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A Steel Industry for Pakistan: An Appreciation

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Steel is such a widely used material and performs so many functions in manufacturing that the existence of an efficiently operated steel industry is of great benefit to the economy of a nation. This metal is essential in numerous manufacturing industries, as well as the production of capital goods and has therefore done much to help expand the economies of nations and raise their standards of living. The recognition of these facts has had significant influence on the expansion of the steel industry in countries where it already exists and the desire for the establishment of an industry in the developing countries where it does not.

Independence and aftermaths

In 1947 the newly emerging nation of Pakistan was devoid of productive capacity of iron and steel and nearly so for coal and was totally dependent therefor on imports. The country also inherited a poorly developed economy based largely on agriculture which still accounts for approximately 50% of its national income, 70% of total employment and 60% of export earnings. With the object of achieving speedy advancement, the development aims and aspirations of the younger nations, with backgrounds of agrarian economies, are often characterized by a number of conflicting demands. A rational solution in the best interests of the country between intensive promotion of the agrarian economy, on the one hand, and industrialization, on the other, has to be found. The agrarian industry has not only to secure the food basis of a quickly growing population but also to help the country in the ever-increasing export of the agrarian raw materials through intensive cultivation. The successful achievement of these aims makes it indispensable that agriculture and the connected activities should be mechanized. The objectives of the agrarian and industrial sectors of the national economy are therefore not contradictory; in fact mechanization of the agrarian industry is the first logical step towards the integration of these two sectors of the economy.

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Industrialization

Further development in the agrarian sector is simply not feasible without a corresponding promotion of industrialization in selected fields. Purposeful and carefully planned industrialization not only increases the national income considerably but also creates additional possibilities of employment, has a marked influence on the balance of payments and in addition promotes development of many other sectors of the economy. Apart from the promotion of agriculture as an economic policy, diversification through industrialization should not be neglected as an instrument of political policy. From the start, the Government of Pakistan concentrated on a policy of diversification, including the development of manufacturing capacity with the result that industrial output is now the source of about 20% of the national income. This has been accomplished mainly by a series of five-year plans. The Third or the Current Five Year Plan attaches special importance to the promotion of heavy industries and shifts emphasis from the consumer goods industries to the establishment of basic industries for capital goods. These form the very foundation of integrated national industrialization. Steel, heavy machinery (agricultural and electrical), transport and chemicals are some of the key industries. The shifting of emphasis in the framework of national economic aims cannot be carried out with success, unless a national steel industry creates the essential basic conditions for its fulfilment.

Steel Imports

Pakistan's per capita consumption of steel is amongst the lowest in the world. A substantial increase in steel consumption has contributed to and also resulted from the general growth of the Pakistan economy. This is indicated from the imports of iron, steel and manufactures thereof. In 62-63 the imports were for a value of $94 million, $125 million in 63-64 and $184 million in 64-65 or an average of $100 million yearly over the past six years. As industrialization and prosperity increases consumption of steel and manufactures would correspondingly increase and may be doubled in 1970.

The extent of steel import is however not an accurate index of the actual steel requirements of the country or its steel using potential but more correctly represents the foreign exchange availability position. Many developing countries that must import steel and export raw materials have been faced in the past few years with a serious deterioration of their foreign exchange availability. In the absence of a large increase in the export opportunities by which Pakistan might earn enough foreign exchange, domestic production of steel offers the only means by which the country can hope to meet its growing requirements of steel. A steel plant with an annual capacity of 500,000 tons of finished products will require almost the same foreign debt financing as would be necessary for importing less than eighteen months' requirements of steel. The desirability of using such financing to create an enterpriseable to generate the means of repaying the debt rather than for the expendable products is obvious. The annual foreign exchange savings over a plant of a limited capacity of 500,000 tons with a product mix of about half in flats and half in sections and based on imported raw materials have been conservatively estimated at over $30 million based on the present-day landed costs of similar products, and may easily exceed $43 million after the foreign debts and loans have been discharged. The alternative of carrying on without a basic steel industry is untenable, it involves the periodic reimposition or relaxation of restrictions on steel imports in response to fluctuations in the foreign exchange position. Such a situation could only result in a marked instability in the private industrial sector, sharp and sudden shifts in the employment picture, and a lowering of standards of living specially among the rapidly growing urban population.

