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UNITED NATIONS

INTERREGIONAL SYMPOSIUM ON THE APPLICATION OF MODERN TECHNICAL PRACTICES IN THE IRON AND STEEL INDUSTRY TO DEVELOPING COUNTRIES

11-26 NOVEMBER 1963

STEEL Symp.1963
Technical Paper/A.12
24 September 1963
Original: ENGLISH

05468

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Summary

1. Accelerated economic growth of emergent countries during the Sixties, in conformity with the modest 5 per cent target of the U.N. Decade of Development, will call for substantial increases in steel consumption throughout the poorer two-thirds of the world. This follows from the fact that steel consumption and economic development are positively correlated. In a decade in which the trade deficits of these countries may multiply four-fold, very vigorous efforts for import substitution will be needed. This will require many emergent countries to start indigenous production of steel because of its crucial importance in the process of growth. While setting up steel facilities admittedly requires a large capital outlay in relation to output, as in power or other infra-structure items, the indigenous availability of steel stimulates the growth of steel transforming industries. Very often the foreign exchange expenditure on new steelworks is recouped through direct import substitution in the first few years, quite apart from the savings made possible on a wider front by the transforming industries. The paper points out that the wide-spread occurrences of iron ore, coupled with technological developments which seek to use energy resources and reductants other than coking coal, make effort in this direction entirely feasible. The initial size of new plants is less important than making adequate provision in design and engineering for future expansion to take care of the rapid increases in demand now in prospect.

2. It is shown that the choice of metallurgical processes has been greatly widened by modern technology. While the minimum economic size of large integrated works has increased from a million tons a few years ago to 2-4 million tons today, new technology has at the same time made it possible to initiate a plant on a small yet viable scale. The economic and technical factors favouring the dispersal of the steel industry are discussed to show that, both internationally and within the same

country, the market potential has in certain situations an important bearing on the locational decision. This trend is accentuated by the possibilities of specialisation opened up for market-oriented small plants. In conclusion, the paper stresses that there is not, or should not be in a well-ordered scheme of things, a conflict between large and small plants. Both may be needed in a country with a large enough market, while those starting on the road to industrialisation can begin by setting up small plants which may in the fulness of time become major works. A rational definition of the respective roles of small and large plants in each economy is necessary, lest vested interests of one should hold back the progress of the other.

STEEL AND ECONOMIC GROWTH

1. The widening gap between income levels of developed and developing countries underlines the importance of accelerating growth in the poorer two-thirds of the world. The endeavour to stimulate economic advance in developing countries will inevitably call for large inputs of steel as shown in a recent study of Indian requirements(1). This follows from the correspondence that exists between levels of economic growth and the quantum of steel consumption.

2. Any programme of economic development calls for substantial steel inputs for the obvious reason that steel is a component of all production equipment and machinery, power stations and transmission lines, dams and bridges, railway lines and transport vehicles. The relationship between steel and growth, systematically presented in a recent study by the Economic Commission for Europe(2), will be of interest in this connection. Figure 1 shows the correlation on a per capita basis between steel consumption and four macro-economic variables - gross national product, industrial production, gross capital formation and consumption expenditure. It will be observed that every increase in economic well being calls for a correspondingly greater increase in steel consumption.

Rising Demand

3. It is noteworthy that the level of per capital steel consumption tends to outpace the growth in national income or industrial production in the initial stages of development. This is evidenced by India's example where steel consumption has risen by 12 per cent a year over the Fifties, compared with an increase of only 4 per cent in the national income and 9.4 per cent in industrial production. The fact is also brought out by international comparisons. Chile with a national income per capital four times higher than India has a steel consumption eight times greater. Per capita national income in S uth Africa is five times India's but steel consumption is fifteen times higher. This phenomenon confirms the crucial importance of this basic material for stimulating economic growth.

4. The correlation between levels of economic development and steel consumption is not invalidated by such exceptional cases as that of Venezuela, which has an economy over three times more steel-intensive than, for instance, Argentina, a country with a higher national income per capita. The departure from the rule is explained by Venezuela's export surpluses which permit import of a range of steel-made consumer goods, and the predominance of the oil industry in her economy which creates a large demand for steel-made equipment.

5. According to one projection[3] steel consumption is expected to rise over the next 15 years at rates ranging from 10 to 20 per cent in the world's developing regions. This rate of growth, far surpassing anything achieved in the past, will require a major effort to develop indigenous production facilities because it will otherwise be impossible to sustain increasing consumption. From this it is evident that the effort to develop new steel capacity in developing countries is not motivated by a false sense of prestige, but rather by the conviction that assured supplies of steel constitute the surest base for economic advance on all fronts including agriculture. The conviction is supported by the experience of areas like India, China and Latin America, where the planned acceleration of development has exerted such pressure on steel consumption that substantial imports have been found necessary, despite increases in indigenous production at annual rates of 15 to 30 per cent during 1956-61.

Widening Trade Gap

6. A 5 per cent increase in the national income of developing countries per year during the Sixties - the modest target set by the U.N. for the Development Decade - calls for raising the gross annual investment in these economies collectively from an actual of $ 28 billion in 1959 to $ 52 billion by 1970[4]. This will require vast inputs of capital goods, a large proportion of which will have to come from industrially advanced nations. At the same time, rising population and standards of living will raise the demand for food and consumer goods above what the developing economies can themselves meet. In the circumstances, economic growth in the next decade will unavoidably call for a very substantial increase in imports.

