlier, can readily be used to convert molten iron into steel.

Electric arc furnace for steelmaking

At the same time, mention must be made of electric arc furnaces for steelmaking which have increased in size to about 200 tons capacity. In countries with ample sources of cheap electric energy—which unfortunately do not include India—electric furnaces produce steel at costs comparable with open-hearth furnaces on a cold charge. At the same time, investment is much lower, only about 60% of the open-hearth. Till recently, one of the major drawbacks of electric furnaces for production of plain carbon steels was that molten iron could not be used effectively in them. However, the recent work in the steel plants at Brymbo (UK) and Gerlafingen (Switzerland) points to the feasibility of refining liquid pig iron in the electric arc furnace, thus improving its economics and increasing its scope.

Continuous casting

Another technique worthy of mention, but still in the development stage, is the continuous casting of steel. Theoretically, this will make it possible to cast molten steel direct into billets, blooms and slab sizes, thus eliminating conventional casting, stripping, soaking pits and primary cogging mills, which are the most expensive factors in steel production. In addition to the lower investment cost, there is a substantial improvement of 10 to 12% in the overall metallurgical yield of the primary rolled product from liquid steel. A large four-strand continuous casting installation with a capacity of about 400,000 tons is being built at Stalino in the USSR for the production of plain carbon steel slabs to be later rolled into flat products. The success of the plant at Barrow, UK, in casting mild steel into small billets is of significance for India's small electric furnace-*cum*-rolling mill plants.

Sendzimir mills

While the hot strip mill is the most economical mass producer of flat products, the new Sendzimir hot planetary mill makes it possible to roll slabs to strip on a relatively smaller scale. Continuous casting together with a hot planetary mill to roll slab to strip and a cold Sendzimir (cluster) mill to further cold roll the strip to the required finish are likely to provide a very satisfactory combination for steel production on a small scale.

Human Implications

The crucial role of steel in economic development having been established, and the technological possiblity of achieving, in successive stages, a production level of over 100 million tons by the end of the century considered, we now go on to discuss the human requirement of this dynamic programme. Our concern here is with the organization of management and with the training and development of Indian technical talent on a scale adequate to the size of the task before us.

This concern is prompted by the difficulties that have developed over the steel programme during the present Plan period, which forcefully underline the fact that proper management organization and competent personnel are as vital to success as any other factor. In view of the scarcity of capital resources, future development in our conditions is bound to be jeopardized unless plant and equipment installed at such great cost are fully utilized to generate the maximum surplus for reinvestment. It is important, therefore, to examine in some detail the requirements of efficient management of design, construction and operation of large industrial complexes such as exist in the steel industry. Since it is mainly through the agency of the public sector that future steel development is to be realized, our discussion will relate to State undertakings.

Autonomy in management

Most of these State industrial undertakings were organized as joint stock companies, with the idea of ensuring to them a degree of autonomy in management and free them from the elaborate and cumbersome Government procedures. This autonomy is needed because decisions in a productive enterprise must be made far more rapidly than in Government departments. As the distinguished economist, Prof. J. K. Galbraith, has said, 'The State having created the organization must in effect, be willing to hold it at arm's length. It must remove it from any close connection with the civil service. It must accord it freedom from civil service clearances, procedures, and working rules. It must give it freedom of decision—this is the most difficult point of all—including freedom even to the point of making mistakes. Some mistakes are inherent in the tempo of business decisions.'[34] These mistakes could, perhaps, be avoided if we were prepared to wait and let each decision be approved, recommended and eventually finalized in the normal course of civil service procedure. As the professor remarks, this dilatory method is just the thing that inhibits and retards economic growth. In his judgment, the civil service procedure ensures 'that each decision is right at the price of overall failure in the result. While the individual trees are being saved, the forest is destroyed.'[34]