The Steel Problem

Pakistan has been struggling for the last fifteen years to find a solution to its steel problem. The high cost of importing all its steel requirements cannot be supported indefinitely. Its economic development programme has already suffered serious setbacks because of its dependence on imported steel. The obviously ideal solution and the one least vulnerable to fluctuations in the foreign exchange position either due to export earnings or foreign aid would be domestic production of steel using indigenously available raw materials. On the evidence of known material deposits this position may become possible ultimately but good ores are situated in remote areas, and it would require very large investments to render them accessible. Ores of the poorer quality are more readily accessible. For the production of steel, ore has to be considered in conjunction with the use of energy resources available; *i.e.*, coal (coke) liquid or gaseous hydrocarbons, electricity etc. As far as the requirements of steel manufactures are concerned Pakistan is poor in the basic raw materials namely ore and coal. There is a sufficient quantity of natural gas but its development for use as well as the production of additional power must of necessity fit in with the overall development plan of the country where the most useful employment of the limited resources available is essential for balanced development in all fields. The investment required for the establishment of a steel plant based on indigenous raw materials would be totally disproportionate to the present level of overall development expenditure in the country. Under the present-day status of resources and fund availability in Pakistan a choice would have to be made between the extremely high cost of exploitation of local raw materials and the use of high quality imported raw materials available in the world market at competitive prices, and manufacturing at reasonable prices with moderate capital expenditure. For an answer to the question, "How much of a basic steel industry can Pakistan afford at this time", must include not only the cost of a new plant and facilities but also the cost of ancillary services which are generally not necessary for a developed country but would have to be provided in our case. With modern loading and unloading facilities, and use of carriers, a sea-coast location of a steel plant can enable utilization, at very economical costs, of the highest grade raw materials. Japan affords the typical example of a country which is dependent upon imports for more than 60% of its requirements of coking coal, 90% of its requirements of ore, 70% of its requirements of scrap and all its oil. In this country coastal plants are built on land which is reclaimed from the sea at very high cost near artificial harbours and yet steel output is nearly 45 million tons per annum and fully competitive in the world markets.

Demand for Steel

Careful market surveys, studies of the steel imports and an assessment of the development requirements have been undertaken to determine and forecast the overall steel requirements of the country. A United Nations survey predicts a consumption of 2 million tons by 1975, whereas other surveys carried out by experts of worldwide repute place the requirements of West Pakistan at about 500,000 by 1965 and almost a million tons by 1970. These surveys have further revealed the existence of sizeable demands of various varieties of steel by indigenous manufacturers who have had to refuse orders for not being able to arrange for the steel requirements. In addition to the indentifiable demand for steel, therefore, which has been listed above, the suppressed demand for steel is already considerable. It has also been observed that the development of a steel industry tends to encourage the growth of steel consumers at home. In Brazil, for example, steel consumption rose from 24 lbs. to 44 lbs. per capita in the first five years after completion of the country's first large steel mill. In Chile, a rise per capita consumption of 150% was experienced in a corresponding period. It may thus be clear that the most conservatively estimated projection of West Pakistan's steel requirements in the future cannot be met by imports because of difficulties with regard to the availability of foreign exchange and the solution lies in establishing a mill in the country itself. A steel mill of approximately 500,000 tons annual capacity should form a satisfactory basis for future expansion to meet the increased requirements. This mill would be in a position to produce much of the material for its own enlargement as well as providing the base generally for the development of a domestic capital goods industry.

"Prestige" Project

For yet another reason for which the steel plant is generally considered justified is said to be the concern for "prestige" particularly in developing countries where it cannot be connected with one of the more conventional reasons. Examined a little more closely, it is clear that the concern is not as much for prestige as for security. The demands of security call for self-sufficiency to be achieved to the maximum extent practicable in all spheres of activity. This may lead to costs of local production which are apparently higher than the cost of imported products, and too much subjected to market fluctuations. Before one attempts to draw conclusions from the feature of higher costs of local manufacture one must bear in mind the facts that, on the one hand, production costs include labour which would otherwise be a burden on the national budget and, on the other, imports require forign currency which must often be obtained at a great expense and sometimes by sacrificing other projects of equal national importance.

There would appear to be really no question about the fact that Pakistan needs and should have a basic steel industry. A modest project with a production capacity of 500,000 tons annually need not be considered and is not an end in itself but rather a first step in a process that will require further steps. The need for steel in Pakistan will be so large in another 20 years that the nation will not only require all of the production of an expanded Karachi Steel Plant but that of a number of additional basic steel plants in the country.

Choice of a Steelmaking Process

Extended debates have been held in the country as to whether the first steel plant in Pakistan should be based on imported ore and coal/coke to be processed in blast furnaces and the allied plant, or scrap and pig for use in open hearth or electric arc furnaces, or whether the steel project for a start should merely be a large enough re-rolling unit which should reduce imported billets and slabs into sections and flat products. A lot has been said in favour and against each or all of the proposals mentioned above. An attempt has been made in the paragraphs that follow to discuss some of the basic issues involved for making a decision in the light of the conditions that obtain in Pakistan.

Iron and Steelmaking

The manufacture of steel comprises three distinct but interrelated areas of activity. The first is the making of iron from iron ore; the second, the conversion of the iron to steel, and the third, the forming of steel into various shapes and forms. A plant with all the three stages included is considered integrated and produces the lowest cost steel, provided the quantities involved are sufficient. Steel is also manufactured in what are called non-integrated plants, that is, plants where mixtures of iron and scrap steel may be used as raw materials instead of ore.

