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## APPROPRIATE TECHNOLOGY FOR HEAVY INDUSTRIES

APPROPRIATE TECHNOLOGY FOR THE IRON AND STEEL INDUSTRY,

Background Paper

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# APPROPRIATE TECHNOLOGY FOR THE IRON AND STEEL INDUSTRY

An analysis of the appropriateness of the present steel technology for India; the causes for deviations and a strategy for developing and adapting steel technology in India

by

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# CHAPTER 1

## 1.0 INTRODUCTION

### 1.1 The Four Corner Stones of Appropriate Technology.

The Industrial Policy Resolution promulgated in 1948 was motivated by the objective of raising the standard of living by exploiting the country's resources, increasing the level of production and offering opportunities to all for employment. The Directive Principles of the Indian Constitution enjoined the states to undertake measures to assure citizens an adequate means of livelihood and raise the standard of living without leading to concentration of wealth and means of production to the detriment of the common good. The above two are the beacons which guided industrial development in India for the past 3 decades. Despite the good intentions of the industrial policy, the fact remains that in 1978, India, with a population of over 600 million, cannot consume more than 14 kg. of steel per capita. This can directly be attributed to the lack of purchasing power by the majority of the population. For accelerating industrial growth, the purchasing power of the population plays a vital role since there are close backward and forward linkages between industries such as metal and equipment on the one hand and consumer goods and agriculture on the other. The purchasing power can be increased by fuller employment of the population towards productive output. For the developing countries, employment is the chief of the socio-economic objectives. Technology infrastructure, technology transfers, and manpower planning should be directed towards fulfilling this objective. It is in this context that one needs to define appropriate technology.

Technology choice in the industrialization of developing countries is no more an independent factor in deciding the production structure of a community. On the contrary technology selection should be determined after setting the production targets and identifying social goals. The typical condition of the poor in most of the developing countries is the restricted work opportunities which in turn prevent the poor from working their way out of misery. For a poor man the chance to work is the greatest of all needs. Gabriel Ardant* has said that it is important that there should be enough work for all because that is the only way to eliminate anti-productive reflexes and create a new state of mind. It is more important that everybody should produce something than that a few people should each produce a great deal.

From the above premises, one concludes that the task, then, is (i) to bring into existence sufficient workplaces in the areas where the people are now living. Since creating a workplace requires 'capital' it follows that (ii) these workplaces on the average should be cheap enough so that they can be created in large numbers without calling for an unattainable level of capital formation and imports. (iii) It is also essential that the production should be mainly from indigenous or local materials and mainly for local consumption. (iv) The requirement is that the technology used be cognizant of the skills, managerial inputs, raw material supply, financing, marketing etc. These are the four corner stones defining the broad terminology of appropriate technology. In the subject matter discussed in this paper, the appropriateness of the Indian Steel Technology will be tested and an analysis will be made into the factors which mandate transgression of the boundaries defined by the corner stones.

*References are given at the end.

## 1.2 Multi-Dimensional Aspects of Appropriate Technology of Steel.

Besides capital equipment, technology comprises of production processes including the length of gestation period, production designs, an organisational system to effectively utilize industrial inputs and managerial skills for efficiently co-ordinating the various factors of production. Development of appropriate technology requires a careful direction of these activities. A country has to pass through the phases of accumulation, diffusion and adaptation of technology before it can become self-sustaining. During the early stages of development, it may be necessary to acquire the required kind of technology from advanced countries. It is necessary to ensure that the capital equipment can be adapted to local conditions and the necessary expertise developed indigenously. Adaptation of transferred technologies, along with indigenously innovated ones, require a multi-dimensional systems approach, which takes into consideration the economic, social and political aspects.

### 1.2.1 Economic Aspects of Appropriate Technology

The question of appropriate technology has risen after the stark realization by people like Schumacher that the world economic system is living on irreplaceable capital which it cheerfully treats as income. This capital can be categorized as natural minerals and fuels, the tolerance margins of nature and the human substance.

During the past decades the 'rich' nations have been consuming fossil fuel at a rate of 4.5? tons per head compared with the consumption of 0.32 tons per head by the poor nations. In this process, this once-for-all endowment of relatively cheap and simple fuel is rapidly being depleted. At the present economic growth rate, the world's cheap and simple fuels could easily become dear and scarce long before the poor countries have acquired the wealth, education, industrial sophistication and the power of capital accumulation needed to apply the alternative fuels on any significant scale.

Keynes, the father of modern economics, advised that economic progress is possible only if we employ those powerful human drives of selfishness, which religion and traditional wisdom universally call upon us to resist. The modern economy is driven by a greed which is the very cause of its expansionist success. The question is whether such causes can be effective in the long run, or, do they carry within themselves the seeds of destruction of the human substance. It is common experience that despite the rapid rise in Gross National Product, people find themselves oppressed by increasing frustration, alienation, insecurity and so forth. After a while even the GNP does not rise due to a creeping attitude of non-cooperation, as expressed by various types of escapism. The cultivation and expansion of needs is the antithesis of wisdom. There can be growth towards a limited objective, but there cannot be unlimited, generalized growth. Gandhiji has said: "Earth provides enough to satisfy every man's need, but not for every man's greed". Permanence and predatory attitudes are incompatible.

Capital is largely a product of human labour, set aside for and used in further production. It is a product of work carried out in the past which was not consumed. The quantity and quality of land and other natural resources being fixed, with a growing population, output per head will rise only if the rate of growth of capital or improvements in technology, or both combined, is far greater than the rate of growth in population. The two domestic sources of capital available are voluntary savings and taxes. In a developing country where the bulk of the aggregate money income is spent on food and relatively primitive items of clothing and household necessities, capital formation by increased savings is difficult.

The next problem is of capital required to generate one rupee's worth of extra output. Experience of the past 3 decades has shown that the actual capital-output ratio is well over 4:1 implying that we have to increase our savings and investment by 4% for each percent increase in the population just to maintain the present standard of living. For the present rate of population growth of 2.5% per annum, aspiring for a modest economic growth of 1% in the output requires an increase in the savings and investment by 4 (2.5 + 1) = 14%. During the past decades the ratio of savings to national income was 5% in 1950 - 51, 6.3% in 1955 - 1956, 3.5% in 1960 - 61, 4.1% in 1965 - 66, and 4.8% in 1971 - 72 which is far below the minimum savings of 14%.

From the above discussion it may be concluded that:

i) Developing countries cannot consume at the same greedy rate as the developed countries have done in the past.

ii) Our objective for economic growth should be towards satisfying our needs and not wants.

iii) With the present capital to output ratio of around 4:1, it will require a herculean task to build up savings and pump this money into the economy to maintain a modest growth rate.

iv) Improvements in technology and introduction of technology with low capital to output ratio should be given a high priority.

### 1.2.2 Social Aspects of Appropriate Technology

The modern world has been shaped by its metaphysics which has shaped its education, which in turn has brought forth its science and technology. Today the world finds itself involved in three crises. The first is the dehumanizing of life as a result of the technological, organisational and political systems.

The second is the partial breakdown in the environment which supports human life and which has caused a disruption of ecological balance. The third is the rapid depletion of non-renewable resources which will pose severe bottleneck to future generations. On the other hand the hopes and expectations that modern technology can alleviate world poverty and unemployment have not been fulfilled during the past three decades. It still remains a challenge whether a technology can be developed which helps us solve the problems mentioned above.

From a sociological view point the primary task of technology is to lighten the burden of work of man in order to help him stay alive and to develop his potential. Technology has been most successful in reducing or even eliminating skilful, productive work of human hands. Virtually all real production has been turned into an inhuman choice which does not enrich a man, but deprives him of the opportunity to express his potential in the quality of the work. Modern technology has deprived man of the creative aspects of work involving his hands and brains. It gives him instead plenty of work of a fragmented kind, which he may not enjoy at all. Karl Marx had predicted that the production of too many useful things results in too many useless people.

Gandhiji had envisioned a system of production by the masses which mobilizes the priceless resources possessed by all human beings; their clever brains and skilful hands which support them with first class tools. The technology of production by the masses makes use of the best of modern knowledge and experience, is conducive to decentralization, is compatible with the laws of ecology, is gentle in its use of scarce resources and is designed to serve the human person instead of making him the servant of machines. We are, today, in possession of all requisite knowledge to systematically and by creative effort, bring this technology into active existence and make it generally visible and available. There is no industry, no matter how sophisticated the technology it requires, that need be inhuman, ignorant of ecological balance or depend totally on non-renewable resources. If the present technology can destroy human individuality, natural life and resources, then an appropriate technology must be developed to overcome these destructive tendencies.

1.2.3 Political Aspects of Appropriate Technology

The political system of the world to-day suffers from the Mansholt syndrome, which demands further, quicker, richer results which burst into newspaper headlines every day with the message "a break-through a day keeps the crisis at bay". Today, the main content of politics is economics and the main content of economics is technology. Everybody believes in growth; for growth is an essential feature of life. The important point is to determine what constitutes progress, growth and development.

Despite the stated objectives of the Industrial Policy Resolution, two phenomena are giving rise to nationwide concern, mass unemployment and mass migration into cities. In addition, one of the unhealthy and destructive tendencies emerging in India as well as in most of the developing countries, is an ever more accentuated form of 'dual economy'. In this system, two different patterns of living are coexisting in which the humblest member of one group has a daily income which is far in excess of that of the hardest working member of the other group. Recognizing the fact that there are at present two somewhat distinct economies, Tarlok Singh suggested four main directions in which a new orientation is needed. First, the economy of each distinct region has to be strengthened systematically to eradicate the existing extremes of poverty. Secondly, a variety of fresh approaches to reorganise land management must be developed. Thirdly, the conditions of household and rural industries should be developed into progressive industries. Finally, the two disparate sectors - the organized and unorganized parts of the Indian economy must be brought into a much closer relationship, so that they may grow together. To achieve a more unified and integrated economy, the resources of the modern industrial sector must be applied intensively to the transformation of the rural sector and raising the levels of the productivity of those subsisting on it.

## 1.3 Definition of Appropriate Technology for Steel

Appropriate technology should attempt to ensure the following four conditions:

i) sufficient workplaces should be provided in the areas where people live

ii) workplaces with low capital requirement are created

iii) use indigenous raw materials and produce mainly for local consumption

iv) be cognizant of the available skills, managerial inputs, raw material supply, financing and market conditions.

In addition, appropriate technology must be guided by the following economic, social and political aspects.

i) Minimize the consumption of non-renewable natural resources, strive towards an ecological balance and enrich rather than alienate human life.

ii) The objective of the economic growth should be towards satisfying our needs.

iii) Evolve those technologies which require a low capital to output ratio.

iv) The appropriate technology should fit into a system of production by the masses which mobilizes human resources and which supports them with first class tools.

v) The two disparate sectors of developing nations i.e. the organized and unorganized; must be brought into a closer relationship so that they may grow together. To achieve this the resources of the modern industrial sector must be applied to transform the rural sector and raise its productivity.

The purpose of this paper is to determine to what extent the present steel technology fits into the broad guidelines given above. In the subsequent chapters, the history of the growth of steel industry, its use and requirement are discussed. Next, the technological factors which have decided the course of steel technology to date will be analyzed. Thereafter techno-econo-social aspects for future steel plants are elucidated. Finally, some suggestions are made on the adaptation and implementation of appropriate technology.

# CHAPTER 2

## 2.0 HISTORICAL PERSPECTIVE

### 2.1 Historical Review of Development of Steel Technology

The art of smelting iron was known in India in ancient times. Reference to iron has been made in the Rig Veda (2000 BC) and it is said that India was the first producer of carbon steel (Wootz). The famous iron pillar of historic antiquity was built in India. In fact, India is considered to be the centre of origin of the iron industry in the world. It is probable that the iron age in India had started about 3000 years before the industry started in the European countries. In those days, Hyderabad and Madras in South India were the centres of production of wootz, which was highly valued in the world market.

#### 2.1.1 Emergence of Industrial Revolution in the West

Before the eighteenth century charcoal-fired furnaces were used in Britain and other Western countries for smelting iron. Areas rich in ore and timber were, therefore, the sites of the iron industry. In the second half of the eighteenth century, there was an expansion of the foundry trade. Pit coal was substituted for charcoal, and cast iron industry made its appearance. The puddling furnace, a coal fired reverberatory furnace was perfected by Henry Cort in 1783 - 4. In this furnace the pig was stirred to get rid of the impurities. A cheaper fuel could be used in this process and the rate of production could also be accelerated. In 1790, Homfray devised a method of refining so that the surplus silicon could be removed from the pig before treatment in the puddling furnace. In Cort's process two tons of pigs were required to make a ton of wrought iron bars. The introduction of the refining process invented by Homfray reduced this amount to between 30 and 35 cwt. Thus the invention of Cort and Homfray helped the production of malleable iron and Britain was the foremost country in its production during the period 1784 - 1875.

Economy in fuel consumption could be made for iron production, thanks to the efforts of J.B. Neilson, who found that raw coal could be used to smelt the iron stones of Scotland if the furnace blast was heated. The use of anthracite coal for smelting became possible due to this invention of Neilson. This inspired the development of the iron industry south of Lake Superior in USA due to availability of vast resources of ore in close proximity to anthracite coal.

In 1856, Sir Henry Bessemer invented a process for converting molten pig iron into steel without using additional fuel. In a converter, carbon and silicon could be burnt out of the metal by a blast of air blown through it. The requisite carbon could then be restored in the form of ferro-manganese or spiegelison. This process took between twenty and forty minutes only. The Siemens Martin of the Open Hearth process which differed from the Bessemer, and proved more popular than the latter, was introduced by 1869.

The invention of the basic process in 1879 by Gilchrist and Thomas marks a significant event in the history of the iron and steel industry. They showed that if the Bessemer converter of the Open Hearth furnace were provided with a lining of some basic material, the phosphorus from the ore could be taken away during conversion and good quality steel could be produced from phosphoric ores. During the nineties, the electric furnace was introduced for steel-making. The production of special alloy steels containing mananese, silicon, chromium and nickel steel started before the First World War (1914 - 18). From 1894, Open Hearth Steel became very important and in 1913 it formed about four-fifths of the total British output.

Towards the end of the nineteenth century, America developed the steel industry. By 1890 American output exceeded the British and by 1913 it was four times as great. In 1913 the German output of steel was more than twice the British output.

In 1913 Great Britain, United States and Germany were together responsible for 87% of the world's pig iron and 75% of the world's steel output.

The above historical survey shows that the iron and steel industry is dynamic. It shows that technical changes bring changes in supremacy of different countries in steel production. With the introduction of coal as fuel in iron making due to the inventions of Darby and Cort, England with her abundant coal supplies gained supremacy over countries with timber resources in wrought iron production. The introduction of the blast furnace made Scotland an important iron producer. South Staffordshire declined as an iron producer with the invention of Bessemer and Siemens processes and the industry in Britain migrated to the coastal areas. The Lorrain ores could be utilised for steelmaking, thanks to the introduction of the Thomas process, so that Germany became the chief European producer. Technical changes bring changes in leadership in an industry and the iron and steel industry furnishes a good example of this.

## 2.2 Steelmaking in the Current Era

The current era of steelmaking started after the initial shock of the Second World War was over. All the advanced countries began producing steel on a large scale.

This was helped by the development of oxygen steelmaking and continuous casting. In this steelmaking race USA became the top producer during the 1960's. It was later compelled to cut down its production for economic reasons. USSR is making steady progress and became the top producer during the 1970's and is still going ahead. Japan was another country which was trying to get to the topmost position within the next few years, but was compelled to cut down production due to increase in cost of fuel and decline of export market.

The developing countries, which became independent from foreign rules after the Second World War, took steelmaking as one of their national developmental programs. India, China, Brazil, Iran, Nigeria, etc. are giving high priority to the steelmaking front.