7. The relative inelasticity of exports which developing countries make to industrially advanced nations will lead inevitably to a widening of the trade gap. One estimate places the trade deficit at $ 20 billion in 1970, a four-fold increase over the actual of $ 5 billion in 1959[5]. This trend may be illustrated by India's example where total imports have increased by 60 per cent but exports by only 12 per cent during the Fifties, resulting in an almost four-fold increase in the trade deficit[6]. Incidentally, the quantum of rolled steel import has risen in the period by 300 per cent, despite which the economy has suffered from an overall steel shortage.

Import Substitution Imperative

8. A very serious effort is, therefore, required throughout the under-developed world to reduce the trade gap through vigorous import substitution. The scope for this varies from country to country depending on the individual resource endowment. One major possibility is the development of local steel industries, both because of the crucial importance of steel and the opportunity afforded by the fact that the under-developed areas account for three-fifths of the world's probable iron ore reserves(7). It is of course true that developing areas are as poor in coal as they are rich in iron. However, other alternative fuels - oil and gas - are relatively more abundant. Efforts are being made to overcome the lack of coking coal by technological advances which attempt to utilise other reductants and energy sources. Several countries in Latin America and Asia are already major oil producers, and reserves of natural gas are being developed in North Africa and in Pakistan. Large untapped hydro-electric reserves are also available in many of these countries.

9. In India's case, the annual drain on meagre foreign exchange resources has made it necessary to pursue an ambitious programme of steel development, capitalising on the country's favourable raw material situation but immediately motivated by the compelling necessity of import substitution. It has been seen that foreign exchange (a scarce resource in Indian conditions) expended on building new capacity is recouped in a few years, after which the net savings should be very substantial indeed. Similar logic has set Pakistan thinking in terms of developing a local steel industry. Burma, Ceylon and Nepal are other neighbours who have started in the same direction. So have many other countries in Asia and Latin America including some of the newly independent nations of Africa such as Nigeria, Tanganyika, Morocco and Tunisia.

Spread Effects of Steel

10. The arguments in favour of indigenous manufacture for import substitution are reinforced by the spread effects that steel development has on the rest of the economy. Assured availability of steel encourages the establishment of fabricating and processing industries, widening the range of import substitution and export capability, and generating larger income and employment. The point may be noted that steel transforming and processing industries have a capital-output ratio 50 to 75 per cent lower than primary metallurgical industries(8). A developing country trying to achieve a satisfactory capital-output ratio over the economy as a whole has,

therefore, a strong incentive to combine primary iron and steelmaking with metal-working industries. Import constraints, endemic in developing countries, require that these industries should be able to depend on supplies of steel from domestic sources as the full utilisation of their capacity may otherwise become exceedingly difficult. This is, indeed, the situation in India where in spite of an expanding steel industry and the import of about one million tons of steel per year, import restraints keep the engineering industry working substantially below its capacity and constitute a major obstacle to its expansion.

Widening Geographical Dispersal

11. In addition to the compelling need to minimise dependence on imports of steel through local production, there are geographical and technological factors favouring the dispersal of steel capacity, both internationally and within the same country. Beneficiation and other modern techniques are reducing the weight of raw materials to be transported for ironmaking, while bulk handling has brought down transport costs substantially in recent years. This tends to reduce the pull of raw materials in the location of the steel industry. There is the example of Japan which in 1961 imported over long distances 80 per cent of its iron ore and 40 per cent of its coking coal requirements to produce 28 million tons of steel. Japan is not only meeting her growing demand but is successfully exporting 10-15 per cent of her annual production. The factor powerfully helpin in the spread of the steel industry internationally is the availability of bulk carriers which can transport commodities over long ocean routes at very low cost. The effect of this is seen in the increasing adoption of seaboard locations, as in the case of such recent plants as Newport (Britain), Dunkirk (France), Bremen (West Germany), Taranto (Italy), Tobata (Japan) and Karachi (Pakistan).

12. Finished steel does not lend itself, however, to bulk handling; there are as yet no economies in sight comparable to those offered by bulk carriers in the transport of raw materials. The impact of the higher transport costs on finished steel gives an advantage to local manufacture in preference to imports. This is shown by a study undertaken by the Economic Commission for Latin America comparing costs of local manufacture in several Latin American locations with the delivered price of steel imports from U.S.A. This established that a domestic industry would in many cases enjoy a comparative cost advantage even if its initial scale of operations was small in comparison with the size of the plants in exporting countries(9).

13. The implications of these locational trends for developing countries are clear. If they have to choose between importing finished steel and raising the volume of steel production by bringing in one or another of the essential raw materials, the choice must obviously be for the latter.

FACTORS FAVOURING SMALL STEEL PLANTS

Dispersal within the Country

14. Dispersal need not be thought of only in international terms, but may also be envisaged for stimulating regional development within a large country. Even in countries with large integrated plants, dispersal of facilities may be encouraged by the impact of transport costs. Planning of new steel capacity anywhere, but more so in a developing country, will have to take into account the cost and availability of transport in relation to possible locations. Considerations of such transport economies may well indicate the need for small plants in areas distant from major works.