The large-scale production of steel direct from iron ore in a single operation has not yet become a practical proposition. Iron according to the most popular and universally accepted methods, is produced in the blast furnace from iron ore and coke. The coke not only helps in reducing the ore by removing oxygen from it by virtue of the interaction of the carbon in the coke but also produces by its combustion the high temperature necessary for the smelting of iron ore. The second stage in steelmaking is to convert iron into steel by fixing the carbon content at desirable levels by removing unwanted constituents like phosphorus and sulphur which impair the quality of steel. This may be accomplished either by converter refining or the open hearth or electric furnace processes. In the converter process molten iron is refined by means of oxygen without an external source of heat supply, whereas in the open hearth and electric furnace processes steel is manufactured with the use either of restricted quantities of molten iron in combination with steel scrap or of cold metal charges of steel scrap and pig iron. The steel thus produced may be converted into various forms and shapes by either casting, forging or rolling.

Mention should also be made of what are known as the direct reduction processes. These aim at bypassing the usual blast furnace smelting operation and obtaining a metallic charge from iron ore suitable for processing into steel. Some of the more important processes that have attracted attention are the HyL, Krupp Renn, the R-N and the combined direct reduction and smelting processes like the strategic UDY and Thysland Hole. One of the largest installations employing a direct reduction process on a commercial scale is the HyL plant in Mexico where low cost natural gas and a suitable local ore are used to produce sponge iron that is charged directly into electric arc furnaces for conversion into steel.

Winds of Change

A period of change now exists in the developing areas of the world and in the steel industry. Far-reaching technical developments have been taking place in the steel industry during the last ten years and the centre seems to have shifted from the steel mill to the blast furnace section. While planning a new steelwork, we must take into account the up-to-date advances in technical knowledge and at the same time avoid solutions not yet sufficiently proved.

There is sometimes excessive enthusiasm for adopting the new and the glittering we have to guard against such a tendency to depart from traditional solutions, unless the technical and economic proposals advanced are fully backed by extensive usage and experience in existing installations.

Changes involving raw materials include the increasing use in blast furnaces of highly beneficial iron ore in forms such as pellets and other agglomerates. Such changes combined with other developments, such as fuel injection, high blast temperatures and high wind rates have greatly increased the production capacity of the blast furnace, and reduced the capital cost per ton output.

In recent years, however, probably the most spectacular advances have been made in basic oxygen steelmaking. The world capacity of oxygen steel is nearly 136 million tons a year which, just ten years or so previously, was confined to only one plant outside Austria. Some estimates place this figure at 200 million tons for 1967. Oxygen steelmaking is characterized by high capacity, low plant capital and operating costs, relative simplicity of operation and the ability to melt a high percentage of scrap.

Extensive work has also been carried out in different countries on the use of hot iron in electric furnaces. In some countries use of 25 to 30% liquid iron in electric furnaces with oxidation of the charges' impurities by gaseous oxygen is now being adopted fairly widely.

Tendencies towards introduction of highly mechanized and automated equipment for data recording, processing and programming are fairly widespread. Selection of sophisticated techniques and specialized equipment, despite the long periods required for training, deserve careful consideration, as thereby the requirement of a large number of routine technicians whose training is also long drawn out can be eliminated.

Advances in techniques for the continuous casting process involving the direct casting of bars, billets and slabs is another major development in the steel industry. In this process the use of ingot moulds, soaking pits and the primary mill is eliminated bringing about considerable economies in the cost of production of steel.

The use of pre-reduced ore sponge iron is also advancing rapidly and points to radical changes in the years to come to continued use of blast furnaces. The direct reduction methods have still to go through a long period of experimentation and trial before these can be accepted as standard methods for the manufacture of steel for developing countries. Their success depends upon the use of high quality ores, which must be finely divided and ultimately mixed with or placed carefully over the reducing agent. Use of direct reduction processes forms about 2% of the total steel production of the world at present.

Open hearth furnaces have been one of the major processes for the manufacture of steel and produce steel economically in the size ranges of 200—400 ton heats and possess the advantage of being used with hot or cold charges. Possibilities of the use of natural gas as fuel, if found in countries, are also offered. At the present time the trend is accelerating throughout the world away from the use of open hearth furnaces particularly in the light of new and cheaper processes involving use of scrap having been found.

Cost Estimates

Perphaps the most important consideration in the case of Pakistan is the matter of available capital. And here we are to make a choice from amongst a number of conflicting conditions. The country's rational and balanced development in all fields has to continue without impediment. The introduction of a major project like the steel plant in the industrial field is not to be allowed to bring about any undue economic strains. The possibilities of capital formation in the country and the prospects of raising the foreign exchange requirements through the loan and aid giving agencies have to be carefully weighed. The size and capacity of the steel plant has to be sufficiently large so as to ensure economic production.