Today, the trend in every country is to become self-sufficient in iron and steel production, consequently the exporting countries are being forced to cut down their production. As iron ore is fairly evenly distributed all over the world every country will become more or less self-sufficient in steel if other raw material and technological skills are also acquired. The large producers will have to cater largely to meet their domestic requirement.

## 2.3 Iron and Steelmaking in India in Modern Times

The first smelter for iron ore in India was started by Joshua Marshall Hearth at Porto Novo, Tamil Nadu in 1830. In 1833 furnaces, forges and rolling mills were also created at Boigpur Malabar. In 1853 a company called East India Co. was formed in London. This company erected smelters and works at Tiruvanamalai in North Arcot and at Palampatti.

About the year 1874 the Bengal Iron Works Company was formed. The works of the company were constructed in 1975 at Kulti, 145 miles West of Calcutta. In 1875 the works consisted of 2 blast furnaces, yielding 40 tons of pig iron per day. There was also a foundry to convert the pig iron into railway sleepers. The works were acquired by the Government in April 1882 and since were known as the Barakar Iron Works. One blast furnace was started in January 1884. A second blast furnace was erected in 1889. The same year the Government transferred the undertaking to M/s Martin and Co. The works were then remodelled. Towards the beginning of the present century, the new concern called the Bengal Iron and Steel Co. had 2 blast furnaces, producing 40,000 tons of pig iron per year. In the first decade of the twentieth century another blast furnace was added so that the annual capacity rose to 75,000 tons.

The Tata Iron and Steel Company was formed in 1907. The works of the company were erected at Sakchi (now Jamshedpur), a village in Singhbhum. Originally there were two 200 T blast furnaces, four 40 ton open hearths, a steam-driven blooming mill, a rail and structural mill and a small bar mill.

The Indian Iron and Steel Co. was formed under the managing agency of M/s Burn and Co. in March 1918. The works of the company were erected at Hirapur, situated about 140 miles from Calcutta. There were two blast furnaces each of 800 tons per capacity. In 1936 the Bengal Iron and Steel Co. was amalgamated with the Indian Iron and Steel Co.

The Government of Mysore erected a small charcoal furnace at Bhadravati in 1923. A small steel plant was added later and it started production in March 1936. Steel rolling mills were also started in April of the same year.

In 1937 the Steel Corporation of Bengal was formed under the managing agency of M/s Burn and Co. for producing steel from pig iron manufactured at the works of the Indian Iron and Steel Co. The works of the steel corporation were sited at Burnpur adjacent to the works of the Indian Iron and Steel Co. The initial ingot capacity of the works of 270,000 tons a year was subsequently doubled by the addition of two basic Bessemer converters.

### 2.3.1 Dawn of Independence - Massive Industrialization

During the first five year plan emphasis was laid on the development of agriculture. In the steelmaking sector, the plan included (a) the modernization and expansion of the works of the Tata Iron and Steel Co. for increasing the capacity of its plant from 1 million to 1.3 million tons of ingot steel per annum, (b) the expansion scheme of the Indian Iron and Steel Co. to raise its capacity from about 0.3 million tons to 0.5 million tons of steel ingots a year and (c) the expansion of the Mysore Iron and Steel Works to a capacity of 100,000 tons of finished steel, to be achieved by 1965.

In 1953 the Steel Corporation of Bengal was amalgamated with the Indian Iron and Steel Co. and as a result, the Indian Iron and Steel Company became an integrated iron and steel producing unit.

### 2.3.2 Development during the Second Plan

The Iron and Steel Industry had the most spectacular and eventful growth during the second plan which began in April 1956. Highest priority was given to the development of the iron and steel industry and provision was made in the plan to raise the capacity in one step from 1.5 M ingot tons to 6 million ingot tons.

It was planned to achieve the target of 6 million tons of steel ingots a year by (a) installing three integrated steel plants in the public sector, each with a capacity of 1 million tons of ingot steel a year and (b) increaing the capacity of the Tata Iron and Steel Co. to 2 million tons of ingot steel per year and that of the Indian Iron and Steel Co. to 1 million tons of ingot steel per year.

A public sector undertaking, the Hindustan Steel Ltd. was set up to look after the three one million ton steel plants. The steel plants were set up with the help and technical support from foreign countries, at Rourkela in collaboration with a German Combine, M/s Krupp and Demag, at Bhilai in collaboration with the Government of USSR and at Durgapur in collaboration with the Indian Steel Works Construction Company Ltd., a special consortium of 13 British companies.

## 2.4 Consequences: A Fresh Look at the Problems and Opportunities

From the above historical review, one can discern a consistent trend in which innovation in technology enabled the use of material resources which were locally available. It may be stated that prior to 1950, the steel industry fulfilled most of the criteria laid down in the first chapter for appropriate technology. It was less capital intensive, it employed more people per capital invested due to the many hand operations in the various stages of production, the plants were centered around the regions where coal or iron ores were accessible and finally most of the steel was for domestic consumption. The major drawbacks, from a modern viewpoint, of the steelmaking of the pre-1950 era were that it did not permit massive steel production and it demanded severe physical exertion from the workers. Andrew Carnegie recognised the latter and had a policy of giving each batch of crew sufficient rest and recreation between each period of work while another rested and refreshed batch took over the work. It was the experience of the Carnegie-Illinois Steel that the production was more than double than if only one crew had worked consistently. This was one of the most appropriate technologies of human endeavour which was abandoned after the introduction of the concept of industrial engineering, automation and trade-unionism.

The deviation of the steel technology from our criterial of appropriate technology started as a consequence of several technological developments in other industries. These were the production of tonnage oxygen, development of hydraulics and electrical machinaries to replace steam power, refractory development and the concept of leisure as a necessary part of human life. Social workers and trade unionists demanded less physical exertion for workers which forced innovation of automatic handling devices. The economics of these devices demanded large through-put and the adage of "the bigger the better" became a catch word. With bigness came speed, speed at high temperature demanded more automation and only skilled human intervention. As the production capability grew, the demand on raw materials increased. Since the local resources were either insufficient or inadequate in their property requirements for the higher production rate, they were imported from the countries where they were cheaply available. On the other hand the massive increase in the output flooded the domestic markets and it became necessary to export the steel to keep the high production units operating most of the time. The net result of all this was to employ less unskilled labour, depend on non-indigenous material and foreign markets and make the plants so large that the capital block per ton of steel produced increased rapidly.

India's entry into the steel age during the second five year plan was in the midst of the world-wide whirlwind of faster, bigger and more sophisticated technology. Despite TISCO and IISCO, India had lost its primordial position of the earlier centuries in iron production. Our planners were enraptured by the promise of modern technology to uplift human life. If India adopted the post-1950 steel technology with a pre-1940 feudal social system, it was because no one realised that sociological factors are important in industrial growth. It was sincerely believed that a technologically sophisticated industry can economically prosper in a sociologically backward society, even if the bulk of the people had not even seen a simple machine. The Indian Steel Technology did use local iron ore, coal and most material except refractories and ferro-alloys It did produce for domestic consumption and it did employ a larger number of workers per unit capital invested than the western countries. In this respect it fulfilled to some extent the criteria of appropriate technology. However, it did not maximise output per capital invested by adopting and adapting the concept of Andrew Carnegie of a rested and refreshed worker. If such attempts failed, then it may be attributed to the ethos, culture and the attitude of the Indian worker towards production work. In this sense the steel technology in India may not be appropriate as it ignored the vital resource within the human being which can only be nurtured by education, organisation and discipline.

If the steel technology adopted during the early years met to some extent the criteria of appropriate technology, those steel plants which came in subsequently began to deviate more in one major criterion i.e. block capital invested per worker and per unit output. The future trends will cause still further deviation if we continue to use the present technology of iron making. Finally, our inability to expand our output by our own technological innovations and our reliance on foreign experts to improve and innovate underscores a chronic problem which is due to our social and administrative attitude as well as lack of training, education, organisation and discipline in technological fields. These are the opportunity areas that India should concentrate on to make the steel technology appropriate.

# CHAPTER 3

## 3.0 STATUS OF STEEL AS A BASIC MATERIAL

### 3.1 Utility of Steel as an Engineering Material

Iron, in the form of steel, is one of the most widely used engineering materials of construction. The reason for this lies not only in the abundance of its ores in nature and the ease with which it can be extracted, but also in its mechanical and physical properties which make it possible for steel to be used in a host of applications to meet the complex demands of modern civilization.

#### 3.1.1 Stiffness

Among metals iron was a very high value of Young's modulus. This value is exceeded only by Tungstun, Molybdenum and Chromium. The value of shear modulus, G, lies in the range of 0.35 - 0.41 times the Young's modulus. This makes steel an attractive material for applications requiring structural rigidity.

#### 3.1.2 Strength

A fundamental property of metals is the yield strength, and this can be further enhanced by alloying, reduction in grain size, dislocation hardening and precipitation strengthening. The phase transformation which occurs in steel can also be used for strengthening. Strength and touchness are conflicting requirements of steels. The production of fine grain size in steel not only improves the strength, but also enhances its toughness.

### 3.1.3 Fatigue Strength

Under dynamic conditions of loading, statistics have shown that the single largest mode of failure of a component is by fatigue and hence this property is important. For machined members the fatigue strength of steels is a about half the tensile strength and increases linearly up to a certain point and thereafter remains constant. Unfortunately, for structures fabricated from hot-rolled materials or those fabricated by welding, and hence, likely to contain severe notches, the fatigue strength remains static at a low level. Thus for dynamic structures, full use cannot be made of very high strength steels because the failure originates from surface or sub-surface flaws. There is an urgent need to detect the maximum size of surface and sub-surface flaws in machined components for fatigue failure prevention.

### 3.1.4 High Temperature Properties

Creep becomes important at temperature of the order of 0.4 $T_m$ where $T_m$ is the melting point of the metal on the absolute scale. For high temperature use, therefore, the melting point of the material becomes important. Steel has a fairly high melting point and maintains its modulus of elasticity up to its highest termperature of use of about 550°C. For gas turbines, transport engines and vehicles two more properties become important. They are the specific tensile strength (tensile strength/density) and the specific creep strength (creep strength/density). Because of its high density, steel is at a disadvantage here in comparison to Al and Ti on account of their lower specific gravity and to nickel on account of the higher creep strength of its alloys.

### 3.1.5 Weldability

The mode of fabrication by riveting has now been superseded by welding, but has brought many new problems in its wake. As it is a high temperature fabrication method, most often using consumables to fill the joint, it may create not only the problems of defects in the weld metal, but also of lower toughness of the low temperature transformation structures in the heat affected zone. Considerable work has been carried out in the establishment of carbon equivalent as a measure of weldability, but many problems remain to be solved. Current research is aimed at understanding the various factors which effect the weldability of steels.

### 3.1.6 Corrosion Resistance

Corrosion protection can be given to steel by painting, galvanizing, electroplating, etc. The introduction of weathering steels of the Corton type gives adequate protection against corrosion for use of steels in exposed conditions.

Stainless steels contain chromium, nickel and molybdenum and have superb corrosion resistance. These steels are used as turbine blade material, in the fabrication of chemical and pressure vessels, and in nuclear industry. In India, they are very popular for household utensil making. Stainless steel is also used as an architectural material. Recently coloured stainless steel has been used extensively for architectural purposes.

### 3.1.7 Magnetic Properties

Iron and steel occupy a unique position both as a soft and a hard magnetic material. The principal soft magnetic materials are non-oriented, silicon and non-silicon steel and cold rolled grain oriented silicon steel. Superior magnetic properties are offered by Alnico and a rare earth family of magnets.

3.2 **Materials that Compete with Steel**

It has already been pointed out that for high temperature applications nickel and cobalt-base super alloys replace steel above about 600°C. However, it is from plastics, concrete, aluminium and titanium that steel faces its greatest challenge.

3.2.1 **Plastics**

The chief attractive properties of plastics are their corrosion resistance, attractive colours and formation into various shapes by injection moulding. This is testified by their increasing use in automobiles, containers, etc. Steel will be meeting, in future, greater competition from plastics and composite materials like glass-epoxy etc. The latter have superior specific strength properties besides corrosion resistance.

3.2.2 **Concrete**

In high multi-story buildings steel has yielded place to reinforced concrete columns since dead weight is no problem. Further, a steel structure would need fire protection also. It has been shown that the specific strength of steel is about five times that of reinforced concrete in compression. Considering the strength to cost ratio, however, a steel column would be twice as expensive as a concrete column for the same load carrying capacity. For this reason reinforced concrete scores heavily over steel for short span bridges. For long span bridges it is important to keep dead weight as low as possible and, therefore, steel emerges as the material of choice for construction on account of its superior strength to weight ratio.

For exposed structures the problem of corrosion remains in reinforced concrete on account of the presence of cracks in the concrete. It is completely eliminated in pre-stressed concrete on account of the compressive force of the reinforcing members. It is hoped that with the introduction of weathering steels the corrosion problem of an exposed steel structure and its maintenance will be greatly eased, if not entirely solved.

### 3.2.2 Aluminium

Aluminium is partly replacing steel in the field of transport and containers. In automobile industry too it is replacing the cast iron engine block and brake drums and other steel fixtures. This trend is bound to continue as petrol prices continue to escalate. In the field of tin-coated containers for food stuffs, aluminium is making a strong attempt to replace steel. However, higher strength steels are becoming available in the thinner gauges. With the replacement of the hot-dip coating technique by electrotinning resulting in a thinner and more uniform tin coating and the introduction of tin-free steels, the resulting economies may be sufficiently great for steel to maintain its position in the container industry.

### 3.3 Materials that can be Replaced by Steel

Steel has been replacing wood in furniture in homes and offices. It has also replaced window frames in large buildings. In our country, brass household utensils have been replaced by aluminium and stainless vessels. With the increased standard of living it can be foreseen that stainless vessels will replace aluminium vessels in homes. Before this can happen, the industry will have to improve the thermal conductivity of steel cooking vessels by coating the underside with copper or making use of mild steel cladded on both sides with stainless sheets in the manufacture of cooking vessels.

# CHAPTER 4

## 4.0 PRESENT AND FUTURE DEMAND FOR STEEL

### 4.1 Per Capita Consumption

The per capita consumption of steel is an indication of the economic prosperity of the country. While Japan leads the world with about 800 kg. of steel per capita, we are placed 22nd in the list with a meagre 14 kg. Brazil which is often compared with India has 94 kg. per capita consumption. Iran and Korea have 90 kg. each, China 75 kg., and even Egypt 22 kg. Steel is an essential raw material for economic and industrial growth. This demands an increase of the steel consumption in the country.

### 4.2 Fluctuations in Demand

Short-term and long-term fluctuations in demand are a common feature of any market. Variations in steel demand in India were more frequent and pronounced in the period 1967 - 76 than in the earlier period 1951 - 60, reflecting the structural changes taking place in the Indian economy.

There are various reasons for short-term fluctuations in steel demand and consumption.

1. The level of output in the individual sectors of the economy where steel is a major input.

2. The attitude of the users and stockists towards steel prices and supplies.

3. The impact of economic factors which determine the level of steel consumption and the industrial climate in general.

The long term trends in steel consumption are principally determined by the level of economic development and by the structure of economy. Both steel consumption and gross domestic product continue to rise when the economy has reached a stage of industrial maturity, or 'take-off', even though short term variations in the steel use and overall economic activity occur periodically.

## 4.3 Current Demand and Sixth Plan Requirement

According to recent estimates, the domestic demand in 1977 - 78 was about 7.0 MT of finished steel which is expected to rise to about 7.75 million tons in 78 - 79, corresponding to about 10 MT of crude steel. As against this, the production from integrated steel plants is expected to be about 9.965 MT of crude steel in 1978 - 79. Accordingly a steel target of 9.9 MT has been fixed for the current year. For an indication of present demand for steel in India, Table 4.1 lists the sectorwise sales for the financial year 1976 - 77 as compiled by JPC. It takes into account the sales of all the major steel producers in the country. Sector-wise sales for different finished and semi-finished products have also been shown in the table.