15. Small plants, manufacturing a smaller range of less sophisticated products for a local market may be fully viable even when there are major plants existing or proposed within the same country. A good example of a small plant developing to serve a local market is provided by Mukand Iron & Steel Works in Bombay, which starting primarily as a steel castings foundry today supplies a substantial portion of the rod requirements of the area. The company is now installing a new plant with a capacity of about 100,000 tons consisting of two 20-ton arc furnaces, a twin strand 'S' type concast machine, and a 20-stand wire rod mill. The plant is so laid out that it can expand readily to 250,000 tons per year in stages, and also diversify its production to include wire, wire rope, nails, springs and miscellaneous light products.

Scope for Specialisation

16. Another factor reinforcing the viability of small operations subsisting side by side with large works is that the optimum size of integrated plants is increasing everywhere with a corresponding rise in the minimum economic rolling tonnage. The high speed of the rolling mills requires concentration on a relatively small number of sections and sizes to achieve the economies flowing from long production runs. In contrast with this production trend, steel consumption has an inescapable tendency towards diversification. Rationalisation can and should reduce the range but there is a point beyond which effort in this direction begins to yield diminishing returns.

17. A good example of a specialised non-integrated operation is a rolling mill in Leningrad which has a production of only 140,000 tons per year but a sales value of over $ 300 per ton, because it rolls and further processes a range of specialised products, such as watch springs, wire rope, bolts, nuts, etc. An interesting feature of this plant is the use of twelve cluster-type (Sendzimir) cold mills in a single bay for the rolling of ultra-thin strips of precision alloys, which sell up to $ 30,000 per ton.

LARGE AND SMALL PLANTS COMPATIBLE

18. For a developing country where the steel industry starts from one or two nuclei, the concept of large and small works operating in tandem is particularly useful. The large works concentrates on producing economic tonnages in a comparatively small range and feeds small satellite plants with the basic materials to work into individual sizes and shapes required. An example from India may help to clarify this point. The two million ton Tata works at Jamshedpur has drawn to the same location a number of secondary works - one producing hot-dipped tinplate, another wide rods, wire and merchant products, and a third producing steel tubes. The Tata plant has also an interest in two non-integrated operations, one located within 150 km and the other at a distance over 1,500 km. The main works supply billets to these two units which produce a high proportion - 50 per cent or more - of specialised products, e.g. coir and cotton baling hoops, wire and wire nails.

19. Steel is a powerful lever of development and the emergence of new steel nuclei in dispersed locations will unfold new possibilities of regional advance. In the U.S. the development of the steel industry on the west coast is attributable directly to the cost advantage of local manufacture against high priced deliveries from the east coast. It is stated that the great increase in steel consumption in western United States after the war was facilitated by the operation of war-built steel plants in Utah and California[10]. In the USSR, the steel industry originally concentrated in the Ukraine has been steadily moving out to new areas. The second metallurgical base in the Urals was already well-established by the time of the Second World War. Since the war, units in Urals have been further developed and now provide 35 per cent of the total USSR production compared with 21 per cent immediately after the war. The share of Ukraine has correspondingly declined from 49 to 40 per cent in the same period[11]. A third metallurgical base is coming up in Siberia and preparations for a fourth and fifth base are under way during the current Soviet seven year plan.

20. India starting on an ambitious programme of steel development has already seen the need for geographical dispersal of the industry. Her first two plants were located within 150 km of each other. Of the three new plants built in the Fifties, only one is in the same general location as the older plants, but the other two represent a shift of the industry westwards from the region where India's coking coal deposits are concentrated. Further plans are now being drawn up for moving the industry into new areas, including coastal locations such as Goa on the west coast and Vishakapatnam on the east coast which will permit the use of imported fuels should this be necessary to stretch out domestic supplies.

21. The point to note is that there is no (or should not be in a well ordered scheme of things) conflict between large and small units. In countries or areas with large enough markets both may be needed. The distance from the large integrated works is not the only decisive factor in the location of smaller plants. In the U.S. - at Birmingham, Alabama - there is, for instance, the Fairfield works with a capacity of over 2 million tons per annum but also working alongside in the same city is the Connors steelworks with a capacity of about 100,000 tons per annum, producing hoops, strip and concrete reinforcing bars. Apart from this remarkable example of co-existence in the same location, it may be pointed out that the U.S.A. has today over 100 units rolling less than 100,000 tons per annum. In the USSR 8 per cent of all rolled products but 20 per cent of merchant sections come from non-integrated operations with a capacity of 150,000 to 200,000 tons each. They usually roll special sections for agricultural and engineering industries, produce merchant bars and rods, and serve to meet the demands in regions which are not suitable for locating integrated works.

<u>Modern Technology and Plant Size</u>

22. The effort to establish a local nucleus of steel production immediately raises the problem of optimum plant size. It is axiomatic that there is economy in large operations where favourable raw materials and markets exist. But at the same time, there are many situations in both developing and developed countries where the lack of resources or the need for specialisation or the factor of transport costs, may require - indeed dictate - plants to start on a modest scale, with initial capacities of between 50,000 to 200,000 tons per year. The initial operations may be either integrated or non-integrated, restricted at the outset to ironmaking, or only steelmaking starting with scrap, or rolling based on purchased billets etc.