Elaborate market surveys along with an examination of the yearly imports of steel products have clearly established the feasibility of a mill approximately a million tons annual capacity for Pakistan. For the first steel plant in West Pakistan the basic raw materials, namely ore, coal, scrap and pig together with the technical know-how and basic skills would have to be imported. In addition to this, infrastructure facilities like an electric power house, a special dock etc., may also have to be provided to meet the large scale requirements. The question, therefore, for examination is whether it is within the capability of the country to bear the burden of the capital needed for the entire million tons at this stage, which would be the right capacity of a fully integrated unit, or whether it would be more judicious to make a somewhat modest start. A number of alternatives present themselves:—

A start might be made by the installation of finishing facilities only for use with imported semi-finished steel;

A start might be made with a limited capacity steel manufacturing facility and only such finished products (flats) as would bring in greater revenue.

A start might be made by selecting suitable steelmaking processes with limited overall output and manufacturing flat and sectional products.

A study carried out in 1964 by a firm of steel consultants of international repute indicated that for a plant of an annual capacity of 198000 tons of flat products manufactured from imported slabs and for a plant of 216000 tons annual capacity of flat products manufactured from steel produced in the country, the average cost per ton of installed capacity for plant and facilities was $350 per ton for the former and $590 per ton for the latter. Despite the higher installed cost for the latter, it was proved that the plant based on imported slabs was neither economical nor advisable mainly because of the higher cost of imported slabs and the unreliability of the world market with regard to the availability of slabs. In fact there were no foreign exchange savings in the former arrangement, whilst in the latter substantial savings accrued.

The same firm showed on the basis of very careful estimation that the per ton installed capacity cost for plant and facilities of a unit with a capacity of manufacturing 456000 tons annually of steel and finished products was approximately $352 per ton using steel scrap and pig iron as the raw materials and manufacturing steel by the electric arc furnace process. These are 1964 figures and may have now gone up to about $385 per ton. A fully integrated plant, on the other hand, of approximately 500,000 tons annual capacity based on imported ore and coal, is likely to cost, in the present-day conditions, approximately $480/ton of installed capacity for plant and facilities only. This means that for an integrated plant the overall costs, that is, after the other charges pertaining to consultant services, engineering fees, overhead costs of supervising authority etc., have been added, the difference in costs may be of the order of $60 million.

These costs may appear to be high but are nevertheless realistic and take into account the provisions for infrastructure facilities, the cost of import of technical know-how and collaboration, the cost of all ancillary processes. These items make for significant additions in the project costs. It is indeed possible to present very modest and attractive project cost estimates by not including items of infrastructure or other essential facilities, services, and contingencies, but this would be misleading and would lead to a wrong appreciation of the economic returns.

It would, therefore, appear that from the point of view of the investment potential of the country, the choice for Pakistan would lie in favour of a non-integrated plant of about half a million ton capacity, at least for the start.

Integrated *versus* Non-integrated Plants

Comparing iron and steelmaking processes is an extremely difficult task. The three well-known and tried out methods of iron and steel manufacture are the blast furnace/basic oxygen furnace; the open hearth furnace and the electric furnace. Iron-making equipment which extracts iron from ore adds considerably to the capital cost and should, therefore, have a location which is economically sound for handling the very large quantities of raw materials needed. Irrespective of the process selected, the essential raw materials namely, ore coal/coke, scrap, pig iron etc., of suitable quality, would have to be imported. Transport and handling facilities would have to be specially provided, power supply arrangements made and agreements for the supply of technical know-how finalized.

Further consideration of open-hearth furnaces has been dispensed with largely on account of the reasons that it is no longer economical to manufacture steel by this process up to 500,000 tons annual output. It has been estimated by steel consultants that not only would an open-hearth plant of ½ million ton capacity cost about $7.2 million more than an equivalent electric furnace plant, but that the cost of production would be about $3.6 per ton higher. The production of steel from cold charges is slower than in the case of other processes; the operation is more complex; the larger furnace ranges (200-400 tons) are not suitable for use with continuous casting plants.

The use of iron ore and coal is characteristic of integrated plants. The latest experience and the most modern techniques involving increase of agglomerate percentage, increase in blast furnace size and productivity, and use of oxygen converters, indicate that the best and most economical results are obtained with a minimum capacity of approximately one million tons annually. We would now proceed to examine various aspects of the blast furnace/basic oxygen and electric furnace plants even if the capacity is limited to 500,000 tons annually in the conditions peculiar to Pakistan. A product mix of approximately 270,000 tons of bars, bellets and structurals and 230,000 tons of sheets and plates has been assumed.

Raw Materials and Costs

For the integrated process using good quality imported ore and coal/coke approximately 3 tons of raw materials per ton of steel produced would be needed as against approximately 1.3 tons of scrap and other raw materials for the electric arc steel furnace process based on imported scrap. Assuming the following costs of the important raw materials:

60% Fe ore	.. $	13/ton	delivered	at	site	at	Karachi.
Metallurgical coke	.. $	31/ton	,,	,,	,,	,,	
Pig iron	.. $	63/ton	,,	,,	,,	,,	
Scrap	.. $	48.47/ton	,,	,,	,,	,,	
Manganese ore	.. $	16/ton	,,	,,	,,	,,	
Sinter fuel	.. $	27/ton	,,	,,	,,	,,	
Ferro Alloys	.. $	284/ton	,,	,,	,,	,,	
Lime	.. $	3.2/ton	,,	,,	,,	,,	
Dolomite	.. $	6.3/ton	,,	,,	,,	,,	
Coal	.. $	18/ton	,,	,,	,,	,,	

the total yearly costs for 500,000 tons annual production would be:

For the integrated plant	*For the electric furnace plant*
$27.7 million	$30.0 million
the foreign exchange component of the cost would be:	
$26.7 million	$28.2 million.