The Steering Group for Steel set-up by the Planning Commission has, in a recent study, projected the following demand and availability figures for the sixth plan period. Category-wise details are given in Table 4 - 3.

Table 4 - 2

| Year | Demand MT | Expected Availability MT |
|---|---|---|
| 1978 - 79 | 7.61 | 8.74 |
| 1979 - 80 | 8.36 | 9.31 |
| 1980 - 81 | 9.12 | 10.22 |
| 1981 - 82 | 10.09 | 11.42 |
| 1982 - 83 | 11.06 | 12.24 |
| 1987 - 88 | 15.91 | 17.33 |

Table - 4 - 1

**MAIN PRODUCERS SECTORWISE SALES FOR PIG IRON AND STEEL MATERIAL DURING 1976 - 1977**

Thousands of tonnes

| Groups | Semis | Rails & Rly Materials | Structurals | Bars & Rods | Plates | Sheets | Skelp/HR Coil | Total Steel |
|---|---|---|---|---|---|---|---|---|
| Steel & Coal | 122,5 | 8,7 | 34,4 | 32,5 | 58,2 | 16,2 | 9,3 | 281,8 |
| Defence | 0,1 | 0,2 | 7,6 | 23,1 | 17,5 | 13,3 | 0,1 | 61,9 |
| HE Power | 13,5 | 2,9 | 99,1 | 34,2 | 24,3 | 2,6 | - | 176,0 |
| Other Govt. Depts. | 0,1 | 0,7 | 10,0 | 50,4 | 11,7 | 3,6 | - | 76,5 |
| Rly. Wagon Builders | 8,8 | 169,8 | 43,9 | 24,5 | 111,5 | 25,7 | 3,3 | 387,5 |
| Ports & Shipments | 0,5 | 0,5 | 2,9 | 8,0 | 15,0 | 0,4 | - | 27,3 |
| P & T | - | - | 3,2 | 6,6 | 0,2 | 0,1 | 9,2 | 19,3 |
| P [illegible] D | 0,7 | 0,3 | 14,5 | 84,2 | 14,7 | 4,6 | - | 119,0 |
| Major Public Sector | 0,3 | 0,2 | 2[illegible] | 4,4 | 33,4 | 8,1 | - | 70,0 |
| Bright Bars Mfrs. | 2,6 | - | 0,6 | 38,0 | 1,0 | 0,8 | - | 43,0 |
| Elect. Mfgrs. | 0,1 | 0,1 | 0,5 | 0,4 | 1,1 | 15,8 | - | 18,0 |
| Re-rollers | 505,7 | 2,0 | 6,4 | 66,0 | 3,8 | 4,7 | 2,4 | 611,0 |
| Jute Mfrs. | 40,2 | - | 1,4 | 3,1 | 25,1 | 12,3 | 685,0 | 767,1 |
| Wire Drawing | 23,0 | 0,3 | 3,7 | 180,6 | 2,3 | 20,2 | 0,9 | 231,0 |
| Cement/Oil/Textile | 0,9 | 0,1 | 16,7 | 20,1 | 24,8 | 33,3 | - | 95,9 |
| Basic Metal | 21,3 | - | 1,4 | 3,6 | 3,6 | 3,2 | 2,9 | 34,8 |
| Main fabricators | 1,4 | 0,2 | 3[illegible] | 7,1 | 20,0 | 8,7 | 4,6 | 74,[illegible] |
| Auto Mfgrs. | 1,4 | 0,1 | 5,1 | 4,7 | 21,8 | 18,4 | 3,4 | 54,9 |
| Furniture Makers | - | - | 0,5 | - | 5,4 | 28,7 | 1,4 | 36,0 |
| Drum & Barrel | - | - | 0,8 | 0,8 | 1,3 | 51,7 | 0,4 | 55,0 |
| Fastener Inds | 11,6 | - | 0,1 | 8,0 | 0,1 | 0,5 | 1,3 | 21,6 |
| Multipurpose | 28,7 | 1,8 | 39,7 | 40,1 | 33,9 | 51,8 | 10,1 | 266,1 |
| Foundry | 7,7 | 0,1 | 3,2 | 1,5 | 4,4 | 2,9 | 0,3 | 20,1 |
| House Builders | - | - | 1,5 | 8,6 | 0,4 | 1,5 | - | 12,0 |
| Corporation Bodies | 2,6 | - | 11,6 | 34,6 | 22,1 | 4,3 | 0,2 | 75,4 |
| SSEC/Agro | 0,1 | - | 38,2 | 16,6 | 23,9 | 34,4 | 0,5 | 113,8 |
| Misc. | 0,1 | - | 0,3 | 1,0 | 0,2 | 0,3 | 1,0 | 2,9 |
| Trade | 192,7 | 3,8 | 225,8 | 165,8 | 35,0 | 297,4 | 29,4 | 999,9 |
| Unclassified | 90,1 | 4,2 | 83,5 | 160,5 | 37,7 | 57,8 | 9,7 | 443,6 |
| **TOTAL :** | 1137,0 | 196,0 | 712,0 | 1049,0 | 604,0 | 723,0 | 775,0 | 5196,0 |

Note : This excludes sales of
1. Tubes - 54,000
2. Tin Plates 53,000
3. R/R (Defective) - 200,000
4. Other Defective - - 164,000
5. Other Misc. item - 40,000

511,000

**Table - IV - 3**

**ESTIMATES FOR PIG IRON & STEEL DEMAND 1978-79 TO 1982-63 & 1987-88**

Thousands of tons

| | CATEGORY | 1978-79 | 1979-80 | 1980-81 | 1981-82 | 1982-83 | 1987-88 |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A. | Pig Iron | 945 | 990 | 1040 | 1095 | 1150 | 1470 |
| B. | FINISHED STEEL : SHAPES : | | | | | | |
| 1. | Bars & Rods, wire Rods, Semis for forging | 3280 | 3650 | 4065 | 4530 | 5039 | 7379 |
| 2. | L & M Structurals | 1095 | 1170 | 1250 | 1335 | 1420 | 2068 |
| | Sub-Total Shapes | 4375 | 4820 | 5315 | 5865 | 6459 | 9447 |
| | FLAT PRODUCTS : | | | | | | |
| 4. | Plates | 820 | 880 | 945 | 1015 | 1084 | 1499 |
| 5. | HR coils/sheets | 1115 | 1200 | 1290 | 1390 | 1500 | 2219 |
| 6. | CR coils/sheets | 520 | 575 | 635 | 701 | 770 | 1175 |
| 7. | Tin Plates | 187 | 206 | 227 | 250 | 275 | 320 |
| 8. | GP/GC sheets | 242 | 270 | 300 | 330 | 365 | 490 |
| 9. | Electrical sheets | 96 | 115 | 140 | 168 | 203 | 305 |
| | Sub-Total flat products | 2980 | 3246 | 3537 | 3954 | 4197 | 6008 |
| 10. | Railway Track Materials | 257 | 294 | 331 | 368 | 405 | 454 |
| | TOTAL STEEL (B) | 7612 | 8360 | 9183 | 10087 | 11061 | 15909 |

## 4.4 Special Characteristics of the Indian Steel Market

Certain features of the Indian economy have directly influenced the pattern and level of steel consumption. Of the total 7.5 MT finished steel produced during 1977 - 78, about 4.5 MT were non-flat products which find their major application in construction activities, whereas about 3.0 MT were flat products which go to the manufacturers of industrial goods. Thus about 60% of the steel produced is in the form of non-flat products. As the country advances industrially the share of non-flat products should come down progressively whereas the share of flat products should become larger and larger. Another special feature is that the major buyer of steel in India is the organised sector, while steel has penetrated the consumer-oriented industries to a limited extent.

Yet another characteristic is that the distributive pattern of actual off-take of steel is highly skewed, as shown below.

**Table 4 - 4**

| Customers | % of total off-take |
|---|---|
| Top 100 | 33 |
| Top 200 | 50 |
| Top 500 | 66 |
| Top 900 | 75 |

In addition to the above, the geographic concentration of steel users is another aspect. Nearly 80% of the total home sales 4.45 MT from SAIL plants during 1977 - 1978 is accounted by 10 centres. In fact the four metropolitan centres, Bombay, Calcutta, Delhi and Madras account for 40% of total consumption.

4.5 Rural Consumption

One way to increase the per capita consumption of steel is to increase the consumption in the rural areas where 80% of our population live. To enhance the purchasing power of the rural masses, massive development of the infra-structure including rural energy and aids to rural production, storage, marketing and transport, decentralised small and oottage industries have to be taken up.

Steel usage in rural areas can be classified in terms of the basic needs of the people. For shelter, energy, tools and implements, water for drinking and hygiene, irrigation, transportation, household applications and grain storage, etc. are other areas where careful review of material selection would enhance the utilisation of steel. The cyclone-prone areas of the east coast would be benefited if a massive program of pre-fabricated steel structures could be constructed. Biogas plants which are just catching up, and utilisation of solar and wind energies would require steel and the consumption would go up if these programs are taken up on a priority basis. Water management and irrigation is another area where massive quantities of steel can be pumped into the rural areas. Regarding transportation, considerable efforts are being directed towards modernisation of bullock carts. There are nearly 13 million carts plying on the roads of rural India. These are linked up with the speedy development of the agro-based industries and small scale industries in the rural sector which in turn will stimulate the demand for various types of machinery and equipment and in turn, improve the off-take of steel through the enhanced purchasing power of the rural people.

## 4.6 Influence of Appropriate Technology on Future Demand Pattern of Steel

So far the iron and steel industry has taken the domestic market for granted and no special efforts have been made to create and build up the market for steel or to extend the uses of steel. Pictorial publications, information letters and other technical guidance material for the general use of all steel consumers and the engineering profession and specially written and designed material will have to be produced in local languages for the rural population to inform and educate them in the uses of steel. Exhibitions and films may be shown relating to agricultural and rural uses of steel, such as rural houses, farm buildings and barns, storage bins and sites, agricultural tools, implements, pumps, etc.

A group of experts of the Steel Authority of India (SAIL) has identified about 50 items of rural use which can be made from iron and steel. The items include 11 for farming, 8 for blacksmithy, 10 for carpentry and woodworking, 4 for masonry, 4 for cobblers, 3 for village transport, 8 for different service facilities, steel bins and silos for grain storage.

To promote the use of steel in the rural sector, the Steel Authority had appointed two groups - the production group and the marketing and distribution group. The production group was asked to look into designs, items to be manufactured, facilities required and the man-power to be trained. The marketing group was asked to identify products to be used in the rural areas. The production group has suggested that on a pilot basis 4 areas should be chosen where workshops are to be developed for the promotion of rural use of steel. In each area there will be village and block level workshops to cater to a group of villages and a group of blocks respectively.

The nucleus for the marketing effort will be the local entrepreneur who will be selected mainly on the criterion of his suitability. The steel personnel will provide the marketing leadership required for customer services. After six months, when experience is gained from these pilot workshops, they would spread to other districts.

It has been estimated that non-recurring investment in each area will be Rs. 4 lakhs and recurring expenditure Rs. 45,000. The turnover from each area will be Rs. 20 to 25 lakhs.

The marketing group's report has also suggested that rural marketing of steel should be linked to the integrated rural development program. It has been estimated that while a village workshop will provide employment opportunity for 10 persons, the block workshop will employ 20.

The SAIL group has also suggested a survey on the existing agro-industry units to assess their capacity. The new items for the farmer suggested by the group include a steel plough, a seed drill, a chaff cutter, a rice weeder, a hard wheel hoe, a potato and ground-water digger. These could be manufactured in the rural workshops.

A suggestion for an advisory body consisting of the representatives of the main producers to formulate policies, evolve a plan of action and coordinate the activities of the steel companies promoting rural use of steel, has also been made by the group on marketing.

The group on production has observed that whatever products the steel plants might manufacture should fit into a decentralised system. The transfer of technology to the villages should be horizontal in place of the present trend of vertical expansion. Under the scheme of rural use of steel local landless labour are to be employed and no village craftsman's occupation should be displaced. Villagers and their local organisations would have to be involved.

If the scheme is successful, it is estimated it would increase demand for steel by half a million to one million tons, particularly of flat products where production surpluses in the existing steel plants is expected to increase in the next few years.

# CHAPTER 5

## 5.0 FACTORS FOR CONSIDERING APPROPRIATE STEEL TECHNOLOGY

The conditions and guidelines defined at the end of chapter 1, will again be referred to in this chapter, to elucidate the role of the various factors which have decided the course of the steel technology to date and how they fall into the classification of appropriate technology.

## 5.1 Capital

The steel industry is one of the most capital-intensive sectors. The capital block per ton of steel produced has risen over the past two decades from a level of Rs. 1,720/ ton for Bhilai to 5100/t for Bokaro and Rs 6,420/- per ton in proposed V.S.P. plants. The table below shows the progressive increase of capital block.

Table 5

| Plant | Year of Commissioning 1st unit/last unit | Capital block per ton of steel ingot |
|---|---|---|
| | | Rs |
| R.S.P. | 1958/1961 | 2060/t |
| B.S.P. | 1958/1961 | 1720/t |
| D.S.P. | 1959/1962 | 1790/t |
| B.S.L. | 1964/1968 | 5100/t |
| V.S.P. | Proposed | 6420/t |

The capital block per employee also increased with time. The table overleaf shows the capital investment per employee.

Table 5 - 2

| Plant | No. of employees | Capital investment per employee (approx.) |
|---|---|---|
| B.S.P. | 50,000 | Rs. 34,000 |
| R.S.P. | 35,000 | Rs. 60,000 |
| D.S.P. | 31,000 | Rs. 60,000 |
| B.S.L. | 22,000 (excl. construction) | Rs. 3,70,000 |
| V.S.P. (Proposed) | 20,250 | Rs. 50,000 |

The turnover to capital invested also decreased in time. The turnover to capital ration in TISCO was 0.63 in 1971 - 72 compared to 0.58 in HSL as a whole during the same period. The proposed Vishkapattanam Plant will have a ratio of 0.2 only. These figures show that there is a steady decrease of output to investment despite the introduction of more modern technology.

It may be concluded that from the viewpoint of capital per man employed as well as capital to output ratio that the present steel technology as a whole cannot be considered appropriate for the developing nations. This may be elucidated as follows. The average annual income per worker in the steel plant is around Rs. 10,000/-, whereas the average capital per employee is 3,70,000 in the case of Bokaro. In the developed countries these two stand in the ratio of 1.1. This implies that in the developed countries it takes a one-man-year of savings to create one work place. In case of Bokaro it will take 37 man-years to create one work place to employ another man. If this capital is to be generated from the internal resources generated from the workers' savings, then it will take one employee's savings for 37 years if all of his income is invested. Thus with this high capital to employee ration, the steel industry will be for ever dependent on external financial resource for further growth.

The following table shows the various capital intensive centres in the steel production flow diagram for the integrated steel plant.

Table 5 - 3

| Production stage | % of total capital invested | Share in Rs./ton (Rs. 6000/t total block) |
|---|---|---|
| Iron Making | 20 | 1200 |
| Steel Making | 15 | 900 |
| Processing (Rolling Mills) | 30 | 1800 |
| Supporting Services* | 35 | 2100 |

*The supporting services are:

a) Emergency power plant
b) Oxygen plant
c) Water treatment plant
d) Machine shop and structural shop
e) Foundry and Forge Shop
f) Refractory Material Plant
g) Internal transportation in the steel plant
h) Township

The major reason for the high capital block for an integrated steel plant is the investment required for the captive supporting services. It may be possible to disperse the bulk of the investment required for the supporting services by allowing satellite and ancillary industries to be established around the main integrated steel plant. It may be possible to adopt less capital-intensive technologies for some of these ancillaries such as machine shops, structural shops, foundry, forge shops and refractories plants. Most of these facilities were established during the years when sufficient expertise and capital was not available in the private sector. For the future integrated steel plants, it may be possible to exclude some of these services from the steel plant and introduce less capital-intensive technologies which employ more labour.