23. This is possible today because technology is expanding the horizons for both small and large scale units, thus making the 50,000 ton plant and the 5,000,000 ton plants both viable under different conditions. During the last five years modern technology has more than doubled the capacity of various metallurgical units. A single blast furnace producing a million tons per year, a single working LD converter producing 2 million tons of ingots, and a universal slabbing mill with a throughput of 5 million tons are today commercially and technically feasible. But at the same time as modern technology is enormously increasing the throughput of production units, it is evolving other processes which are viable even when scaled down to a small annual output.

Long Term Planning

24. As new steel capacity has a long gestation period, it is necessary that planning for steel should be undertaken on a long-term basis(12). This first calls for a forecast of future steel requirements. Methods based on extrapolation of past trends are not meaningful in an economy where growth is being accelerated by an intensive planned effort. More reliable estimates can be obtained, as India has attempted to do, by the 'end-use' approach which works out demand by applying to projected targets in steel consuming sectors well-established norms of steel required per unit of manufacture or construction(13).

25. A similar 'end-use' exercise can help in breaking down the aggregate demand into various steel categories. It will be seen that in the early stages of economic development, steel consumption has a strong investment bias. In developing countries like India and Turkey 87-90 per cent of steel goes into investment, of which more than half goes into primary construction including mining and railways.

CHOICE OF TECHNOLOGY

26. Planning for steel requires a correct choice of technology corresponding to the pattern of steel requirements and available raw materials resources. Since developing countries are characterised by a shortage of capital in relation to their needs an effort may be made to reduce the capital output ratio by adopting more labour-intensive production processes but this is not to be interpreted as a plea for outmoded technology. The limitation of finance is often less decisive than the determination of a country to find the required resources and make the best use of its facilities. The capital outlay on steel capacity may legitimately be viewed as basic investment which an economy makes to lay sure foundations for

further industrialisation. In judging the value of investment, the same considerations will apply as in the case of power, transportation or other infrastructure developments.

Small Scale Ironmaking

27. A range of new processes and improvements to existing ones are now available. As noted earlier, many developing countries are poor in coking coal but rich in other fuels such as oil and natural gas. This is the main reasons for interest in direct reduction processes which do not require coking coal. Such direct reduction processes normally produce powder or sponge iron for use as metallic charge to blast furnaces, cupolas, open-hearth or electric furnaces. These processes utilise a reaction vessel (Hojalata y Lamina and Madaras process), a shaft furnace, (Wiberg process), rotary kilns (Krupp-Renn, S-L, R-N, and Orcarb processes), and fluidised beds (Esso-Little, H-iron, NU-iron and Stelling processes). A number of such processes has been technically successful but only very few are in commercial operation as, for example, HyL at Monterrey and Wiberg in Sweden. The new 500 ton per day unit of the HyL process was investigated in connection with a proposed steel plant in Pakistan where natural gas is now available. The wider adoption of direct reduction processes has to date been restricted because few have been proved in continuous commercial operation outside of the special combination of circumstances in which they were first set up. The blast furnace remains the most efficient mass producer of iron, with direct labour costs reduced over the past hundred years from 55 per cent to 4-6 per cent per ton of iron (14). It pre-heats, reduces, melts and separates iron from gangue in one composite operation. It is to be noted that blast furnaces are operating at the Fundidora plant in the same location as the HyL units at Monterrey in Mexico. This is not to suggest that a viable direct reduction process will not emerge in course of time, nor indeed that direct reduction may not be the right solution to adopt in certain circumstances.

28. One direction in which considerable work has been done to overcome raw material handicaps is to use a smelting unit with reduced stack height, as at Calbe in East Germany, Liege in Belgium, and the National Metallurgical Laboratory at Jamshedpur in India. A series of tests (15) have been run at the 1.3 m hearth dia furnace at Jamshedpur using low-temperature carbonised coke, lignite coke and other inferior fuels. Self-fluxing ore-coal briquettes as well as lump burden materials have been tried over a three year period. These campaigns have shown that the

direct charging of uncoked coal or ore-coal briquettes presents considerable operational difficulties, and that some form of low temperature carbonisation is essential. It is necessary also to utilise all by-products fully - high calorific gas and slag from the furnace and by-products from the carbonisation process - to compensate for the somewhat higher coke consumption and improve the overall economics. It has been established, however, that it is possible to obtain smelting conditions which permit the production of high-silicon pig iron for use in foundries.

29. A significant development for small-scale ironmaking is the use of additional facilities ahead of an electric smelting furnace partially to reduce the charge materials. This helps to reduce power consumption per ton of iron, a factor of considerable importance to developing nations in most of which power requirements are rising very fast indeed. This thermal and chemical pre-treatment can be done in shafts, where the charge is heated counter currently by ascending gases from the electric furnace. A higher degree of pre-reduction is obtained by passing the iron ore together with some reductant in a rotary kiln, followed by a hot transfer of the kiln product into the furnace. More than half the oxygen in the ore can be removed by such means, which reduces the power consumption drastically, and permits a corresponding increase in iron production.

30. The effort in this direction is represented by such examples as pre-reduction kilns being installed at Skopje in Yugoslavia, while one of the nine 33 MVA furnaces in Venezuela is being adopted for pre-reduction by the Strategic-Udy technique. The Mo-I-Rana plant in Norway is adopting pre-reduction in the charging chutes of its smelting furnaces. This plant, which is already producing 360,000 tons per year from four 33 MVA furnaces, is now installing two 50 MVA units and is now expected to produce 750,000 tons per year of iron. These operations will be followed with interest by developing countries as they hold out the promise of successful ironmaking using inferior reductant.