It was, as I said, to ensure business-like operation that the company form of management was adopted, but the object is frustrated by the fact that the majority of members on the Boards are permanent officials attached to the controlling Ministry or seconded temporarily to the enterprise. This official predominance has led many to doubt whether the Boards can at all function as genuinely autonomous units. There can be no objection to formal and manifest intervention by Government under the powers legally reserved to it, since such specific steps attract the constitutional responsibility of the minister in charge and he becomes answerable to Parliament for his actions. But when interference is informal and takes place behind the closed doors of the Board Room, autonomy of the enterprise becomes a facade 'erected', as has been said, 'mainly to defeat parliamentary control.'[35]

Delegation of authority

Apart from interference with autonomy, the basic fact is that there is insufficient delegation of authority to the Boards. This view finds authoritative endorsement from Shri Asok Chanda, former Comptroller and Auditor-General of India, and one time Chairman of the Sindri Fertilizers and the Hindustan Machine Tools, who cites the case of a Rs. 100-crore multipurpose river valley project whose administrator's powers were less than those the same person previously enjoyed as Chief Engineer of a State. Criticizing the insufficient delegation of financial powers, Shri Chanda points out that the delay in the issue of sanctions results in considerable idle overheads being added to the capital cost of a project, often affecting its economics. In Hindustan Steel, the company charged with the execution of projects costing over Rs. 500 crores, the Board's powers for sanctioning capital expenditure are limited to a maximum of Rs. 40 lakhs or one-twelfth of one per cent of the total capital cost. It is suggested that industrial enterprises should be required to draw up periodic capital budgets, say, on an annual basis, which once accepted should obviate the need for executive sanction on individual items. Otherwise, financial restrictions and delays will seriously militate against efficiency and it will be impossible to run these enterprises on commercial lines. As Shri Chanda has remarked regarding the present financial and administrative structure : 'The cumulative effect of these arrangements has been to make these companies move even slower than departments of the Government, although quick decisions and speed are essential for their efficient operation. A comprehensive reorganization should now be effected, and the conception on which this form of management was adopted should be fully introduced.'[35]

The limited autonomy most public undertakings enjoy is rendered even less effective by the present practice of giving the finance man a veto over the decisions of the Board since anything he disagrees with has to be referred to the Ministry. Where large sums of public money are involved, the Government admittedly has to retain a degree of control over their disbursement, but arrangements whereby a financial adviser is made primarily answerable to his parent Ministry and who cannot therefore identify himself with the goals of the enterprise or take responsibility for its overall efficiency, are not conducive to the management functioning as a team. His special prerogative undermines the authority of the chief executive, and a sort of dual control operates to the detriment of the efficiency of the enterprise.

The basic organizational defects referred to have contributed to the poor performance of a few public sector undertakings, causing some demoralization amongst young engineers within the country and concern abroad among India's important and influential friends. As examples of the latter, I invite your attention to the comments of Prof. Galbraith, the American Steel Delegation to India, and the World Bank Mission, widely published in the last few months. To quote Prof. Galbraith : 'Even a fairly brief stay at the actual sites of the new steel mills reveals numerous faults and further difficulties are on the way. Competent executives are frustrated and angry over the centralization of purchasing, personnel and financial decisions in New Delhi. These delays are a source of discouragement to the younger engineering and technical personnel who should be showing great enthusiasm. The result is poor morale where it should be high.'

Role of engineers

It is undesirable that the management of large and complex industrial undertakings should be entrusted to persons with no previous background of the particular industry or in many cases of any other. In the USA, most of the top management personnel in its mature and long established steel industry are qualified technical people with a wealth of practical experience acquired as they have risen up the ladder from junior positions. In the USSR, as a paper on the management of industrial enterprises states,[36] 'all leading appointments are occupied by engineers or people with technical education, who have shown their ability in practical work.'*

There is now widespread appreciation of the need for radical changes in the present pattern of administration. As the Third Plan outline recognizes,[37] the efficiency of public enterprises to yield the maximum results feasible is one of the important conditions to be fulfilled in order to sustain a large plan of economic and social development. It is proposed, therefore, to strengthen the executive machinery 'to function effectively on their own responsibility.' In the second place, within the sphere of responsibility assigned to the executive, the planners desire that 'there should be no interference with his decisions.' There is thus a healthy recognition of present shortcomings. It is reasonable, therefore, to hope that once the proposed reorganization of the administrative apparatus is effected, industrial growth in India will proceed apace, unhampered by procedural delays and red-tape. I believe that those who doubt our ability to mobilize our technical manpower resources, to cope with the large expansion we visualize, exaggerate our difficulties—and also do not take into account the progress we have made in the last decade despite heavy odds.