5.2 Raw Material and Iron Making

The blast furnace process (BF) is currently the predominant iron making process accounting for over 97% of the iron produced in the world. Modern BF technology has a low fuel consumption of about 500 kg. coke with oil injection, using the top gas mainly for blast preheating and generation of power for running the furnace and its associated agglomeration plant and coke works. The total energy consumption of BF is about 4 G. cal./tons liquid iron. The principal requirement for an efficient blast furnace technology are:

a) Need for agglomerated ore.
b) Need for mechanically strong coke.

The cost of agglomeration as well as the cost of coke have risen rapidly in the recent past and have thrown open the field for an alternate process route. It may be noted that the BF route enjoyed its biggest growth and success when cheap coking coals were abundant and energy costs were low. This enabled an economic operation of coke ovens and permitted extensive burden preparation at low cost.

It is now generally accepted that for optimal operation of BF the pre-requisites are:

a) Large unit size
b) Nearly 70 - 80% agglomerated (Sinter/Pellet) ore

c) High quality coke, with minimum of ash

d) Extensive raw material preparation and sizing to minimise physical and chemical fluctuations in practice.

e) Auxiliary fuel injection

Most of the above factors have been difficult to fulfill, especially in developing countries like India, with the locally available raw materials. Optimal BF operations have been attained in Japan with fully imported raw materials; in Germany, USSR and to a limited extent in USA. However, even in these countries, the operations are subject to growing strains due to:

a) Increasing freight costs; a direct result of the energy crisis).

b) Escalation in raw material cost, especially coking coals.

c) Uncertainty in market conditions.

5.2.1 Specific Factors of Relevance to Indian Conditions

The BF process under Indian conditions is subject to extreme constraints. The major factors are:

i) Poor quality of coking coal (coke ash is currently averaging 25% in the plants, which has a crippling effect on productivity and operations.

ii) High $Al_2O_3$ content of ores which very adversely affects the slag regime in the furnaces.

iii) Poor quality of flux.

iv) Limited availability of coking coal

The BF practice in the country is consequently caught in a vicious circle of high coke rate and low productivity besides producting poor quality hot metal for steelmaking. Several remedies have been suggested from time to time including:

i) Benefication of raw materials: iron ore and flux

ii) Washing of coal

iii) Better raw material preparation and use of a high percentage of agglomerates in the burden.

iv) Auxiliary fuel injection.

v) Adoption of modern technology like high top pressure operation, high blast temp., bigger BF etc.

vi) Stable operation of furnace.

However, a stage has been reached where the gap in the best performance of BF in India and the advanced countries is widening year after year. In India the coke rate is in the range of 700 - 1,000 kg./THM and the best productivity is about 1.3 tons/m$^3$/day as compared to 450 kg/THM and 2.3 - 2.5 tons/M$^3$/day in Japan. Hence, there is an incentive to develop and adapt an "appropriate technology" in view of the techno-economics of furnace operation, the high investment for BF complex, which is of the order of Rs. 800 - 1,000/annual ton of hot metal and the depletion of coking coal deposits in India. It may again be emphasised that the extra cost of agglomeration (Rs. 80/THM) also adds to the incentive of developing better and appropriate technology for iron making in India, including the technologies of burden preparation and coke making.

5.2.2 Pelletisation of Ore Fines

Agglomeration of iron ore fines is an established technology in the world today. The most sought out agglomeration processes are sintering and pelletisation. Whereas sintering is a process which has been established for long, the process of pelletisation has been gaining momentum in the last two decades. Use of agglomerated burden in iron making is a well established practice and in this field sinter plays a dominant role in advanced countries like USSR, Japan etc. Pellets on the other hand have found their way mainly in USA to a large extent pelletisation of iron ore fines is attracting the attention of metallurgists for further development.

During mechanised mining of iron ore about 40 to 50% of fines is generated, most of which can be sucessfully used in sintering. However, the super fines (-1 mm. fraction) can be used successfully only in pelletisation. Apart from this, India is endowed with large deposits of blue dust which is high grade ore fines and which cannot be used in the sintering process. Hence, the technology of pelletisation is necessary from the view of utilisation of national resources.

The conventional process used for pelletisation is to manufacture heat hardened pellets. In India, there are only two plants under private sector which together make about 1.5 million tons of heat hardened pellets. One of them, namely the TISCO plant, uses the pellets for its own Iron and Steel Plant at Jamshedpur, whereas the other belonging to M/s Chowgule and Co. is exporting the same mainly to Japan. The use of any agglomerated burden in blast furnace will have to be techno-economically feasible for sustained operation of the furnace with this type of agglomerated burden. Whereas sinter as an agglomerated burden has established itself in this country, pellets have yet to find its way in iron making in the majority of the blast furnaces. The main reason for not using pellets in blast furnaces in India is the high cost of pellets. The reduction in coke rate and increase in production obtained by the use of pellets in blast furnaces do not offset the increased cost of hot metal with the present cost structure of various raw materials input in the pelletisation as well as blast furnace. Moreover, firing of pellets for heat hardening of the same, necessitates the use of a scarce and costly and imported commodity like oil.

Estimate of the effect of the use of oxide pellets on the production, coke rate and hot metal cost, based on a cost of coke of Rs.270 per ton for 2,000 $m^3$ furnace is given below:

Table 5 - 4

| % of oxide pellet in the burden | Daily production t/day | Coke rate kg./THM | Cost of hot metal Rs./THM |
|---|---|---|---|
| 0 | 1,720 | 895 | 540 |
| 20 | 1,800 | 860 | 550 |
| 40 | 2,000 | 790 | 556 |
| 60 | 2,200 | 740 | 562 |
| 80 | 2,540 | 705 | 568 |
| 100 | 2,680 | 685 | 574 |

The table shows very clearly that despite the decrease in the coke rate by use of pellets the cost of hot metal increases and no economic benefit is realised by the use of pellets in blast furnace under Indian conditions.

Efforts have been made for manufacture and use of fluxed pellets ($CaO/SiO_2$ 1.3). The effect of their use on the production coke rate and cost of hot metal is shown below and in this case the cost increases.

Table 5 - 5

| % Fluxed pellets in the burden | Daily Production t/day | Coke rate kg/THM | Cost of hot metal Rs/THM |
|---|---|---|---|
| 0 | 1,730 | 920 | 532.0 |
| 20 | 1,820 | 890 | 550.0 |
| 40 | 2,000 | 855 | 553.0 |
| 60 | 2,270 | 810 | 554.0 |
| 80 | 2,600 | 762.0 | 555.0 |
| 100 | 2,800 | 740.0 | 556.0 |

The capital cost of a pelletisation plant will depend on the process, raw material characteristics and plant capacity. The capital investment for a two million ton pelletising plant is 515 million rupees. The cost is reduced by use of larger units and reduction is primarily due to reduction in labour costs. The capital investment increases when fluxed pellets are produced. The capital cost will be less if the plant is located in a place where the required infrastructure facilities are available. An idea of capital is shown below.

Table 5 - 6

| Type of pellets | Maching size $m^2$ | Plant capacity mill tons/yr. | Capital cost mill Rs. | Specific capital cost Rs./T |
|---|---|---|---|---|
| Oxide | 300 | 2.0 | 515 | 260 |
| | 500 | 3.0 | 660 | 220 |
| Basic | 300 | 1.7 | 515 | 300 |
| | 500 | 2.5 | 660 | 250 |

Among the other methods for pelletisation of iron ore fines, the process of cold bonded pelletisation of ore fines is becoming more and more important. This process which is being exploited commercially in countries like Sweden is characterised by low investment cost, better flexibility in the raw materials and lower cost of pellets. Such a process may be appropriate under Indian conditions and development of this process to the stage of commercialisation will ultimately brighten the prospect of pelletisation and the use of pellets in this country.

5.2.3 Fuels

As one of the key raw materials for the production of steel, coking coal reserves are found only in a few places around the world. The present steel technology is consuming the non-renewable resource at a rate that poses a severe threat to the developing countries like India. Many technologies have been developed to reduce the consumption or totally eliminate the use of the choking coal.

For the modern Blast Furance, a combination of technologies have been developed for lowering the coke consumption. The injection of oil, natural gas and tar or pitch through tuyeres is attractive since the equipment needed for injection is simple and not so costly. In the world as a whole, 80% of the pig iron is produced with some form of injection of fuel. Oil or natural gas injection only partially meets our requirement of appropriate technology in that it is still a non renewable resource. Only in countries such as USSR where natural gas is abundant does it become appropriate. Injection of tar and pitch which are generated internally in the steel works fit in well as appropriate technology for India. To this could be added the technology of pulverized coal slurry injection through tuyeres which is successfully used in USA, China and on an experimental basis in USSR. However, the equipment for a coal slurry injection is expensive and complicated and the coal should be of low ash content, the availability of which is limited in India.

An appropriate blast furnace technology to reduce the consumption of coking coal can be selected by a combination of the various innovations that have taken place over the past 10 - 15 years and which is given in Table 5 - 7.

Charcoal based blast furnace iron making is a well established technology and is currently producing 4 million tons of iron in several developing countries like Argentina, Brazil, Malaysia and Thailand. Where forest resources are abundant or where it can be developed, this technology can be appropriate to develop foundry and steel industry. Brazil has opted for this route and is putting up a major steel complex based on a charcoal blast furnace attached to a larger forest development scheme. In India the Bhadravati Iron Works was operating on charcoal blast furance even after independence.

Use of low grade coal or soft coke, when available locally, could be an alternative to produce pig iron. Small and low shaft furnaces require low capital investment and are suited to small markets. In developing countries most of the small furnaces are using charcoal. In China coal or low grade coke are used. Not much information is available for techno-economic analysis of these furnaces.

Another development of appropriate technology for reducing consumption of coking coal consists of blending of charges, grain size adjustment of coal fines, oiling etc. In some cases this technology allows the blending of non-coking coal to some extent. Based on the blending of coals, the technology of pre-heating of coal fines allows use of up to 25% non-coking coal in the charge. In order to prevent environmental pollution with this technology, sophisticated and expensive equipment is required which is difficult to install in existing coke ovens.

For conserving energy and reducing coke loss as coke breeze, the dry quenching processing for red hot coke developed in USSR and Europe promises to reduce coke consumption. This technology also decreases part of the environmental problem of coke ovens.

Table 5 - 7

Fundamental requirements

(a) Careful preparation and charge of raw materials (high strength coke, controlled ore size, minimal powder, adequate distribution of charges in the furnace, etc

(b) Skilled BF operation technique

(c) Well established maintenance system

(d) Appropriate furnace design and set up

| Coke rate per ton of HM | Technology* | Application | Effect on coke rate |
|---|---|---|---|
| Kg. | | | |
| 700 | Sinter and/or pellet charge | up to 100% | 5 to 12 kg/10% substitution |
| 600 | Blast control | | |
| | (a) high temp. blast | up to 1,300° | 10 to 20 kg/100°C increase |
| | (b) humidity adjust | | |
| | (c) oxygen enrich | up to 4% | Make oil injection possible |
| 520 | Fuel injection through tuyere | up to 120 kg | 10 to 15 kg/10 kg injection |
| 450 | High pressure operation | up to 3 kg/cm$^2$ | 10 to 17 kg/1 kg/cm$^2$ increase |
| 430 | Pre-reduced ore addition | up to 20% (M.Fe/T.Fe) | 30 kg/10% M.Fe addition |
| 400 | Stack gas injection | Pilot plant stage (Coke rate may drop to 250 kg orso) | |
| 250 - 300 | | | |

Chart 2. Technologies which lead to the reduction of coke rate in blast furnaces

*Does not necessarily indicate the order of technologies to be applied; in most cases a combination of several technologies is used

The briquette blending coking process, where a mixture of coal fines and coal briquette is coked in conventional coke ovens, allows a reduction in coking coal of up to 30%. The additional capital investment required consists of only a briquetting equipment. This is another appropriate technology which will find wide applications in existing coke producing plants.

A formed coke process might solve the problems of scarce and unevenly distributed coking coals and environmental pollution. Despite many successful large scale trials, the wide scale adoption of this process requires technological development of carbonisation furnaces and large scale hot forming machines with a long life, availability or development of binding additions, development of BF operation technology best suited for formed coke and improvement of formed coke characteristics, best suited for BF operation. Another major impediment to the rapid adoption of this technology is the capital investment in the existing coke ovens which have a long life (20 - 30 years) and the energy balance of the steel plant which depends largely on the coke oven gas.

5.2.4 Conversion and Processing of Steel

The technology of conversion of pig iron to steel has been dynamically changing over the past one and a quarter century. The present technology of pneumatic oxygen steelmaking; the LD and the more recent Bottom Blown Oxygen Process (BBOP), has displaced OH which required an external fuel supply and which posed more severe environmental pollution problems. The pneumatic process, on the other hand, is more automated and therefore employs fewer people per capital invested.

Since these processes are dependent on Blast Furnace hot metal, the selection and operating technology of these steel making plants do affect to some extent the choice of raw material and fuel consumption. The BBOP permits more flexible blast furnace operation in terms of the quality of metal (sulfur, silicon, phosphorus and temperature) than the LD. This can permit a BF practice which can produce more hot metal in the existing installation with reduction in coke rate.

The recovery of the rich off gas from the BBOP is easier. It can be used to reduce the consumption of fuel oil. A future innovation of the bottom blown process is not hard to contemplate, wherein hot metal may be continuously refined to steel by injecting coal and iron powder into liquid metal to (1) increase output of steel in the existing plants, (2) use the more abundant iron ore fines and coal dust, (3) generate sufficient high calorific value off gas to replace to a large extent fuel oil in the steel plant.

For the integrated steel plants, the advent of the bottom blown oxygen technology takes us a few steps closer to our definition of appropriate technology than the LD process. The BBOP requires 10% less capital, has the ability to increase the output per capital invested, is an easier technology, requires less raw material such as burnt lime, is easy for environmental control and reduces the strain on fuel and other resources at the blast furnace. Further development in this process may well reduce the capital to output ratio.

Technology development for processing of liquid steel into semi-finished products has led to two alternate routes. From capital investment to the output ratio aspect, the continuous casting route is cheaper than the conventional ingot casting-blooming mill route, for the production of small tonnages of flat and non-flat products. As the size of the plant increases and approaches 2.5 million tons per year, this advantage is narrowed especially for non flat products. For heavy structural and forging quality steel, continuous casting is not favourable.

The energy savings and increase in the output/input is in favour of continuous casting, which also is less harsh on environmental pollution. The continuous casting technology has enabled installation of small scale steel plants producing from 40,000 tons per year and in this sense fits into the definition of appropriate technology better than the conventional ingot casting, blooming and billet mill.

The more recent development of horizontal continuous casting in USSR, USA and UK takes one additional step towards making this an appropriate technology. The flexibility of the horizontal continuous casting process to cast a larger size range of billet and bloom from (70 mm to 200 mm) on the same machine reduces the capital investment by eliminating the need for a separate billet and a bloom caster. In addition this technology eliminates auxiliary handling facilities such as a crane, a ladle tower or a dummy bar pit, thus further reducing the capital cost.

The technology of producing finished steel products varies depending on the size, shape and the product properties required. For alloy steels required for tools and implements, forging is more appropriate in that it can be dispersed over a wide geographical area and can employ a substantially large number of people. Simple steam or hydraulically operated forging machines are also suitable for producing items such as farm implements and simple tools and tackle.

Production of wire rods for reinforced concrete application can easily be done by simple re-rolling mills with coal fired furnaces, whereas for the production of sheets required for simple applications, such as spades "gamelas" etc., the hand rolling operation is still appropriate in terms of low capital investment and more labour employed.