31. In this connection, recent tests run for establishing the feasibility of a steel plant in South India in the Neyveli-Salem area may be of interest. An electric furnace with pre-reduction was used for smelting local materials - pellets from beneficiated Salem magnetite together with carbonised lignite from Neyveli. Power consumption averaged under 900 kWh per ton of iron, which is only 35 to 40 per cent of consumption in conventional electric smelting without pre-reduction. A half-million ton steel plant is now being projected in this area, which may be based on

electric smelting with pre-reduction, LD converters and continuous casting. Coking coal reserves in India are confined to a small area in the eastern part of the country but iron ore deposits are widely dispersed. There is, therefore, a strong case for dispersing steel capacity outside of the present steel belt (in which all existing integrated plants are located) by use of techniques which eliminate or reduce reliance on coking coal. A similar combination of circumstances also obtains in Latin America where coking coal resources are scarce in every country except Colombia.

32. Another development of particular interest to emergent countries is agglomeration because this can substantially reduce investment in ironmaking and at the same time conserve scarce coking coal reserves. Agglomeration is in any case a pre-requisite for several direct reduction processes because they must have a high grade, easily reducible material. In the blast furnace, the use of agglomerates (sinter, pellets or briquettes) can lower the coke-rate by 30-40 per cent and increase productivity by 50 per cent and more, with a significant reduction in capital costs per annual ton of output. A study of ironmaking under Indian conditions(16) indicates that capital cost of all facilities (such as coal mining, washing and carbonising, ore mining, sinter plant and blast furnace) is about 20 per cent lower with full sinter burden as compared to operations without sinter. The advantage in production costs works out to about U.S. $ 1.50 per ton of iron.

Several Advantages

33. Thus, there are several advantages of small-scale ironmaking, some of which cannot be readily quantified but are nevertheless very real. First, it may use raw materials - inferior lignite coke or small-sized coke - which are not suitable for the large blast furnace. It should also reduce strain thrown on the transport system by the movement of pig iron or steel from distant integrated plants. Secondly, the small furnaces will produce foundry iron of closely controlled analysis, thus leaving large blast furnaces at the integrated steel plants to produce basic iron for conversion to steel. Thirdly, it may be possible to build small furnaces, doing away perhaps with some of the mechanisation incorporated in large furnaces, by depending very largely on indigenous fabrication. This is an argument being currently advanced in India, and it is claimed that the import content can be reduced to as little as 10 to 15 per cent of the total investment. Finally, the installation of small ironmaking plants will have a catalytic effect on industrial

development in the surrounding area by encouraging the installation of iron foundries and machine building units. The plants will generate a familiarity with modern technology which will be of value in broadening the industrial base.

Steelmaking

34. Small scale steelmaking does not present the same problems as ironmaking. The new basic oxygen processes as well as the electric arc furnace can be readily adopted to produce any desired steel tonnage. The LD process combines the advantages of a pneumatic process, such as low investment cost and rapid refining rate, with some of the flexibility of the open-hearth in accepting a wide range of materials. An LD shop with one operating converter, say, of 15 tons capacity may be considered as a minimum economic unit which will give a production of about 150,000 tons per year. At this level of capacity the idea of a replaceable converter with one blowing station is attractive as it will greatly reduce the investment cost. In any case, investment on a LD converter installation will be substantially lower than on equivalent open-hearth capacity. The quality of steel produced in the LD converter is comparable with open-hearth and in some respects (e.g. low nitrogen content) better. In many plants such as Donawitz (Austria), Bochum-Verein and Witten (West Germany), and Colorado Fuel & Iron (U.S.A.), a range of high carbon and alloy steels are now being produced in LD converters. Developing countries are generally poor in scrap with little industrial and obsolescent scrap returning to the steel mills. This is a handicap which the LD converter is well suited to overcome. At higher levels of scrap availability, the combination of basic hot blast cupola and LD converters or electric furnaces would be attractive.

Continuous Casting

35. A technique of great significance for both large and small plants is the continuous casting of steel. This enables the investment in equipment, buildings, cranes, etc. for teeming, stripping, mould preparation, soaking pits and primary rolling to be eliminated by direct pouring of liquid steel to slab or billet. Consequently, the capital outlay in a continuous casting plant may be 30 to 40 per cent lower than for a comparable blooming mill installation. There are economies also in operating costs primarily because the yield from liquid steel to intermediate product is as high as 95 per cent and over. This represents an improvement of over 15 per cent in yield when compared to conventional operations. Because of these advantages, the 70 continuous casting plants, today in operation or under construction,

are expected to double in number and produce some 20 million tons of steel per year by 1965. It is estimated that out of the 50 million tons of new steel capacity being added in the USSR in the Sixties, as much as 35 million tons will be continuously cast(17). A developing country like India is now installing three such plants, and further installations are in prospect.

36. Continuous casting together with the use of a hot planetary mill permits the production of strip on a relatively small scale. Compared to a steckel or semi-continuous strip mill, the planetary mill has the advantage of high yield and low capital investment. As it has only one stand plus a planishing stand, it requires less floor area, building space, utilities, etc., than other processes for rolling strip on a small scale.