The cost of raw materials is slightly higher for the electric furnace process which is mainly on account of the high cost of scrap assumed. In all probability scrap would be available at a cheaper rate. The quantity of raw materials needed for the electric furnace processes, however, is almost three times less *i.e.*, 0.6 million tons as against 1.5 million tons. It has been established that from the point of view of raw materials consumption the lowest are found in the case of electric furnaces.

Having to deal with a considerably larger quantity of raw materials in the case of the blast furnace plant raises the question of handling the extra quantities involved at the port of Karachi. The available capacity for handling increasing cargo is fully taxed and whereas the port may be in a position to handle the 0.6 million ton cargo largely of scrap steel in a suitable (bundled) form, it certainly would not the 1.5 million tons largely of ore and coal delivered in bulk form, every year. This involves the provision of an independent dock for the use of the steel mill, which for a particular location has been estimated to cost between $15—16 million. This would be an addition to the capital cost and would ultimately reflect in the manufacturing cost of the finished products.

As far as the sources of supply of raw material are concerned, U.S.A. is the principal exporter of scrap. Japan has been one of the largest importers but, owing to changing steelmaking practices, is becoming almost self-sufficient and may become an exporter of limited quantities. Other countries from where possibilities of limited imports of scrap exist are Australia, Burma, Ceylon, Arabia, Iran etc. Changing steel plant practices, such as the increased productive capacity of the blast furnaces with the use of high grade, beneficiated or pellet ores, basic oxygen steelmaking etc., have tended to maintain the prices of steel scrap more or less steady. It has been forecast that these prices would continue to remain steady, if not reduce further. Graded scrap is generally available in the form of standard-sized compressed bales or bundles and is handled with great ease at the ports. For the blast furnace/basic oxygen plants the sources of high grade ore best suited for Pakistan are India, Malaya, Australia, Africa and South America. Possibilities of obtaining highly beneficiated ores or pellets also exists, which in due course of time may preclude the necessity of erecting one's own sintering or other such expensive upgrading plant.

The other important raw material for the blast furnace process is coal or coke of the requisite metallurgical quality. It is cheaper to import coal and convert it to coke at the steel plant's own coking ovens, but the cost of a battery of coking oven is high. The advantage, however, lies in the manufacture of the by-products like ammonia, coke-oven gas, tar, light oil etc. which more than pay back the costs of local conversion of coal into coke. The most economical and known source for the import of suitable coking coal is again America, Africa, Australia, Poland and China may also hold possibilities. For coke the European continent and the U.S.A. are the likely and convenient markets. Transport of ore and coal has now come to be greatly simplified through the use of large-capacity bulk carriers and the distance of the source of supply has ceased to have significant importance.

Whatever the manufacturing process selected, the sources of supply of scrap and coal at the most competitive rates are restricted to a single source. It is useful to have a larger number of sources of supply but this argument cannot be used to rule out manufacturing processes which bring about economical production.

Manufacturing Costs

It has been estimated by steel consultants that cost per ton of molten steel, for a 500,000 tons capacity plant at raw materials cost assumed earlier and average labour and supervisory costs at Rs. 7 per day and Rs. 650 per month, is likely to be $3—4 per ton more for the integrated process than the electric furnace process. This position would be more favourable to the blast furnace plant when the capacity is increased to a million tons or more.

Power Supply

The question of supply of electric power in the large quantities required by an electric steel plant of 500,000 tons annual capacity assumes important proportions and must be given special consideration in the peculiar conditions obtaining in Pakistan. The production and distribution of electric power in developing countries is generally a state monopoly and the programmes for the present and future requirements are planned on a long-term basis. The electric power plant is considered an infrastructure of public utility and as a factor for the promotion of other industrial activities which are possible only if electric power is available. The state can, however, charge very advantageous rates because it can apply very low amortization and profit schedules being compensated by a direct income deriving from the sale of electric power, on the one hand, and by an indirect income derived from the development of other activities, on the other.

For the Karachi steel plant the power supply question has been carefully examined. It would appear that the conditions under which supplies of 120 M.W. could be arranged from local sources would not be quite favourable. It seems difficult to obtain a guarantee for continued and satisfactory supply, in view of the problems connected with voltage regulation and voltage flicker arising out of operation of electric arc furnaces. The cost of supply, moreover, is high and may be about $.0146/KWH, in addition to substantial initial expenditure. An independent powerhouse of 120 MW capacity could however be estabilshed for the mill alone and manufacture power at about $.0083/KWH and satisfy all other requirements. There is a recurring saving of approximately $4 million per year, based on these rates, in the operating budget of the mill. Notwithstanding the technical problems posed through supplies from local sources, this feature alone justifies the installation of an independent power plant for the mill.