The modern hot strip mill does have alternatives for producing the sheets and plates. These are the semi-continuous mill and the steckel mill. The capital invested per actual output is less for the steckel mill compared to the continuous hot strip mill, although the energy requirement is higher due to constant reheating of the coils. The planetary hot rolling mill has not been developed fully for consideration here.

The production of non-flat products is feasible in mills of various sizes and sophistication depending on the end use. In these mills there is always a trade off between low capital invested and high labour intensity on the one hand and high energy consumption on the other.

For engineered products such as rails, rounds, beams etc., the technological choice must always consider the end use which can be catastrophic if proper process technology is not employed. Here appropriate technology must take a back seat.

At present most of the steel used for making simple tools and fixtures in the rural areas comes from selective use of scrap The forming and fabrication is done mainly by the rural blacksmiths who pay over 5 times the price of scrap in the urban centres. This robs the rural entrepreneur of the margin required to make cheap steel products which can be consumed by the rural masses. In order to make the steel available to the rural entrepreneur at a cheaper rate, so that he can plough back some of the surplus into the rural economy, a detailed study is required on the feasibility of dispersal of the re-rolling and metal forming industry to rural areas. This will generate scrap closer to the rural consuming centre and reduce the number of middle-men in the present system of steel trading. The dispersal of the metal forming industry in the rural areas can be done by upgrading the blacksmithy to small scale forging operations and the rural carpenters to steel fabricators. This concept has been accepted in principle by the Ministry of Steel and Mines and the Steel Authority of India Ltd. and a program to set up rural workshops has been drawn up.

CHAPTER 6

## 6.0 STRATEGY FOR STEEL PRODUCTION

### 6.1 Alternate technologies for Increasing Steel Production in India

The first UNIDO consultative world meeting on steel in 1977, predicted an increase in the world steel production to 1,750 million tons by the year 2000 AD. It has further been forecast that 30% of this should be met by the developing countries. UNIDO have projected a growth rate of 7.8% for the developing countries for the period 1974 - 85 and 5.8% for 1985 - 2000 AD. Considering the above factors, the demand of steel in India emerges as 17 million tons by 1985 and 43 million tons by the year 2000 AD, compared to the present capacity for production of crude steel in India of 13.6 million tons.

The increased demand for steel can be met by either recycling scrap or by the production of fresh metallics like pig iron/sponge iron and conversion of the same to steel.

The various alternatives for the production of steel starting from ore is given in figure 6 - I. One of the important factors for the production of metallics from iron ore is the choice of reductant. The alternative choices of reductants for various iron making routes is shown in figure 6 - II.

#### 6.1.1 Strategies for Increasing Steel Production in Integrated Steel Plants

The strategy for the production of crude steel depends on the rate of growth of the domestic demand, the availability of raw materials, reductants, energy, infrastructure and capital. Out of the capital invested in a new integrated steel plant 35% is for supporting services and infrastructure.

The break-up of the cost of production of finished steel in a new plant shows that 40% is in the raw materials, 10% is in the conversion cost and the rest, 50%, is the depreciation and interest on capital block. From the above it may be concluded that for meeting the increase in the demand of steel, introduction of technology to increase the output of the existing plants will be more appropriate from the capital to output ratio view point.

In selecting the appropriate combination of technologies for augmenting the production of iron from the existing blast furnaces, we should ensure that there is a reduction in the specific consumption of coking coal. Otherwise we will be depleting this resource at a faster rate and violate our guiding principle on conservation of non-renewable resource. One more guiding principle may be established - that the restriction on maintaining hot metal quantity within certain specification may be removed in those steel plants which adopt external desulfurisation and/or the bottom blown oxygen process. The strategy for the production of hot metal should be to maximise output per capital block invested while decreasing the consumption of coking coal. The exact package of the appropriate technologies may be worked out from the data given in table 6 - 1. For example, it is estimated that a combination of technologies consisting of use of sized ore, use of higher sinter in BF charge and higher hot blast temperature can increase the blast furnace productivity by 78%. The additional capital investment required for this increased hot metal production is around Rs. 400/ton compared to Rs. 1,000/ton for a new blast furnace. These technologies can reduce the coke rate by 38% which will in turn lower the cost of hot metal production by around 90% after providing for interest and depreciation on the new capital.

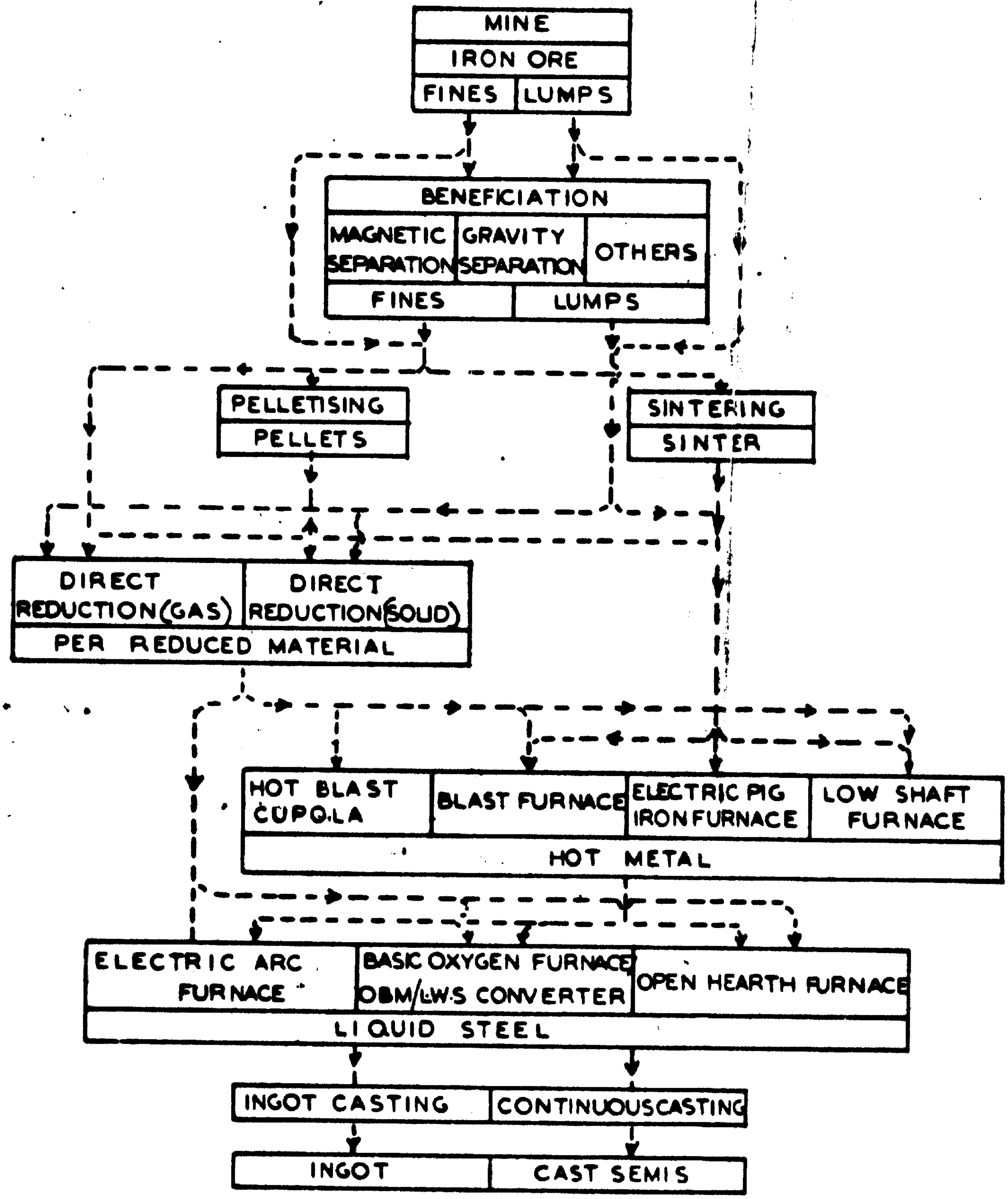


FIG - [illegible] - ALTERNATIVES FOR PRODUCTION OF STEEL FROM IRON ORE.

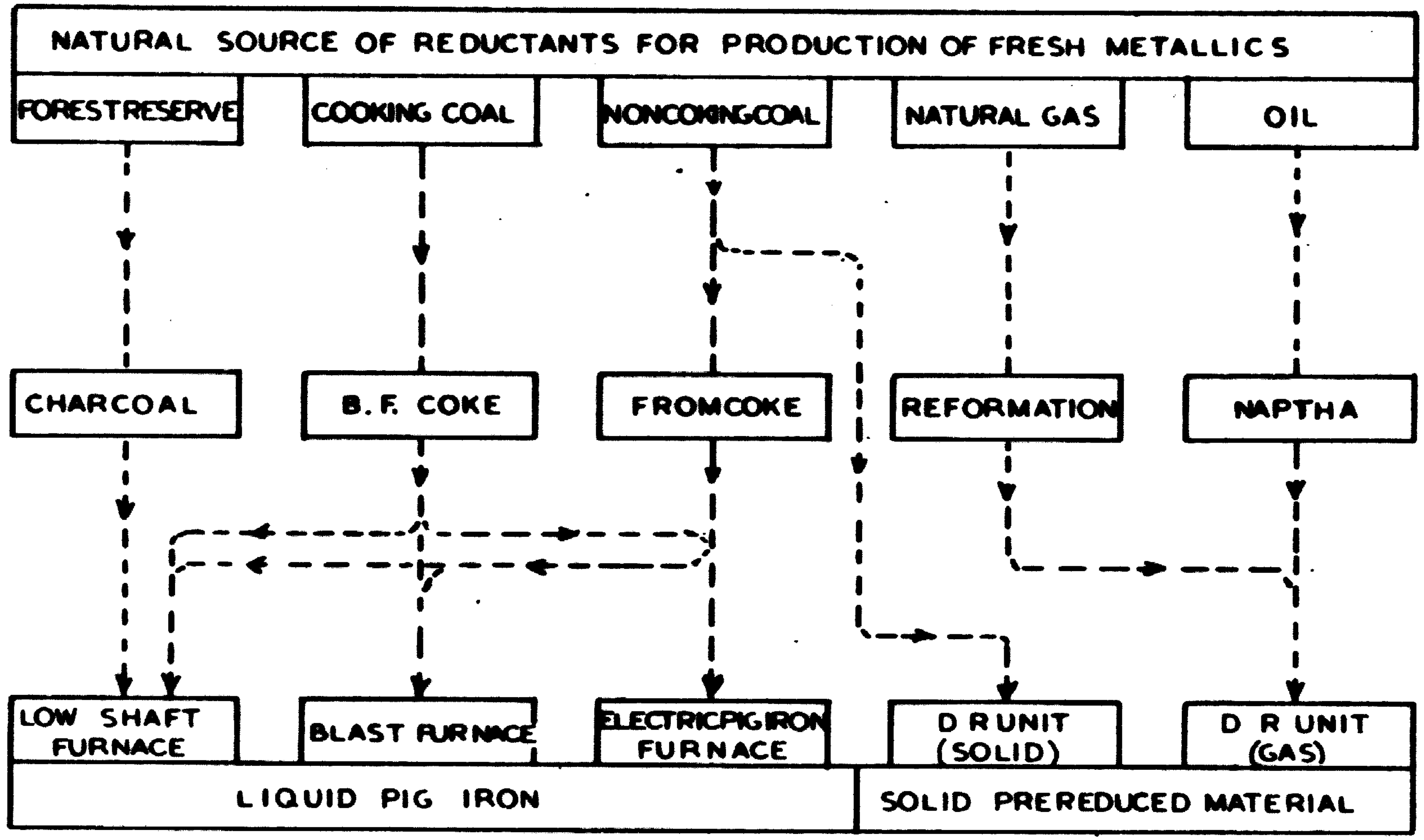


FIG- 6 - 11. VARIOUS OPTIONS OF REDUCTANTS FOR IRON MAKING.

Table 6-1

**Effect of various Technological parameters on Techno-economic Indices of hot metal production.**

| Technological Parameters | Application | Coke rate decrease % | Increase in productivity % | Additional capital cost per thm Rs/t | Change in hot metal cost % |
|---|---|---|---|---|---|
| 1. Burden preparation | | | | | |
| a) Use of sized Ore (10–25 mm) | 100% | 11 | 15 | 150 | - 6 to 7% (If the fines are utilized elsewhere) |
| b) Use of sinter in burden instead of sized ore. | 100% | 22 | 55 | 225 | - 6 to 7% |
| c) Pellet charge | 100% | 26 | 58 | | + 5% |
| 2. Blast Control | | | | | |
| a) High Blast Temperature | 1000 - 1050°C (Higher temp. upto 1300°C useful with tuyere injection) | 5–6 | 8–10 | 70 | - 3 to 4% |
| b) Oxygen enrichment | Upto 4% | 2–3 | 20 | 180 | - 2.5 to 3% |
| 3. High Top Pressure | Upto 3 Kg/cm$^2$ | 4–8 | 20–30 | | - 4 to 5% |
| 4. i) Fuel Injection through the tuyeres | | | | | |
| a) Coal dust injection | 120–150 Kg/t | 10–15 | 5–6 | 170 | - 3 to 4% |
| b) Oil Injection | 100 Kg/t | 16–24 | 15–20 | | |
| ii) Stack gas Injection - | Pilot Plant stage (0.25 Kg coke/Nm$^3$ of reformed gas - about 150 Kg/t hm coke replacement is possible) | | | | |

The combination of these improved blast furnace technologies and the sequence of their introduction will depend on many factors and can only be established by a more rigorous analysis, trials and innovation at each blast furnace.

For introducing high sinter BF technology, advantage may be taken of the proximities of some steel plants to each other and to the mines for installing large or common sintering machines. This will reduce the capital block for all the concerned steel plants.

Since 70% of the steel produced in India is by the Open Hearth Process, it provides a good opportunity to increase the steel production capability of these plants by the Bottom Blown Oxygen Technology, commensurate with the increase in the hot metal production. Appropriate continuous casting facilities can be installed in the Open Hearth shop itself to process the liquid steel into slabs, blooms and billets. These two technologies will release a large quantity of fuel oil or coke oven gas. The capital block for producing an additional ton of slab, bloom or billet is estimated to be less that Rs. 1,000/ton in an existing plant compared to Rs. 5,000/ton for a new facility.

This strategy of expanding the capacity of the existing steel plant by improvement in the blast furnace technology, introduction of the Bottom Blown Oxygen technology to replace the Open Hearth and adding continuous slab, bloom and billet casting can increase the national production by 3.25 million tons, provided the hot metal production increases by 2.60 MT as shown overleaf.

Table 6 - 2

| Plant | Present Steel Making Capacity (MT) | Increased Steel making capacity with BBOP | Increase in Hot Metal Requirement |
|---|---|---|---|
| | | MT | MT |
| Bhilai | 2.5 | 3.5 | 0.8 |
| DSP | 1.2 | 2.0 | 0.64 |
| IISCO | 1.0 | 2.0 | 0.80 |
| RSP | 1.5 | 1.95 | 0.36 |

Whether the introduction of appropriate technology in the Blast Furnace does increase the production, needs to be established by trial and experimentation in a selected blast furnace which at present does not have a good performance record.

When the steel demand increases beyond 3 million tons by a quantum amount of one million tons, then it will be necessary to consider installing an additional 2,000 $m^3$ Blast Furnace in an existing plant, producing around 2,300 tons/day of hot metal for each of the steel plants mentioned above. The additional steel making capability can easily be attained by installing additional converters until there are a maximum of 5 converters. Since the competitiveness of continuous casting of non flat products is only marginal at 2.5 MT production, this may, therefore, be considered as the upper limit for the expansion of the existing steel works. Thereafter, it may turn out to be profitable to go to a greenfield steel plant.

## 6.2 Centralisation vs. Decentralisation

The discussions in the preceding paragraphs advocated the case of expansion of existing steel plants by a maximum of 2.5 million tons, for the production of blooms, billets and slabs. For rolling of these semis to finished products, a different strategy may be adopted.