37. The Bentler plant in Germany is the first to link continuous casting directly with a hot planetary mill to produce strip of 450 mm width. Another such installation is going up at the Tracy plant of Atlas Steels where stainless steel slabs 1,350 mm wide and 125 mm thick from a continuous casting machine will be rolled on a planetary mill into strip or plate. The widest mill in operation today is the 1,150 mm unit at Norbottens in Sweden with a capacity of 70 tons/hour. The hot strip from such installations could be further cold rolled on a cluster mill to provide a very satisfactory combination for a small steel plant.

38. Technology has greatly extended the horizons for the small steel mill, making it possible today to envisage a plant with an initial capacity of 100,000 to 200,000 tons but capable of producing a variety of products of high quality at competitive costs. Figure 2 indicates the combination of processes which presents attractive possibilities for the small steel plant of the future. Conveyor belts would charge small blast furnaces with a two-component burden - self-fluxing agglomerate and coke. Iron would be tapped direct into the mixer of the LD steelmelt shop, thus avoiding cumbersome movements by rail track systems. Steel from the LD converter would be teemed into a continuous casting machine located in the pit, under the normal teeming crane, as the use of curved concast mould would not require a high-bay. The bloom or slab would then move direct through a wash furnace to a planetary hot strip mill or a section mill. This arrangement of processes would result in a compact layout and free the steelworks from repeated handling of small tonnages of hot materials. Also, the processes could be automated in future, if required, resulting in a very modern and efficient steelworks.

Economics of Scale

39. A new steel plant in a developing country can start with a relatively limited range of products, such as light merchant sections and sheets. The decision whether to tie up capital on large capacity rolling facilities, much of which may remain initially unutilised, will depend upon deciding where the balance of advantage lies. The larger the capacity, the lower will be the operating costs and the investment required per ton of annual output. This may favour installing a higher capacity facility than immediately required in areas where increments in demand may be expected to permit full utilisation within a reasonable time. Generally speaking, the provision of an in-built expansion potential will invariably be necessary in the developing countries because of the rapid increases expected in steel consumption. The decision on how much expansion to provide for in the design capacity of primary rolling mills, will of course, vary from plant to plant depending on demand prospects. Historical experience points to the fact that some surplus of steel capacity is needed for expanding steel-consuming industries. In the United States, steel demand grew more than eight fold during the two decades from 1896 to 1916 when steel plants were rarely operating at more than 70 per cent of capacity[(18)]. This freed the investment in steel-consuming industries from the risks of undependable and insufficient supplies from within the country.

Plant Layout

40. Regardless of the initial size or extent of integration at new steelworks, its layout can be planned for large future expansion, and for integration both backwards and forwards. This provision in design and space adds negligibly to the initial investment but will invariably pay handsome dividends in the future. More than anything else, such planning requires faith in the country's future growth, and conviction that the strengthening of the steel base is an essential part of the strategy of growth. The layouts evolved for the steel nuclei today must retain their flexibility and logic for generations to come. The Tata Steelworks is a good example of a plant installed in a developing country over 50 years ago with an initial capacity of about 100,000 tons, but which today has a capacity of 2 million tons and is now to expand again to 3 million tons. Figure 3 shows the initial facilities as they existed in 1912, and the subsequent expansions from 1920 to 1940, and from 1945 onwards.

41. This concept of making provision for future needs was given full consideration in planning the layout and selecting processes for the Chimbote plant in Peru as far back as 1952[19], with which the author was associated. Figure 4 shows the layout of the plant, which started production in 1958 with an output of only 57,000 tons using two 13,200 kVA electric (Tysland-Hole) smelting furnaces for ironmaking, two 4.5 m electric arc furnaces operating on a high hot metal charge (60 per cent) for steelmaking, a 2-stand breakdown mill, bar and sheet mills, etc. The original layout was designed with provision of space for adopting other processes and for substantial future expansion. The plant is now going up to 300,000 tons capacity, by installing a 5-metre hearth blast furnace, two 25-ton LD converters, a continuous casting machine for billets, and a steckel mill.

42. Latin America provides many other examples of plants which began with small capacities, but which are now on the way to medium and large scale operations. For instance, the Huachipato plant in Chile started in 1951 with 180,000 tons capacity and has trebled its output in 10 years. In Mexico, the Altos Hornos plant has expanded more than four-fold in 15 years to a capacity of over 600,000 tons.

43. Figure 5 shows the layout of the new alloy and special steels plant at Durgapur, 200 km north of Calcutta, which is the first metallurgical facility of this size to have been fully designed and engineered in India. This plant, for which major equipment is being supplied by a Japanese Consortium, will start with a capacity of 100,000 ingot tons of stainless, constructional and tool steels, but provision has been made in the layout for expansion to over 500,000 tons per year. Although a high lift blooming mill and hand sheet mills are being initially installed, continuous casting and strip rolling are visualised in the next stage of development. In addition, as is customary in such mills all over the world, considerable diversification of activities is envisaged including a heavy machine shop, alloy steel foundry, electrode shop, etc.

Designing for Developing Countries

44. The determination of steel plant size and the choice of technology for a developing country depends primarily on available raw material resources, market prospects, the capital outlay required and the profitability expected. It must also take into consideration other factors which hardly arise in an industrialised country. It should be the aim to make maximum use of indigenous equipment building capacity, which would itself be greatly benefited by such an impetus. The plant

and equipment should be adequately engineered for local conditions. Even climatic conditions have to be allowed for because of their important effect on the electrical system design.