The estimated requirements of power for an integrated plant are 60—70 MW and the technical problems arising out of the operation of electric arc furnaces are not posed. Under these circumstances it may not be advisable to burden the steel-mill capital cost with an expensive power generating plant. A special rate could perhaps be negotiated for the supply through the steel-mill's own independent power lines from the 137 MW nuclear power plant being installed at Buleji.

Other Energies

From the point of view of energy consumption, the two groups of steelmaking processes are clearly distinguishable. In the first group (the open-hearth and electric furnaces), energy external to the steelmaking process has to be delivered, while, in the other which includes all types of converters, the internal chemical energy evolved during transformation of the liquid iron into steel is sufficient to cover the total demand. In the latter group, the use of oxygen releases a vast amount of excess heat which can be utilized either for remelting scrap or for reducing iron from iron ore. It has been established that the oxygen blown converter process remelting 25—45 per cent scrap gives the best results from the point of view of energy consumption.

Technical Know-how and Skills

An important consideration in developing countries particularly those that are entering in the field of large-scale manufacture of steel for the first time is that the process selected should be the simplest, most reliable and proved method of manufacture, so as to furnish the basis for acquiring the necessary technical know-how pertaining to highly sophisticated production methods. In the event of selection of a highly developed process, a far more complex and wider programme of training of the necessary technical staff would have to be organized and our reliance on foreign technical assistance would have to be for a greatly prolonged period.

The electric furnace using largely a charge of steel scrap is probably the least complicated of all the steelmaking processes to operate successfully. The operation is easy due to the introduction of a large number of improvements, both mechanical and electrical. The operation is simpler and quicker with an almost non-existent possibility of mistakes.

On the other hand, the use of blast furnace/converters involves difficulties in installation and maintenance of the delicate air and oxygen conveyance, the suction, cooling and fumes purification systems. The workers have to be particularly skilled and experienced as, depending upon the type of charge, the analysis of the desired quality of steel, the blow time and the flame, decisions must be made about the addition of slag and the time and limit of refining. It is not that these skills cannot be acquired but that their mastery involves longer training, experience and knowledge.

Product-Mix

In a developing country which is endeavouring to set up a basic steel industry, efforts are generally made to meet as much of the requirements of various varieties of steel as feasible. At the same time, in such countries the economic considerations and the market conditions do not allow for a differentiation or specialization of the steel production unit till such time as, with advancement in industrial development, it is possible to segregate the production of the different qualities of steel.

Electric arc furnaces are generally recognized as occupying the best position from the point of view of the flexibility of the product mix of steel. This plant also provides for sufficient flexibility so that it can be expanded to suit the changing and developing markets, process developments in the steel industry and changes in the sources and prices of raw materials. A wide range and qualities of steels is feasible. In view of the peculiar reducing tendencies of the electric furnace, steel of a higher quality can be produced. Adoption of dual oxidizing and reducing slag processes enables accurate control of the carbon contents and virtual elimination of sulphur and phosphorus. It is also possible to produce alloy steels with a remarkably refined composition. In the case of the latest oxygen steelmaking process, namely L.D., a variety of different qualities of steels, particularly carbon, along with a limited range of alloy steels can be produced.

Hot or Cold Charges

While making comparisions, a cold charge for the electric arc furnace consisting largely of scrap and refining of the hot metal from the blast furnace in a basic oxygen steelmaking vessel for the integrated process have been assumed. In the event of future expansion of a basic electric furnace smelting plant by introducing ironmaking facilities through a blast furnace, the effective and economic utilization of the electric arc furnaces need not pose a problem.

In the blast furnace basic oxygen integrated plants, the use of oxygen has made it possible to increase the introduction of scrap to as much as 40—50% in large top blown vessels, and iron of almost any phosphorus content can be processed quite successfully. Electric furnaces, on the other hand, can be worked with almost 100% scrap, and modern top-charged furnaces can be charged with either bulky or light and voluminous scrap. In recent years, extensive work has been done in different countries on the use of hot iron in electric arc furnaces. In some countries, the process of electric steel production using up to 25 or 30% liquid iron and with oxidation of the charge's impurities by gaseous oxygen is now being adopted fairly widely. If the hot metal can be preceded by a pre-refining stage, this percentage can be increased to 50% or even more. The use of pre-treated liquid metal in electric furnaces considerably increases their productivity and decreases the specific consumption of electric power and electrodes.

If, therefore, an initial 500,000 tons annual capacity project based on imported scrap smelted in electric arc furnaces is expanded to 1 million tons capacity and blast furnace/BOF using imported ore and coal introduced, the blast furnace would have to be of a sufficiently large capacity to furnish approximately 800,000 tons of molten metal per year. Of this, approximately 600,000 tons could be refined in the conventional oxygen vessel and approximately 200,000 tons fed as hot charge to the electric arc furnaces for normal production, thereby reducing the requirement of scrap by about one third. We could continue to manufacture the balance of the million tons from scrap in the electric arc furnaces. These furnaces could also be used for the manufacture of alloy steel requirements for which these would be ideally suited.