Shaping of the bulk tonnage of steel products is generally carried out in the rolling mills set up in integrated steel plants. The modern trend is towards installation of large capacity rolling mills for production of both flat and non-flat products. Large capacity installation brings down the production cost and adds to the economy of operation. However, recently with the concept of mini-steel plants, smaller capacity mills have been installed in other countries, primarily with a view to catering for the local demands of rolled products for limited tonnage. These mills have distinct advantages in terms of meeting the needs of small orders and saving in transportation, cost of feed materials and the finished products.

### 6.2.1 Concept of Decentralisation of Steel making in India

In India, installation of smaller capacity mills outside the integrated steel plants had been based on different concepts altogether. Initially re-rolling mills were started primarily for the conversion of railway scraps into useful steel bars and rods. With the gradual development of various industries in the country, scraps were also available from other sources i.e. steel plants, ship yards, engineering industries etc. The major expansion in the re-rolling industry took place only during the sixties with the installation of mini-steel plants, when continuous cast billets and pencil ingots became available. During the last phase the concept of decentralisation of rolling and setting up of mini-steel plants was based on the following major factors:

- Disposal of industrial development in general and development of backward areas in particular.
- Utilisation of local scrap.
- Meeting the regional demand of steel.
- Lower capital investment, shorter construction and gestation period.
- Shortage of steel in the market leading to higher open market prices of steel bars and rods making the operation economically viable.

## 6.3 Economics of Electric Arc Furnace Steel Making based on Scrap and Direct Reduced Ore in India

Besides iron ore, scrap is a major source of metallics for steel making. In developed countries scrap remelting contributes nearly 30% to the steel production, see Table 6 - 3. In India a small part of the scrap generated is used in alloy steel making, while the bulk of the scrap is used in small size plants which are wrongly called mini steel plants. They are in fact micro steel plants, having electric arc furnaces of 5 to 20 tons capacity. Some of these plants have continuous casting and still fewer have captive re-rolling facilities. Most of the micro steel plants produce pencil ingots.

The scrap generated in India can be categorised as home scrap which is generated in the steel plants and purchased scrap. The latter consists of industrial scrap which arises during the production of engineered products such as automobiles, machines, etc; and the country scrap which is generated from old machinery equipment and from consumable steel goods which have lost their utility. In a developing country the scrap arising from country scrap

Table 6 -3

Process distribution in Steelmaking in Selected countries 1960 & 1975 (percent of total)

| Country | O.H. 1960 | O.H. 1975 | Electric 1960 | Electric 1975 | Oxygen 1960 | Oxygen 1975 | Others 1960 | Others 1975 |
|---|---|---|---|---|---|---|---|---|
| Austria | 31.3 | 7.4 | 12.6 | 11.8 | 56.1 | 80.9 | 91.1 | 7.2 |
| Belgium | 5.8 | 1.3 | 3.1 | 5.4 | - | 86.1 | 91.1 | 7.2 |
| France | 29.7 | 7.1 | 8.7 | 14.1 | 0.6 | 63.5 | 60.5 | 15.2 |
| Fed. Rep. of Germany | 47.2 | 15.7 | 6.4 | 12.6 | 2.5 | 69.3 | 43.7 | 1.4 |
| Italy | 55.9 | 11.2 | 38.6 | 43.0 | - | 45.8 | 5.5 | - |
| Luxembourg | - | - | 2.0 | 2.5 | - | 70.0 | 98.0 | 28.5 |
| Spain | 72.1 | 10.0 | 14.0 | 35.2 | - | 54.7 | 13.9 | - |
| Sweden | 34.0 | 15.7 | 48.0 | 40.9 | 4.0 | 43.4 | 14.0 | - |
| U.K. | 84.5 | 22.1 | 6.9 | 27.7 | 0.1 | 50.1 | 8.0 | 0.1 |
| Yugoslavia | 92.0 | 62.2 | 8.0 | 26.6 | - | 11.2 | - | - |
| Poland | 92.0 | 67.7 | 7.7 | 9.5 | - | 22.8 | 0.3 | - |
| Romania | 89.0 | 53.0 | 10.9 | 10.8 | - | 36.2 | - | - |
| U.S.S.R. | 88.2 | 66.6 | 4.5 | 9.9 | 4.4 | 22.7 | 2.7 | 0.8 |
| Canada | 89.2 | 23.6 | 10.8 | 20.3 | - | 56.1 | - | - |
| U.S.A. | 87.0 | 19.0 | 8.5 | 19.5 | 3.3 | 61.4 | 1.2 | - |
| India | 92.3 | 71.2 | 1.6 | 12.3 | 6.1 | 16.5 | - | - |
| Japan | 24.7 | 1.1 | 20.3 | 16.4 | 55.0 | 82.5 | - | - |

tends to be low because of a) the utility life of a machinery equipment is prolonged by repairs and other maintenance, b) the worn out machines, equipment and consumer steel goods find a secondary application, c) the production of consumable steel goods is low, d) some of the scrap ends up with rural blacksmiths.

It is estimated that the process and country scrap arising in India is 1.7 million tons per year as shown in Table 6 - 4

Table 6 - 4

| Source | Annual Scrap arising tons/year |
|---|---|
| Railways | 120.00 |
| Ordinance Factories | 20.00 |
| Capital Scrap (old machinery) | 300.00 |
| Process Scrap (from engineering units) | 1,000.00 |
| Recirculated Scrap | 300.00 |
| Total | 1,740.00 |

Of the two technologies available for producing steel from scrap the Open Hearth steel making is rapidly being replaced by the Electric Arc Furnace because of external fuel requirement and greater pollution problems with the former. Moreover, the output per capacity installed (block capital) is much higher for the electric arc furnace compared to the open hearth.

With the introduction of ultra high power (UHP), technology and secondary steel refining, the electric arc furnace technology became attractive in comparison with integrated steel plants. The capital investment required for producing one ton of billet in a micro electric furnace steel plant, a UHP electric furnace steel plant and an integrated steel plant are given below:

Table 6 - 5

Electric Arc Furnace

| Micro Plant 15,000 TPY | 0.35 MTPY Plant | | BF based Steel Plant |
|---|---|---|---|
| | DR based | Scrap based | |
| [illegible]* | 4,[illegible]00<br>5,300** | 1,020<br>1,450** | 4,1[illegible]0 |

*with pencil ingots
** with captive power plant

The above data shows that a scrap based UHP electric arc furnace with secondary refining has the lowest capital block per ton of steel produced.

The electric power required to melt one ton of scrap is 560 KWH which in turn requires 260 kg. of steam coal. For a 0.5 million ton electric furnace based steel plant the captive power requirement will be of the order of 40 mega watts. The capital block for the investment should also be added to the steel plant in view of the general power shortage in the country. After including the cost of the electric power plant the capital block per ton increases to Rs. 1,450/ton which is still substantially lower than the iron ore based integrated plant.

The installation of a captive power plant for a scrap based electric arc furnace plant needs further technical study to ascertain the effect of a fluctuating power load on the grid system or on the captive power plant's generating capacity. In the latter case a bank of reactive power capacitors are required to cope with the high surges during melting.

It may be of interest to note that a steel plant based on DR - EF - CC with a captive electric power plant has the highest capital block per ton of steel produced and in this respect becomes highly inappropriate technology for steel production in India.

The cost of production of steel by the electric arc furnaces is compared with that produced by conventional BF - BOF - CC, as shown in the table below:

Table 6 - 6

| Electric Arc Furnace | | | BF - BOF - CC |
|---|---|---|---|
| Micro Steel Plants | DR based | Scrap based | Integrated Plants |
| with captive power plant | | | |
| Rs./ton<br>1,490 | Rs./ton<br>1,430 | Rs./ton<br>1,330 | Rs./ton<br>1,300 |

The conventional steel making via BF is the lowest cost producer followed by the scrap based electric arc furnace steel making. The direct reduced iron based electric furnace plant is the highest cost producer. The scrap based electric arc furnace is thus highly competitive with the conventional BF - BOF, especially if the savings in coking coal is considered. The availability of sufficient scrap is the major constraint in the growth of large electric arc furnace based plants. The possibility of importing scrap from highly industrialised countries such as USA, and locating such plants near the ports needs to be studied in greater detail.

## 6.4 Present Status of the Re-rolling Industry in India

The total number of re-rolling mills of all types in India is estimated to be around 1,200. The capacity of these mills is indicated in Table 6 - 7. The re-rollers were initially classfied into two categories, i.e. billet re-roller and scrap re-roller, mainly for the distribution of billet and scrap. This difference was however, abolished in 1975 to enable all the capable re-rolling mills to roll billet/pencil ingots. Against the total annual capacity of 6.3 MT/yr., the actual production has been a little below 1.0 MT/yr. as shown in table 6 - 8.

Though there are a number of narrow strip cold re-rolling mills in India at present, the products from small capactiy rolling mills are mainly bars and rods for construction purposes. A few small capacity mills are also capable of producing wire-rods, tor-steel bars, light/medium structurals, hoops and strips, special shapes like Z-sections, gate channels, window sections, T. bars, two way keys, loose jaws, rail anchors, etc. The size range of the product from the re-rolling industry is shown in Table 6 - 9.

Annual Capacity of Re-Rolling Industry in India on 2-shift Basis as per Steel Re-Rolling Mills Association (SRMA)

| Sl. No. | Re-rolling Mills | No. of units | Total capacity on 2-shift Basis t/yr. |
|---|---|---|---|
| 1. | Billet re-rollers | 128 | 3,431,052 |
| 2. | SRMA member scrap re-rollers | 102 | 590,660 |
| 3. | Scrap re-rollers on Directorate of Industries (DI) lists who are not members of SRMA, but whose capacity has been assessed | 211 | 920.000 |
| | Sub total: | 441 | 4,241,712 |
| 4. | Estimated capacity of other small scrap re-rollers on DR list | | 1,300,000 |
| | Total | | 6,241,712 |

Table 6 - 7

**Table 6 - 8**

| Year | Production | | |
|---|---|---|---|
| | Billet Re-rollers | Scrap Re-rollers | Total |
| 1966 - 67 | - | - | 980,500 |
| 1967 - 68 | 806,244 | 126,852 | 933,096 |
| 1968 - 69 | 722,016 | 127,008 | 849,024 |
| 1969 - 70 | 693,336 | 117,600 | 810,936 |
| 1970 - 71 | 465,141 | 144,250 | 609,391 |
| 1971 - 72 | 616,000 | 150,000 | 766,000 |
| 1972 - 73 | 675,000 | 152,800 | 827,800 |
| 1973 - 74 | 614,000 | 156,300 | 770,300 |
| 1974 - 75 | 564,130 | 162,617 | 726,747 |
| 1975 - 76 | 621,400 | 158,358 | 779,758 |

Note: **The above figures exclude the production of small scale scrap re-rollers registered with the State Directorates of Industries**

Actual Production by the Re-rolling Industry

**Table 6 - 9**
**Size Range of Rolled Products in Re-rolling mills**

| Sl. No. | Product | Size range mm | Conventional size (mm) | Remarks |
|---|---|---|---|---|
| 1. | Wire Rods | 6 - 12 | 6 - 10 | 250 kg. max coil wt. |
| 2. | Bars, rods, rounds and squares | 8 - 50 | 8 - 25 | |
| 3. | Flats | 12 - 100 width<br>3 - 20 thick | Up to 75 width | |
| 4. | Structurals angles, tees | 20 x 20 x 3 to 75 x 75 x 9 | 20 x 20 x 3 to 50 x 50 x 9 | |
| 5. | Beams and channels | Up to 175 | Up to 150 | |
| 6. | Hoops | 20 - 25 wide<br>16 - 20 gauge | 20 - 25 wide<br>16 - 20 gauge | |

The size range covered by the main steel plants in India against that from small capacity rolling mills is shown in Table 6 - 10.

**Table 6 - 10**
**Size Range of Merchant Products**

| Sl. No. | Product | BSP | DSP | TISCO | IISCO | Re-rolling Mills |
|---|---|---|---|---|---|---|
| 1. | Rounds and Squares, mm | 20 - 63 | 12 - 50<br>80 - 100 | 12 - 125<br>160 - 200 | 10 - 80 | 8 - 25 |
| 2. | Flats, mm | 50 - 100 | 45 - 50 | 25 - 100 | 45 - 50 | Up to 75 |
| 3. | Angles, mm | 40 - 80<br>150 | 35 - 75<br>100 | 25 - 110<br>150 - 200 | 35 - 50<br>65 - 125 | 20 - 50 |

It can be seen from the above Table 6 - 10 that in certain areas like angles 35 mm and below, flats below 45 mm, 8 - 10 mm rods in straight length, the smaller mills do not have to compete with integrated steel plants. In these areas, therefore, decentralisation of rolling could be more meaningful.

As the emphasis is on the lower capital investment for small capacity mills, most of the mills installed in India have skeleton facilities. The mills with individual capacity of 10,000 t/yr. or more have separate roughing group with mill sizes ranging from 250 mm to 450 mm and finishing group with a number of stands (150 . 250 mm) arranged in a single line driven by either one or two motors. Smaller mills have five to seven 150 mm to 250 mm stands driven by one motor working as roughing as well as finished mills. Most of the mills are not provided with any tilting table at 3-High stands, inter-stand transfers or repeaters. They also do not have a mechanised cooling bed.

In order to assess the impact of decentralisation of rolling on economics, it will be prudent to compare the small capacity re-rolling mills against the large capacity mills in integrated steel plants. For this purpose re-rolling mills of two different capacities i.e. 18,000 t/yr. and 36,000 t/yr. have been selected. These mills have then been compared to the light merchant mill of nominal capacity of 500,000 t/yr. The specific capital investment is compared in Table 6 - 11 **on the next page.**

Table 6 - 11

Comparison of Capital Cost Estimate

| Sl. No. | Rolling Mill | Capacity t/yr. | Capital cost million Rs. | Specific capital investment Rs/t |
|---|---|---|---|---|
| 1. | Re-rolling mill | 18,000 | 18 | 1,000 |
| 2. | Re-rolling mill | 36,000 | 30 | 833 |
| 3. | Light merchant mill | 500,000 | 580 | 1,160 |

It may be seen from the above that small capacity mills have some advantage (15 - 30% saving) in capital investment required per ton of installed capacity over large capacity mills. Higher capital cost for large capacity mills is mainly due to investment for improved mechanisation automation, quality control and improved working conditions.

The production cost of finished products depends to a large extent on the price of the feed material. Normally the feed material for the large capacity mills is the billet produced in the same plant, whereas the feed materials for re-rolling mills may be either pencil ingots, continuously cast billets produced by mini-steel plants or the billets produced from integrated steel plants or re-rollable scraps. The net profit margin for re-rollers, therefore, will depend upon the type of feed materials and their prices. Under the circumstances, to analyse the economics of decentralisation of rolling, the conversion cost (excluding material cost) comparison will be more meaningful than the production cost. The conversion cost for the above rolling mills are analysed in Table 6 - 12.

It may be observed from this table that the smaller mills have higher conversion cost compared to large mills which will result in higher production cost of the finished products and lower profit margin.

The economic disadvantage of higher conversion cost for small re-rolling mills will be covered up to some extent by the advantage in transportation cost of feed materials/finished products. This will depend upon the precise location of the re-rolling mill with respect to the sources of feed materials and the market for finished products.

Table 6 - 12

Comparison of Conversion Cost

| Sl. No. | Rolling Mill | Capacity t/yr. | Operating Cost including overhead | Depreciation and interest | Total Conversion Cost |
|---|---|---|---|---|---|
| | | | Rs./t | Rs./t | Rs./t |
| 1. | Re-rolling mill | 18,000 | 270 | 105 | 375 |
| 2. | Re-rolling mill | 36,000 | 240 | 85 | 325 |
| 3. | Light merchant mill | 500,000 | 95 | 140 | 235 |

Notes: 1. The above costs do not include interest on working capital.