45. The new steel enterprise will have to devote considerable attention and expense to infra-structure items such as transport, housing, water and power resources. Another major task will be manpower development to create suitable cadres of supervisory, operating and maintenance labour. As a late starter the new plant will have, however, the opportunity of utilising the most advanced technology and experience. Indeed, a developing country provides a unique opportunity to compare the performance of processes and practices of various countries. In India, for instance, Germany, Britain, USSR and Japan are simultaneously engaged on new steel projects, enabling her to absorb a variety of international experience in a short time.

CONCLUSIONS

46. Correct location of small units is of great importance in ensuring their viability. Location of steelmaking facilities has not been left solely to the decision of entrepreneurs even in highly developed economies. In 1936, the siting of new plants or major expansion in Britain became subject to the approval of the country's Iron and Steel Federation as a measure of voluntary self restraint, which gave way after the war to statutory control by Government[20]. The need for such control is now widely accepted, and Governments of most developing countries have reserved to themselves the power to direct steel and other key industries to particular locations. In fact, planned geographic distribution of industry is a natural corollary of national economic planning that most developing countries are adopting.

47. The factors which should govern the location decision can readily be identified. Raw material assembly costs and the cost of transportation to markets are the obvious ones for any industrial unit. In the case of small steel plants however, the viability will often depend on carving out a market which large plants, existing or proposed within the same country or common tariff zone, are ill-fitted to serve. This implies either specialisation in production or in a geographical segment of the market in the remoter reaches of the area served by large plants.

48. In the larger international sphere, the comparison of the costs of small scale domestic production vis-a-vis cheaper imports is not necessarily meaningful. The choice for a developing country must be conditioned by larger considerations such as

the availability of foreign exchange or the country's strategic needs. In any case, import prices do not always reflect true costs. In periods of shortage, import prices tend to shoot up as in the immediate post-war years, when the world as a whole was short of steel. In periods of ample supplies, when a large proportion of the capacity of well developed steel industries is underutilised, imports tend to be made at marginal prices or at times even below works costs. But developing countries are not usually in a position to profit from these low prices since their own export earnings are sharply reduced in periods when recession renders steel capacity idle in the industrially advanced nations. Cost comparisons are not necessarily valid, therefore, when one judges in terms of prices quoted for exports at any particular time.

49. While foreign exchange shortage provides an impetus to local manufacture, the fact remains that the initial investment on domestic steel capacity will have a large import content - ranging from 40 per cent in the case of a plant shortly to be built in India to 70 per cent or more elsewhere. Even regular operations may call for continued foreign exchange expenditure to service borrowed capital, and pay for imported supplies and personnel. For example, the proportion of foreign exchange in total production costs was estimated at 44 per cent to 57 per cent for seven locations studied by the Economic Commission for Latin America some years ago(21). Yet a saving of this order in the recurring foreign exchange costs may be significant enough to warrant making a beginning with steel production.

50. Very often small plants will enjoy a favoured place, either because of tariff protection given to a new industry or because planning has given a unit an assured share within the large national market. The discipline of competition will in such circumstances be missing and positive efforts will, therefore, have to be made to promote efficiency to allow subsequent exposure to free competition. Competition is not relevant to capitalist countries alone; there is increasing emphasis upon inter-plant competition also in planned economies.

51. The quest for efficiency requires the correct choice of technology related to the scale of production. It also depends upon adopting a product pattern which best enables the plant to make itself viable. In the longer term, efficiency will be governed by the ability of a plant to expand economically in step with demand - a consideration recalling the importance of rational layout referred to above. Labour is cheap in developing countries, but this must not be allowed to result in

overstaffing to compensate for lack of skill. The development of the requisite skills is a managerial responsibility which must not be shirked just because it may be immediately simpler to take on more workers. As standards of living rise, labour costs will go up in step which will heavily penalise an overstaffed plant. The point to note is that the burden of surplus labour tends to become permanent as bad working habits once acquired set a tradition extremely difficult to dislodge not only within the one plant, but in the steel industry as a whole because of the tendency to press for the acceptance of the same labour norms even in the case of newer plants.

52. In conclusion, it is necessary to define clearly the respective roles of small and large units lest vested interests of one should hold back the other. It is also necessary to have a clear idea of the optimum economic size so that a permanent burden of high costs is not foisted on the country. Even when initial demand falls below the level of an optimum-sized unit, planning at both the technical and economic levels should allow for expansion to meet the country's long-term objectives.

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F I G U R E S

Figure 1 - Relationship between Steel Consumption & Selected Macro-Economic Variables (All items per capita)(2)