Foreign Exchange Savings

There are prospects of substantial foreign exchange savings in the event of starting a basic steel industry in Pakistan, irrespective of whether the steel is produced by the integrated or the electric steel processes.

With the investment and raw material costs as indicated earlier, an eighteen-year foreign loan repayment period, with a moratorium for five years, a rate of interest of $5\frac{1}{2}\%$, the foreign exchange portion of the overall cost taken at approximately 60% and the C & F cost of importing 500,000 tons of steel products, half in flats and half in sections, from United States sources at approximately $84 million, the foreign exchange savings have been estimated as follows:—

(*i*) for the scrap steel plant, approximately $31 million annually during the repayment period and approximately $44 million annually after the clearance of the loan and the interest.

(*ii*) for the integrated plant based on imported ore and coal, approximately $29 millions annually during the repayment period and approximately $46 millions annually after the repayment period.

The foreign exchange savings in the case of the scrap steel plant are higher in the repayment period, largely because of the higher capital cost of the integrated process. By the time the foreign loans have been serviced, there may be proposals for further expansion of the plant to, say, a million tons capacity, at which stage it would always be advantageous to have a fully integrated plant. The production costs have a tendency to drop sharply with a fully integrated plant at capacities above the 500,000 tons mark and, with the use of beneficiated ore and hot blasts in the blast furnaces, are considerably lower than for any other process at the million ton annual capacity level.

Labour Productivity and Manpower Requirements

Labour productivity is naturally higher in processes with a high level of mechanization and automation—a trend which is bound to develop in future. As things stand, the manpower requirements for an electric steel plant are somewhat higher than that for other processes of steelmaking. This disadvantage is, however, overcome to some extent by the faster time of heat and the greater efficiency of the process. In Pakistan there is an added factor that is, that labour is comparatively cheap.

World Trends in Steelmaking

Blast furnaces still continue to the main source for the supply of hot metal in the world. These furnaces were excluded some years ago by theoretical scientists who were working on direct reduction processes. It is, however, important that when studying the establishment of a new steel industry, the capital and operating costs up to liquid steel be taken into account, because although it may be possible to obtain a solid sponge by direct reduction methods at equivalent prices to molten iron, the subsequent conversion of these materials into steel shows significant savings in operating and capital costs in favour of the blast furnace process. Technological improvements have increased blast furnace productivity phenomenally during the past decade and the end is not yet in sight. In 1956, for example, in the U.S.A. an average of 6036 lbs. of ore, fluxes and coke were needed to produce a ton of pig iron as against only 5188 lbs. in 1965. This means a reduction of 848 lbs/ton of pig iron. Out of a total production of 131 million tons of ingots in 1965 in the U.S.A., blast furnance production share was estimated at 89 million tons. Wherever large scale production was undertaken (a million tons or over of annual capacity), the basic metal was supplied by the blast furnaces.

Of particular interest to Pakistan is the largely increased activity being directed to the use of the so-called metallized or partially pre-reduced pellets in either conventional or specially designed blast furnaces or direct smelting electric furnaces. This would increase iron production and reduce fuel rates. Such pellets may not only offer the possibility of using a smaller type of blast furnace of much lighter construction than the present units, but also reduce the large-scale handling facilities for raw materials and supplies, if enriched ores in pellets forms are used. The application of direct smelting electric arc furnaces may be particularly important in the case of the first West Pakistan Steel Mill, as a reversion to electric arc furnaces and power-houses could be forecast. This may affect the entire planning of the pig iron, melting shops and transport facilities fundamentally for the same quantities of production, thereby markedly affecting the capital requirements.

The improvements in raw materials and the progress in the blast furnace operation since the end of World War II have indeed been impressive but these have been overshadowed by the spectacular changes in steelmaking methods. The nucleus for this change was the tonnage production of high purity oxygen and its use in steelmaking. Of the total world steel manufacturing capacity of approximately 500 million tons in 1965, as much as 136 million tons was by oxygen steelmaking. This is expected to reach the 200 million ton mark by the end of 1967. These increases from about nil to the present levels, all in a period of about 12 years, reflect upon the fantastic possibilities of oxygen steelmaking.

Electric furnace steelmaking shows a strong growth trend. Technological improvements have contributed to more economical operation as well as the trend toward larger furnaces with much higher power ratings. The essential conditions for installation of electric steel furnace are mainly:—

(*i*) low electric power cost.

(*ii*) availability of low cost scrap on a continuing basis.