2. The financing has been assumed in the debt equity ratio of 1.1. Interest on loan has been taken at 10.5% per annum.

3. The light merchant mill is assumed to work on 3-shifts basis and re-rolling mills on a 2-shift basis.

4. The depreciation and interest charges pertain to the unit proper.

As far as the quality of the products is concerned, the smaller capacity mills cannot compete with large units because of the sophisticated machinery used and the elaborate quality control facilities in the integrated steel plants.

Decentralisation of rolling mills may be desirable from the view point of dispersion of industrial development, utilisation of local raw materials, meeting the regional demand and saving the transportation cost of feed materials and finished products. The specific capital investment for small capacity mills is somewhat lower by about 15 - 30%. However, the conversion cost is appreciably more and the quality of the product is inferior compared to large capacity rolling mills. Research and development effort are needed to overcome this drawback and make these small capacity rolling mills more appropriate to the Indian context, without increasing the capital block per ton of steel. These mills can be made as fulcrum for the rural metal forming industries which can cater for the need of farm implements, household items, tools and tackle as well as supply the consumable steel items to the organised industrial sector.

# CHAPTER 7

## 7.0 ADOPTION AND IMPLEMENTATION OF APPROPRIATE TECHNOLOGY FOR STEEL

Adoption and implementation of a technology is preceded by the choice of the technology, which is not merely a question of mechanical skill or engineering knowledge. In this context it is worth noting that the choice of techniques available in advanced countries need not necessarily be valid in developing countries as developing countries have to consider their own limited resources which can be spent on various lines of production. A new strategy or a different technology is called for producing the same product as the resource distribution may be radically different. Thus the choice of technology in developing countries may pose more serious problems.

The system of production we adopt, critically depends on the society we want to achieve. Technological change which results in higher productivity, diversification, alteration of consumption pattern and new class alignment, brings about new aspects in social change. Often the problem is oversimplified by stating that identification of the need for product would considerably help in specifying a particular technology. The general term "Technology" comprises of many facets of producing a product, i.e. choice of equipment, different alternatives, degree of tolerance, the level of efficiency expected etc. Hence, it turns out to be vague and poses difficulties in identification. The difficulty in identification comes from the fact that although the goal may be one, several alternatives may be available. Thus we have to take into account the way it is achieved for any goal in view.

In this context, appropriateness of any technology choice cannot be decided per se. It is always considered in relation to the need it has to fulfil. Appropriate technology choice is a complicated outcome of considering the various aspects: production of a required article, improvement in quality, achieving economies of scale, efficient utilisation of natural resources, capability for full employment, fabricating goods for the international market, survival of different scales of production and support to non-economic goals such as environmental quality.

## 7.1 Deviation of the Present Technology from Appropriate Steel Technology.

From the above view point of appropriate technology and the discussions in the previous chapters, certain conclusions can be drawn which are summarised below:

1. The integrated steel industry as a whole is highly capital intensive with a major portion of investment going to build up the necessary supporting services.

2. The integrated steel plants are precariously living on a non-renewable resource i.e. coking coal. Fortunately technological options are available to reduce the dependence on or consumption of coking coal.

3. The bulk of the iron produced (97%) in India is produced by the blast furnace technology, which requires a large quantity of input raw materials such as coal, iron ore, limestone, air blast, refractories. The technology and the efficiency of the present blast furnace technology demand a minimum scale of operation which makes it highly capital intensive.

4. Technological developments in the processes for conversion to steel (Bottom Blown Oxygen Process) is in the direction of appropriate technology in terms of lower capital required, use of lower quality raw materials at blast furnace and steelworks, higher output per capital invested, fewer environmental problems, and better recovery of waste products, especially the off gas.

Furthermore the steel conversion technology is efficient over a wider scale of operation unlike the blast furnace technology.

5. The continuous casting and horizontal continuous casting technology are again developments in the right direction from the appropriate technology view point. They are less capital intensive, less severe on environment, produce less waste material (scrap) and are efficient from low scales of operation (40,000 tons/year) to very high scales of operation (2.5 million tons/year). The horizontal continuous casting promises to reduce capital requirement further and may provide for more labour intensification. It also appears to be suitable even for smaller scale of operation than conventional continuous casting.

6. The technology of shaping of steel has wide flexibility, depending on the product requirement. It is less capital intensive as the scale of operation becomes smaller because of the possibility of introducing manual methods of handling. The cost of production is however higher, but can be reduced by further technological development. The lower transportation cost, if these small re-rolling mills are located in regions where rural industrial growth is desired, is a further advantage. The small re-rollers can easily supply steel to a small rural industry which does not have an easy access to the stock yards of the integrated steel plants.

## 7.2 Opportunity Areas for Appropriate Steel Technology

The areas of opportunity to make the present steel technology more appropriate are:

i) Development of new processes and techniques to reduce the capital block required in the integrated steel plants.

ii) Intensify innovations and implementation programs which reduce coking coal consumption and increase the productivity of the existing blast furnaces.

iii) Intensify research and development into those areas of iron making technology which result in lower capital requirement, more efficient smaller scale operation and which use the indigenously available raw materials. From these considerations, the technology of direct reduction of iron ore using coal is grossly inadequate as it is more capital intensive than a small blast furnace as indicated in Table 7 - 1.

**Table 8 - 1**

| Technology/Route | Specific Investment Rs./ton | Production Cost Rs./ton |
|---|---|---|
| DR - EF - CC | 4,900 | 1,350 |
| BF - BOF - CC | 4,180 | 1,300 |

The cost of the production of billets is also higher by the DR - EF - CC route than by the BF - BOF - CC route. Thus with abundant availability of high grade iron ore, India should look for a more appropriate alternate technology to produce iron. In this respect it may be worthwhile reviewing the Chinese experience and looking at the emerging technology based on powder injection.

7.3 The Chinese Experience

The chief characteristic of the Chinese technological approach was indicated by Chou-En-Lai in December 1964. He urged his fellow countrymen to "absorb everything that was good in other countries' experience and techniques while subjecting the innovations to specific conditions of their own country, its topography and raw material availabilities". He emphasised that the lessons learnt must be blended with creative efforts of their own. It was identified that the linkage between rural industries and agricultural development is very intimate.

It may be noted that in the early stages of growth, rural industrialisation is a one way relationship. Sometimes the rural units are capital-intensive, but later, when the technology has been adapted to the indigenous environment, the rural community imbibes knowledge through the establishment of small industries. In the process rural industrial units cause technical skill formation in the agricultural sector and also supply increasing amounts of agricultural inputs. Only later on is the two-ways relationship established where the agricultural sector begins supplying raw material and capital to rural small units. This relationship is gradually intensified and small units begin providing work opportunities to man-power rendered surplus as a consequence of mechanisation of agricultural operations.

The process of industrialisation which is a trans-mission of technological know-how, though a one way move-ment in the beginning, results in changes in the agri-cultural operation, land organisation, income generation and consumption pattern. This establishes new production units, encourages technological adaptations and gives feed back to modern units.

The rural industrial system in China basically comprises of the 'five small industries' - generation of energy, pro-duction of cement, chemical fertiliser, iron and steel; agricultural tools and equipment. All these require raw materials such as coal, iron ore and these extractive in-dustries form the second important component of the Chinese rural system. The third dimension of the system relates to the sequential changes in the agricultural sector. Depending upon industrial inputs and skills available at the commune and the brigade level, new items are taken up for fabrication; increasing production units as well as items fabricated. This leads to mechanisation of life and warrants setting up of engineering repair workshops which form the fourth dimension of the industrial system under reference.

India and other developing countries also have aimed at the same. The outstanding accomplishment of the Chinese rural industrial system is not primarily the installation of a large number of production units fabricating diversified items, but its organic linkage between agricultural development, small fabricating units and modern industries. Chinese rural industries were planned to be compatible with local requirements based on local resources. The impetus for an agricultural development lead to a large number of installations, diversification in the items of production, and the adoption of modern industrial technology. Another feature of the Chinese program is co-existence of large-scale sophisticated technology with small-scale intermediate technology. However, there has been special emphasis on small production units, depending on the special characteristics of the production process.

It is worthwhile noting that in China 20% out of 20 million tons of pig iron produced comes from 1,000 small iron and steel plants spread all over the country. These plants vary in size and the smallest furnace is eight cubic meters. The backyard furnaces have been abandoned. Farm machinery is mostly produced in local plants which doubled their production during the quin-quennium following 1965. The success stemmed from the fact that fabrication technology in rural industrial units is closely linked with indigenous availability of raw materials and technical skills. Production processes are modified to suit these conditions. The main sources of technologies are research institutes, modern industrial units and the local indigenous technology pool. Technology importation in China is highly restricted even for modern industries in the national sector. Even research organisations are not encouraged to undertake fundamental investigation. Their efforts are mainly directed towards solving practical problems confronting different sectors of agricultural and industrial activities. What comes out of these efforts are not highly sophisticated complex technologies; rather they are commonsense techniques solving immediate problems of a practical nature.

## 7.4 Emerging Technologies Based on Powder Injection

The Swedish steel industry, with major Governmental financial support, has embarked on a major R and D program to evolve an alternate process route to the traditional blast furnace. The majors factors contributing to this decision in Sweden have been

1) Lack of coking coals. The currently operating blast furnaces in Sweden are based largely on imported coking coal, primarily from Poland and USSR.
2) Absence of large internal/external markets to justify installation of large blast furnaces.
3) The conventional blast furnace route is regarded as unacceptable in view of the strict anti-pollution laws recently enacted in Sweden.

A serious review was accordingly made on the existing alternatives to the blast furnace route, but none seemed to fit the requirements. Accordingly, a major process development program with Governmental support, was initiated in 1974 with the following objectives:

1) The process must produce a product in liquid form suitable for subsequent oxygen conversion to steel.
2) Must operate on non-premium raw materials, i.e. iron ore concentrates available in Sweden and relatively low grade non-coking coal.
3) Capability of economic operation at relatively small capacities, so that orderly expansion of the plant to meet increased demand is feasible.
4) Environmental pollution should be minimum.

After a critical evaluation of all available techniques in extractive metallurgy, it was decided to concentrate efforts in two alternative approaches, these being:

A. Flash smelting of concentrates coupled with with smelting reduction in an induction furnace (INRED PROCESS).

B. Bottom (side) injection of powders in a converter type reactor with a channel induction heater for supplying endothermal heat requirements (UDDACON PROCESS).

7.4.1 INRED Process

The flash smelting technique was developed independently by Outukumpu Cy in Finland as well as INCO just after the Second World War for matter smelting from copper concentrates. The technology is well established on a commercial scale in copper extractive metallurgy and is characterised by very high throughputs, i.e. high specific capacity due to intense mixing of the reacting phases i.e. powder and gas. This development is now generally regarded as a major break-through in pyro-metallurgy in recent times.

As 'adapted' in the INRED process for iron making, the process essentially consists of the 'burning' of an intimate powdered mixture of iron ore fines/concentrates + coal + flux with oxygen resulting in a high FeO bearing slag and metal which trickles into an induction furnace containing high carbon iron. The endothermic heat requirement for the reaction $FeO + C = Fe + CO$ being supplied by induction heating.

The INRED process concept initially tested in a 1 t/hr scale, has now been scaled up to a 5 t/hr (approx. 30,000 t/yr) pilot plant currently operating in Sweden. This plant operates on iron ore concentrates and non-coking coal containing 20% ash (steam coal quality). The process does not require sintering and coke production. The estimated consumption figures are shown in Table 7 - 2.

Table 7 - 2

(all energy from non-coking coal)

| | | | |
|---|---|---|---|
| i) | Total energy consumption/ton Fe | = | 4.100 G. cal |
| ii) | Iron analysis | = | carbon 2.5%<br>Si 1%<br>About 50 senenters metal. Some dephosphorisation is achieved. External desulphurisation would be required normally. |

iii) The total electrical energy requirement is 680 KWH/ton Fe with the following break-ups.

| | | | |
|---|---|---|---|
| a) | Process (Induction heating) | - | 280 KWH |
| b) | Oxygen (530 $Nm^3$) | - | 295 |
| c) | Blowers | - | 105 |

The entire power requirement is met by steam generation from off-gas. The INRED plant resembles the KT coal gasifier of the slagging type. The additional feature of the INRED unit is that the slag formed falls into an induction furnace wherein metal and slag can be continually tapped.

The process is currently undergoing extensive testing in Sweden. Major funding for the pilot plant has come from M/s BOLIDEN, a non-ferrous company whose major interest in the process stems from the need to utilise large amounts of high grade iron oxide fines obtained in the burning of pyrites for sulfuric acid manufacture.

According to the scientists/engineers engaged in this program there exists scope for further developments in the process concept, especially in the substitution of the induction heating system by the more versatile submerged arc heating system.

Table 7 - 3 gives a comparison of the INRED process with other alternative process routes to iron in respect of raw materials. Also given are the approximate raw material cost/t Fe based on typical prevailing prices for the various raw materials inputs under Indian conditions.

The development of the INRED process is of considerable significance to India in view of:

1) Process can directly utilise high grade ore fines including blue dust which are abundantly available in the country.

2) Non-coking coals with ash content in the region of 20%, suitable for this process ar abundantly available and widely distributed.

3) In-situ power generation is a built-in feature of the process. With the prevailing situation in respect of power in the country, this feature of the process is of particular significance to us.

4) The non-coking coals in the country are generally low in P (<0.01%). The lignite available at Neyveli is 0.006% P. If the INRED process is based on concentrates (as envisaged for Salem) it would be feasible to produce hot metal with P (<0.05%) which has a premium in value.

7.4.2 <u>UDDACON Process</u>

The UDDACON converter developed by UDDEHOLM Steel Co. in collaboration with ASEA in Sweden, is a converter specially designed for injection of powdered material below the bath surface so as to achieve fast and complete reactions and to supply heat in-situ so as to supply the requisite chemical heat or super-heat. The heating is accomplished by fitting a mains frequency channel inductor which supplies the necessary heat to the melt.

A pilot plant of 10 ton capacity was commissioned in October 1973 at the Hagfors Steelworks of Uddeholm. The pilot plant uses a powder dispenser of the type developed at IRSID with a volume of 500 litres. The injection rate can be varied between 5 and 100 kg/min. Air or Argon is

Table 7 -3

**COMPARISON OF DIFFERENT PROCESS ROUTES TO IRON**

**MAJOR INPUTS - RAW MATERIALS**
Unit : Per ton of Iron

| INPUT ROUTE | NON-PREMIUM | | | | PREMIUM | | | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | IRON ORE LUMP Kg(67% Fe) | IRON ORE FINES Kg(67% Fe) | NON-COKING COAL Kg(dry) | LIME STONE Kg | SINTER Kg | COKE Kg (dry) | NATURAL GAS G.Cal | |
| 1. BLAST FURNACE | 380 | | | | 1510 | 720 | | 1. Proposed plant at Vizag.<br>2. Sinter-50.4%Fe, Basicity 1.35 |
| 2. EPIF | 1550 | | | 350 | | 495 | | 1. Proposed plant at Salem<br>2. Power-2500kwh/t Fe. |
| 3. SPONGE IRON (MIDREX) | 1670 | | | | | | 4.0 | |
| 4. SPONGE IRON (ROTARY KILN) | 1670 | | 1050 | | | | | 1. Energy 6.5G.Cal/t Fe (1.5 G.cal in term of char discard) |
| 5. SMELTING REDUCTION | | 1600 | 670 | 350 | | | | 1. CV of 20% ash Coal-6400 K cal Kg. |

**COST OF MAJOR INPUTS/ TON OF IRON FOR DIFFERENT PROCESS ROUTES**

| | Route | | Total Rs. | Rel. Cost |
|---|---|---|---|---|
| 1. | BLAST FURNACE | Cost with due credit for off gas at Vizag | Rs. 465.00 | 100 |
| 2. | EPIF | : Cost of ore @ 101.80/t = Rs.158+Stone @ Rs.80/- = Rs.28.0+ Coke (10.25mm) @ Rs.350/ton = Rs.175 and credit for off gas @ Rs.30 | 331.00 | 71.5 |
| 3. | MIDREX | : Cost of Ore @ Rs.150/t=Rs.250+Natural Gas @ Rs.260.7/G.Cal=Rs.107 | 357.00 | 76.5 |
| 4. | ROTARY KILN | : " Rs.250+Coal @ Rs.17.9/G.Cal = Rs.116 | 366 | 7[illegible]5 |
| 5. | SMELTING REDUCTION | : Cost of fines @ 93.80/t Rs.150+Coal @ Rs.73.5 + Limestone = Rs.30 | 253.5 | 54.5 |

used as carrier gas. The inductor has a nominal power rating of 1,200 KW. Both MgO and $Al_2O_3$ based linings have been tested.