Self-reliance

One of the main purposes of this reorganization must be to give more responsibility and authority to the technical personnel not only at the top management levels, but also at lower rungs. This is particularly important in the planning and execution of our industrial projects which have suffered from a lack of confidence in Indian engineering talent. As a result, we have tended to rely to an undue degree on foreign technical knowhow. It is not my intention to suggest that we are in a position to dispense altogether with foreign technical assistance. But we should make a discriminating choice and import only such talent as is not available within the country. Where foreign experts need to be engaged, we should invariably associate our own technical men with them at each stage of their work.

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* Observations of the American Steel Delegation that visited the USSR in 1958 confirmed the statement quoted here. The delegation reported: 'In general, the plant directors met by the American Delegation were sound, capable men with many years of experience and full technical backgrounds in steelmaking. Delegation members were told that the Soviet Union's aim is to have technically trained men in all management positions.'

The attitude towards Indian engineers is highlighted by the fact that many highly qualified men, with specialization and actual working experience abroad in various technical fields, find it difficult to obtain suitable work in India. As a result, many such men have preferred to work abroad, much as they would have wished to have a chance of working in their own country. A decisive break with the past policy is needed if we are ever to become self-reliant. The argument that Indian personnel lack sufficient experience is misleading, because Indian experience will never develop if the opportunities for acquiring it are constantly denied.

If some of our plan projects have been running into trouble, it is often because they are started without sufficient planning, investigation and adequate technical study of such factors as layout, availability and characteristics of raw materials and services. Such setbacks would be avoided if experienced technical personnel were associated with the projects from the inception, and given responsibility for such vital aspects as the design of plants, particularly from the viewpoint of choosing of processes and equipment suited to Indian raw materials and operating conditions.

Standardization

An important aim of associating Indian engineers would be to secure standardization of equipment going into our new plants. The importance of standardization cannot be sufficiently emphasized if we aim to reduce our dependence on imports for capital equipment. The machine building industries now coming into existence will have a better chance of meeting the country's needs economically if they can concentrate on a limited range of standardized equipment. For instance, we have today five major Indian steelworks, each with plant buildings of varying spans requiring cranes of separate designs ; ladles, transfer cars, and other auxiliary equipment are also non-standard. In the future, equipment size and ancillary units should be standardized to the maximum extent, because this would reduce costs by enabling longer production runs of various components, shorten delivery periods, and cut down on inventories of spares. For instance, we might standardize on two or three sizes of blast furnaces—small, medium and large, and produce standardized castings, forgings, etc. for their components. Similarly, building and construction costs could be appreciably reduced by standardizing.

Reduce construction costs

After the designing stage, the engineers can play an important role in further reducing construction time and cost. Such savings can be effected, for instance, by careful planning and scheduling construction on a continuing basis so that trained personnel and expensive construction equipment are fully utilized. It is unfortunate that at the steel projects today trained construction labour has been largely disbanded, and skilled workers with valuable training on the job have taken other employment. As the expansion of these projects is already decided, and there are new projects like the alloy and tool steel plant at Durgapur and the fourth steel works at Bokaro definitely scheduled, it seems a great waste of scarce skill to allow trained men to disperse.

Careful phasing of construction can considerably expedite a project and reduce costs. For instance, the building of quarters for workers and installation of engineering and maintenance shops to be used initially for structural fabrication and repairs to construction equipment should precede work on the major departments themselves. This construction sequence, which is being used effectively in other countries, would help to minimize the temporary construction facilities and enable a good part of the fabrication work to be done at the site at lower costs.

Training

In the management of large industrial undertakings, particularly in the engineering industry, top level decisions require a thorough knowledge and understanding of the technological aspects as well as of modern management techniques. If Indian engineers and technicians are to shoulder wider responsibilities, we should strive to enlarge the supply and improve the quality of new cadres. An important method to achieve this is to introduce, as is being done all over the world today, industrial management courses as part of the curriculum of all engineering and technological institutions.