In view of reasons already mentioned, this mode of steelmaking offers particular advantages for developing countries intending to instal steelmaking facilities and beset by capital and other difficulties. Steel production trends in some of the advanced countries by this process are indicated below :

Country		Year	Total crude steel prodn. (million tons)	Electric steel of total prodn. (million tons)	Percentage of electric steel (million tons)
U.S.A.	..	1960	99.3	8.34	8.4%
		1965	131.0	20.00	15%
Japan	..	1960	25.0	5.0	20%
		1965	45.0	11.25	25%
West	..	1960	33.6	2.18	6.4%
Germany	..	1965	41.2	4.12	10%
France	..	1960	18.0	1.5	8.7%
		1965	21.5	2.15	10%
Italy	..	1960	8.4	3.1	38%
	..	1965	13.5	5.4	40%
U.K.	..	1960	28.0	..	..
		1965	30.0	3.0	10%

It is expected that the growth of basic oxygen steelmaking will eventually make available larger quantities of heavy melting scrap at favourable prices that may greatly improve further the economics of electric furnace steelmaking.

The open-hearth process is on the decline and this decline, with other advancements in the field, is expected to continue and in due course open hearths may cease operation by about the year 2000.

United Nations' Surveys

The following extracts from a study carried out by the Steel, Engineering and Housing Division of the United Nations Economic Commission for Europe in 1963 regarding the choice of a steelmaking process are relevant to our consideration:

> "On the basis of comparison of the economic results obtained from various steelmaking methods which are in large scale industrial use, it may be said that whenever new steelmaking plants are to be constructed in the next few years, thorough study and preference will usually be given to oxygen converters of the LD and Kaldo types. Production of electric steel is also likely to increase considerably."

" With the increase in oxygen steel to almost 200 million tons the following conclusions may be drawn:—

(*i*) No new Bessemer shops would be built.

(*ii*) There is little possibility that new Thomas converter shops would be built.

(*iii*) Only in special circumstances will the construction of new open-hearth shops be undertaken.

(*iv*) New steel shops would be equipped with oxygen converters of different types and electric arc furnaces."

Kalabagh Ore

A panel of iron and steel consultants of the United Nations was requested by the Government of Pakistan to review the findings of the Pakistan Mineral Survey Project with particular reference to the use of Kalabagh iron ore and the economic viability of an iron and steel industry based on its used and to recommend the choice of a plant, location, and raw materials for a domestic iron and steel industry.

The panel after prolonged discussions with the consultants and a careful study of all the available data regarding experiments and trials carried out in connection with the use of the Kalabagh (Chichali) ore, submitted its findings and recommendations to the Government of Pakistan in May 1966. Relevant extracts from the report appended below are of interest:

"The panel recognizes that it is technically feasible to smelt Chichali ore to produce pig iron. However, the cost would be excessive in comparison with the cost of smelting high grade ores by current blast furnace practice. Moreover, the resulting iron would be high in silicon, phosphorus and sulphur. These facts lead to a cost of finished steel much higher than the present relatively high imported steel prices paid by Pakistan. *Consequently the Panel members conclude that an iron and steel industry based on Chichali ore would not be economically viable.*"

"The Panel recommends that the Pakistan Government locate its iron and steel industry in the vicinity of Karachi because:

(*i*) Karachi is the centre of the major market for steel in West Pakistan.

(*ii*) The Karachi area gives the best possibility for an iron and steel plant site with the lowest cost for imported raw materials.

(*iii*) A steel plant in the Karachi area would be close to existing supporting facilities, including housing and labour."

"The Panel considers that electric furnace melting of imported scrap, followed by continuous casting to semis may be a more desirable route for Pakistan as a first step, since this will require lower capital expenditure. Furthermore, it will take advantage of the availability of scrap in the world market at moderate prices which are likely to remain stable in view of surplus blast furnace capacity.

"The Panel recommends that such an imported scrap electric furnace operation be thoroughly studied, particularly to meet the needs of existing steel re-rollers. If there would be a significant cost advantage using the blast furnace route, then the panel proposes its adoption. On the other hand, if the imported scrap electric furnace operation be shown to be cheaper or marginally more costly than the blast furnace/ BOF operation, then the electric furnaces should be chosen because of the following additional advantages:—

(*i*) Electric steelmaking with scrap is a straightforward process which minimizes training problems.

(*ii*) Electric furnace heats are well suited for use in continuous casting.

(*iii*) By such a step-by-step development of its iron and steel industry, Pakistan will be in a better position to take full advantage of rapidly advancing technology."

Conclusions:

In conclusion one can do not better than to reiterate that West Pakistan needs and must have a basic steel industry. The demand for steel is there and a modest start with a 500,000 tons capacity plant—even though the raw materials have to be largely imported—is more than justified by every rule in the book.

An electric steel plant based on imported scrap and pig, located on the coast and manufacturing its own power appears to be the best solution. It offers prospects of low capital costs, simple, straightforward and foolproof processing technology. Unlike other steelmaking process, electric steelmaking offers the possibilities for the manufacture of the widest range and qualities of steels, a feature which may particularly important to a developing country with limited resources and having to satisfy a variety of demands. In addition to a fairly reliable international import market for scrap, the scrap generated in the country can be put to good use. Full use of modern economical processes like continuous casting can be made and the country gets some time to watch the progress of the rapidly developing technologies in steelmaking, which point more and more to the modification or even the elimination of the blast furnace.

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