The wide range of experimentation has established, that by and large it is only Thermodynamics which imposes the limits because the design of the UDDACON system has removed the kinetic barriers. The converter has been found suitable for a wide range of applications including desulphurisation, dephosphorisation, decarburising and the reduction of easily reducible metal oxides. Some results obtained are discussed in the following:

Table 7.4

| Application | Results |
|---|---|
| Desulphurisation | 0.26 0.006% in 10 minutes |
| Dephosphorisation | 0.16 0.016% |
| Decarburising | 0.005% |
| Mo-oxide reduction | Fe Mo 50% |
| Inclusion level | ESR level |

In the following, two applications of the UDDACON converter are discussed which appear to have immediate commercial possibilities:

i) Processing of zinc-rich dust from Steel Making Facilities

The dust arising from electric arc furnaces processing steel scrap contains varying quantities of zinc and lead, depending on the degree of contamination of the scrap.

In those steelworks, where the zinc content in such dust is of the order of 10 to 25%, it represents a comparatively high value. Since it is relatively costly to obtain pure zinc using present day methods, this dust actually constitutes an environment problem, instead of becoming a source of income for those steel works where such dust occurs. Typical analysis of such dust is given overleaf.

Primary Dust

| | % $Fe_2O_3$ | % ZnO | % Pb | % CaO |
|---|---|---|---|---|
| Dust 1 | 47.1 | 22.4 | 4.7 | 5.2 |
| Dust 2 | 37.1 | 22.4 | 4.2 | 2.1 |

Injection of the above dust in a UDDACON converter results in the following:

1) Iron is fully reduced leading to increase in metal weight.

2) Zinc and lead are vapourised and burnt in a converter mouth forming a secondary dust which is collected in a bag filter.

Typical analysis of the secondary dust is as follows:

| % ZnO | % PbO | % $Fe_2O_3$ | % C | Non-reducible Oxide | Alkali |
|---|---|---|---|---|---|
| 63.0 | 10.8 | 3.0 | 2.0 | 1 | 12.6 |

After minor treatment to remove alkali, the material can be used for zinc production.

In view of the encouraging results, there are plans to commercialise such a technology in Sweden.

ii) Production of Low Carbon Ferromanganese

Low carbon ferromanganese is a premium raw material for steel making which is conventionally produced in electric furnaces from Mn-ore and Si Mn. It is difficult to control this process. Apart from a high energy consumption, the yield of manganese is low.

Low carbon ferromanganese has been produced from SiMn melt in a UDDACON converter. Manganese oxide mixed with lime is injected into the bath, using for example, Argon as carrier gas. The initial SiMn melt contains about 2 % C. The Si combines with the oxygen in Mn-ore to form $SiO_2$. The electrical energy requirement is about 110 KWH/ton product. The process has been successfully tested in the pilot 10 ton converter. The process appears to have major commercial possibilities.

The process appears potentially capable of producing low C ferromanganese (also low P) starting from manganese ore fines including possibly the high P variety abundantly available in India. Major R and D efforts in this area appear well justified in view of potential cost savings in ferro-manganese production. Of particular interest to India is the relatively low power requirement (of the order of 100 - 200 KWH/ton) for the process.

In summary, the UDDACON converter is one of the most versatile process reactors developed in recent times. Even though economics do not appear to justify its usage for the production of ordinary iron, its potential for high value-added processing applications, like ferromanganese, etc. cannot be underestimated.

7.4.3 Application of Injection Technique in Coal Gasification

Gasification of coal is an area of intense R and D activity. In the Royal Institute of Technology, Sweden, Professor Eketorp and his group have carried out interesting experiments in which coal and oxygen are injected into an iron bath (containing about 2.3% S and about 2% C). Despite the very high S content in the bath, no oxidation of S was observed. The exit gas analysed typically 70% CO, 15% $H_2$, 15% $CO_2$ and traces of $SO_2$ ( 2ppm). The yield of carbon was in range 65 - 70%. With higher injection depths of the order of 1 m, which is feasible in a commercial scale higher yields of carbon, close to 100% may be expected.

The practically complete absorption of S in a bath is a major attractive feature of this technique of coal gasification. Similar lines of pursuit are also being looked into in USA.

Professor Eketorp is also carrying out laboratory-scale injection of coal + ore + oxygen in a bath of iron with the endothermic heat requirement being met by inductive heating.

There are plans to pursue this concept in pilot plant scale. Developments in this area are of great long-term interest to the steel industry.

## 7.5 The Pivotal Role of the Steel Sector

The question may arise, what national priority should be given to the steel industry, if despite all the efforts it does not become appropriate technology for the developing nations? This question may be looked at from the surplus generating ability of the steel plants and the catalytic effect it has on the overall economic growth. The cost analysis of finished steel production shows that the value of the finished product is twice the value of all the raw materials and fuels put together.

Table 7 - 5
Productive Material Costs

| | Rate Rs. | Cost/ton |
|---|---|---|
| Iron Ore H.G | 51.75 | 27.73 |
| " " L.G | 37.73 | 13.29 |
| " " Sinter | 97.18 | 59.59 |
| Manganese Ore | 87.91 | 14.07 |
| Iron Scrap | 460.00 | 117.44 |
| Coke BF and Nut | 288.42 | 228.66 |
| Limestone | 49.92 | 11.23 |
| Dolomite | 56.35 | 7.33 |
| Quartzite | 22.22 | 0.44 |
| Handling loss | | 17.25 |
| Total Productive Material | | 382,35 |
| **For L.D.** | | |
| Steel Scrap | 510.00 | 110.67 |
| Pig Iron | 784.19 | 19.92 |
| Iron Ore HG | 52.38 | 0.10 |
| Finishing and Alloys | | 42.73 |
| Fluxes | | 35.80 |
| Handling loss | | .74 |

Total Productive Material Cost = Mixer metal + other in L.D.
= 592.51/ton

Energy Cost/Ton of Ingot Steel

| | Consumption | Rate Rs./t | Cost |
|---|---|---|---|
| 1. Coking Coal | 1.448 t | 130.0 /t | 188.00 |
| 2. Boiler Coal | 0.325 t | 77.50/t | 25.20 |
| 3. Electricity | 268 KWH | 0.20/KWHr | 53.60 |
| 4. Furance Oil | 0.0314 t | 1,050.00/t | 33.00 |
| 5. LSHS/LSFO | 0.0235 t | 1,000.00/t | 23.50 |
| 6. Naphtha | 0.0168 KL | 890/KL | 15.00 |
| | | | 338.30 |

Energy cost/ton of saleable steel taking 80% yield = Rs. 422.5/ton

Total Production Cost for

Plates Rs. 1,484/ton includes interest, depreciation
HR Coils, Rs. 1,324/ton includes interest, depreciation
HR Coils for sale, Rs. 1,349/ton includes interest, depr depreciation
Cold Rolled Coils, CRM 1,700 Mill 1,553.35/ton includes interest and depreciation
Tandem Mill, 1,657.27/ton includes interest and depreciation

For a million ton steel plant the gross value added amounts to Rs. 100 crores for a total investment of 500 crores. Part of this value added is disbursed as wages and purchase of services, etc. which pumps money into the economy. Part of the value added is recovered as excise, taxes and profits which are again available for further economic growth. Finally, the end product of the steel plants is a higher value resource for other capital forming industries. In the latter sense, if we look at steel production from an engineered product view point, e.g. a truck, a power plant, etc., the integrated technology may very well turn out to be appropriate even from capital to output and capital:worker employed ratio.

In the case of less engineered products such as farm implements, such an approach may break down and it is in these cases that effort for developing more appropriate strategies for steel production and its utilisation becomes important.

Technology being a dynamic process, its appropriateness changes with time. This is especially true for the steel industry which has a very long gestation period. In many cases the selection of technology at the beginning of the planning stage may be appropriate, in many senses, but at the time of commissioning, the technology may no longer be appropriate. It is not easy to change a technology once it is adopted. Therefore, these technologies must be constantly improved and developmental efforts should begin right from the planning stage to make the technology more relevant.

India with its vast iron ore reserves cannot afford to ignore the steel industry. The limited national economic resources may not permit giving this sector a high priority in the economic growth plan for India. We should, however, recognise that steel industry forms the backbone of the industrial growth and the present steel industry has already saved crores of foreign exchange which has been available for other priority sectors. Besides, our military strength depends directly on our strong industrial base founded on a healthy steel industry. This was aptly stated recently by Dr. P.L. Agrawal, Chairman, Steel Authority of India Ltd. to SAIL employees, re-emphasising the pivotal role of the steel industry. This is extracted below:

"Our steel plants operate under very trying conditions. Strains on our financial resources have also handicapped us in not being able to keep pace with the fast changing steel technology. By providing for a development fund in the recently announced steel pricing policy, the Government has taken measures to overcome this handicap. There will be no shortage of funds for R and D and your attempt must be to cover the gap, especially between the developed countries and us to innovate technology suiting to Indian raw material condition. It should be your prime responsibility to see that every help and assistance is provided to those who operate the plants. They have to grapple with varying and difficult problems, which when referred to you should be assigned top priority and solutions should be found speedily".

7.6 Role of Research and Development

Saving has generally been held by Adam Smith to be one of the major determinants of economic development. New net saving is necessary to take advantage of the steady advance of technology. Reinvestment of depreciation reserves is not enough. According to Karl Marx "the additional capital formed in the course of accumulation serves mainly as vehicles for the exploitation of new inventions and discoveries or of industrial improvements in general". Marx further stated that "the magnitude of the capital accumulated clearly depends on the absolute magnitudes of the surplus value".

The present steel industry is highly capital intensive. This mandates effort along several fronts to make it more appropriate. One alternative is to increase our effort and spending on research and development into those technologies which will decrease the capital burden. The capital necessary for investment in these R and D efforts can come from the surplus value generated by the research and development effort in reducing the cost of production and for improving the value of the finished product. This is a closed loop whereby one arm of research and development supports the other in a symbiotic manner. The aim of this two pronged R and D effort may be directed towards the development of appropriate steel technology consisting of low capital output ratio, higher employment, reduction in the consumption of non-renewable resources, proper ecological and environmental balance, enrichment of human life in the production process, produce mostly for our needs and some for export. As in any problem with so many facets, the solutions are always arrived by a process of optimisation in which some factors may not be at the desired level. This calls for a laying down of the priorities of the above aspects of appropriate technology.

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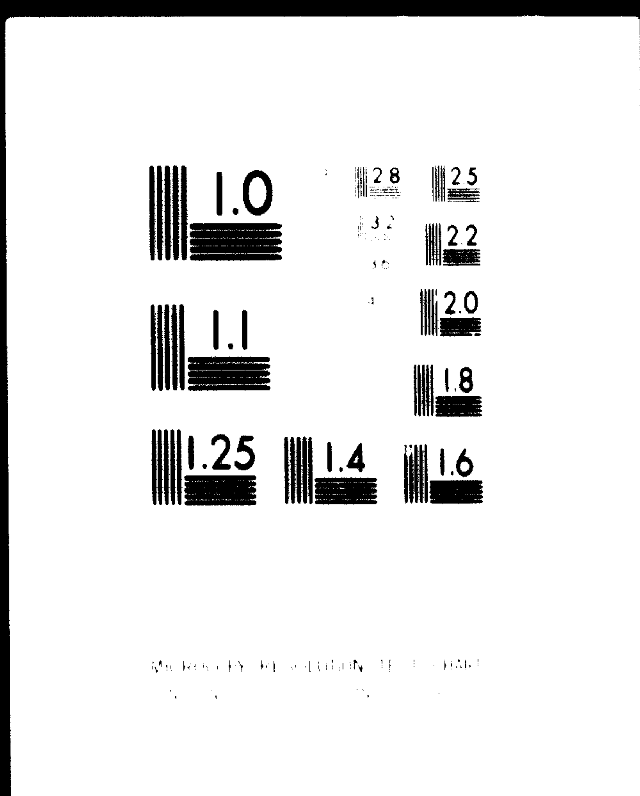


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# CHAPTER 8

## 8.0 SUMMARY AND CONCLUSIONS

An analysis of the socio-econo-technical factors for the industrial growth of developing nations suggests that there is a need for directing effort towards developing industrial technologies which provide more work opportunities, are less capital intensive, reduce the consumption of non-renewable resource and are compatible with the available skills, managerial inputs, indigenous raw material supply and domestic demand for the products. There is an urgent need to bring the organised and the unorganised sectors of Indian economy into a closer relationship, so that they may grow together. To achieve this, the resources of the modern industrial sector must be applied to transform the rural sector and raise its productivity.

A historical review of the steel technology shows that, innovations in technology has enabled the use of material resources which were locally available. The steel technology prior to the Second World War fulfilled most of the criteria for appropriate technology. The deviation from appropriateness came about as a consequence of technological development in other industries.

Despite the threats from other materials and metals, steel is still the most widely used engineering material of construction because of its unique combination of mechanical, and physical properties, the ease of its fabrication and its cost. The per capita consumption of steel is very low in India compared to most of the developing countries. The demand for steel in India is highly biased by the state of the national economy and is mostly in capital intensive industries. A program for increasing the consumption of steel in rural

India has been embarked by the Steel Authority of India Ltd.

One of the major factors which make the present steel technology less appropriate is the high capital block invested to produce one ton of steel and a still larger capital block to employ a worker. This may be partially rectified by dispersing supporting services to the regions around the steel plants. A package of appropriate technologies can be introduced for iron making by the blast furnace route to increase its productivity and decrease the consumption of the rapidly depleting coking coal reserves in India. The development of the bottom blown oxygen process and horizontal casting makes the steel technology more appropriate than the open hearth - ingot casting blooming/slabbing route.

Rolling and forming of steels offers an opportunity for decentralising the steel industry and enable a proper linkage with the rural industries.

The strategy for the future that emerges from the above analysis is that for the production of semi finished products such as billets, blooms, slabs, more developmental and innovative effort is required in the areas of blast furnaces, bottom blown oxygen processes, LD steel making and continuous casting.

For the forming of steel as per the customer's need, technological effort is required to make the small re-rolling mills more economical and bring about a proper development of rural metal forming industry. In addition the Chinese industrial approach is worth studying and the possibility of introducing smaller scale iron and steel works based on the Swedish injection technology needs to be fully explored.

The steel industry has a pivotal role to play in the total industrialisation of India. In the present Indian context, capital reduction per output is important. However, depletion of non-renewable resource may be more important than capital invested per output. For example, an additional investment of Rs. 645/ton in the blast furnace for introducing several appropriate technologies can reduce the coke rate by 42% while increasing the blast furnace productivity by 70%. This will correspondingly lower the capital block per output of steel. Another alternative may be to import bulk quantity of scrap for remelting in ultra high power electric furnace, the power for which is generated from non coking coals. For each new or improved technology it is necessary to evaluate these aspects and then adopt the proper course of action. In this way, even if we do not get the most appropriate technology, we will at least arrive at the optimally apporpriate technology for steel.

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