Another important reform needed is a better integration of practical training and theoretical study. One way in which this can be done is to run pilot-scale production units as adjuncts to teaching institutions. Working in such plants will give the students an understanding of the dignity of labour and of team spirit, and train them in organizing and managing production.

An aspect of training that deserves very special attention is that of developing personnel for maintaining the highly complex and expensive facilities already installed. The maintenance function, which unfortunately tends to be generally neglected at the Indian plants, requires engineers and technicians of high calibre, with training in modern preventive maintenance techniques. Such maintenance can contribute substantially towards continuous and trouble-free production.

A problem of more immediate importance is to find technical personnel with specialized training for each of the numerous industrial projects now being established. It is interesting to note in this connection that a high level Government committee recommended,[38] as early as 1956, that even before the construction of a new factory, requirements of technical personnel at different levels must be carefully assessed and recruitment made from training institutions. Recruits should then be 'sent to the industrial undertakings of the country similar to the one proposed to be set up and trained on the job with the result that, when the factories are built and machinery installed, no time is lost in manning it by persons of requisite skill.' However, the experience of some of the current industrial projects shows that such advance recruitment and training is not yet being effectively done. This situation must be altered, especially since the establishment of steel and other engineering complexes has created a large base for technical training within the country itself.

Suitably qualified and correctly oriented cadres of engineers and technologists can make all the difference between success and failure in Indian planning, provided, of course, they are given the opportunity to make a full contribution. In other words, engineers would have to broaden their horizons in order to equip themselves to perform administrative functions in addition to technical tasks. One of the most outstanding

23. 'Productivity Team Report on Iron & Steel', op.cit., page 90.

24. Based on D. P. Cromwell, 'Modern Trends—Sintering Plants & Blast Furnaces', Iron & Steel Engineer, Pittsburgh, Pa., USA Volume XXXVII, No. 6, June 1960, page 129, and other published reports.

25. Notini Ulf, 'Experience with Sinter Burden in Swedish Blast Furnace', Report to the Metallurgical Congress, Belgium and Luxembourg, 1958 of the British Iron and Steel Institute and Journess Internationales de Siderurgie.

26. J. S. McMahan, 'The Use of Self-Fluxing Sinter', Blast Furnace and Steel Plant, Pittsburgh, Pa., USA, Volume 47, No. 1, January 1959, page 52.

27. Dr-Ing. Helmut Wendeborn, 'The Importance of the Sintering Process in the Production of Pig Iron', Reprint from 'Metalgesellschaft—Review of the Activities', Number 1, 1959, page 3.

28. Ibid, Based on figures on pages 4 and 5 ; USSR figures for 1958-59 from other published sources.

29. 'Long Term Trends & Problems of the European Steel Industry', op.cit., page 87, figure 3.

30. Ibid, Based on figure 4, page 89.

31. N. B. Melcher, J. P. Morris, E. J. Ostrowski & P. L. Woolf, 'Use of Natural Gas in an Experimental Blast Furnace', U. S. Bureau of Mines, R.I. 5621, 1960.

32. 'Long Term Trends & Problems of the European Steel Industry', op. cit., page 100.

33. Ibid, page 103.

34. J. K. Galbraith, 'Industrial Organization and Economic Development', Colombo, April 15, 1959, page 11—as quoted in paper no. 23, presented at seminar on management of public industrial enterprises, New Delhi, December 1959, page 8.

35. Asok Chanda, 'Indian Administration', (George Allen & Unwin Ltd., London), 1958, page 204.

36. S. S Norozhilov, 'Basic Principles and Task in the Management of Industrial Production in the USSR', paper no. 64 presented at seminar on the management of public industrial enterprises, New Delhi, 1959.

37. 'Third Five Year Plan : A Draft Outline', op.cit., pages 58 and 59.

38. Government of India, Planning Commission, 'Report of the Engineering Personnel Committee', 1956, page 21.