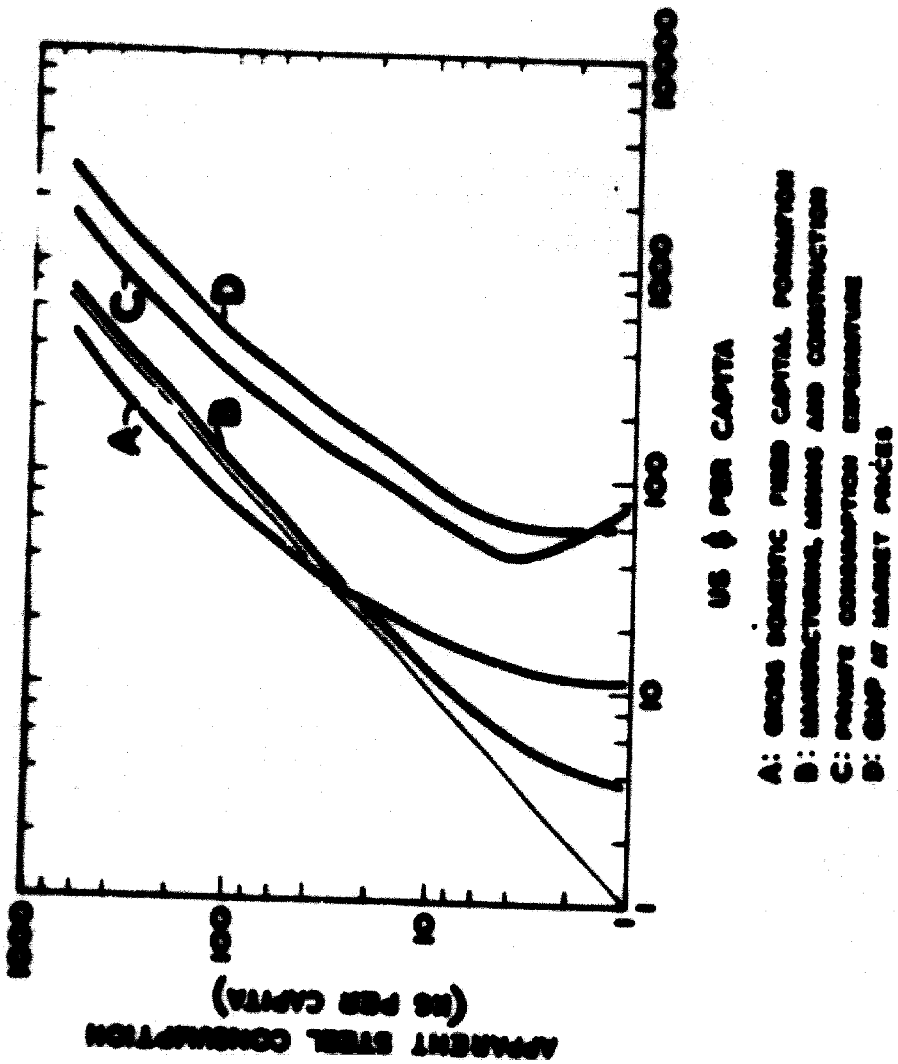

APPARENT STEEL CONSUMPTION
(KG PER CAPITA)
1
10
100
1000
US $ PER CAPITA
1
10
100
1000
10000
A
B
C
D
A: GROSS DOMESTIC FIXED CAPITAL FORMATION
B: MANUFACTURING, MINING AND CONSTRUCTION
C: PRIVATE CONSUMPTION EXPENDITURE
D: GNP AT MARKET PRICES

Figure 2 - Schematic Diagram of a Hypothetical Small
Integrated Steel Plant

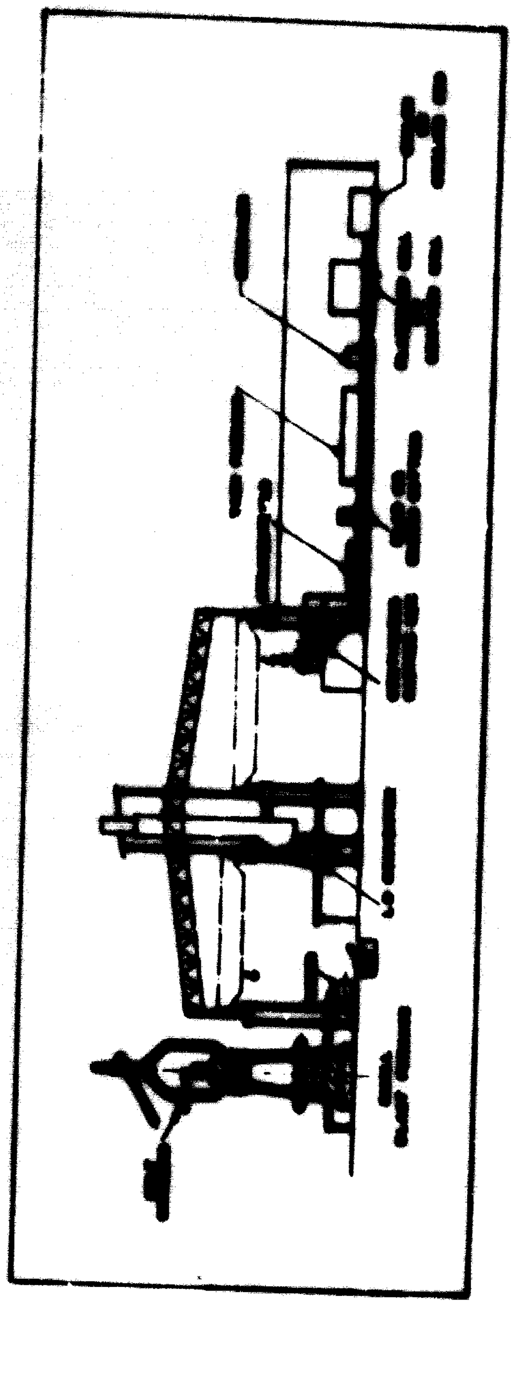


Figure 3 - Schematic Layout of Tata Iron & Steel Works, Jamshedpur, India.

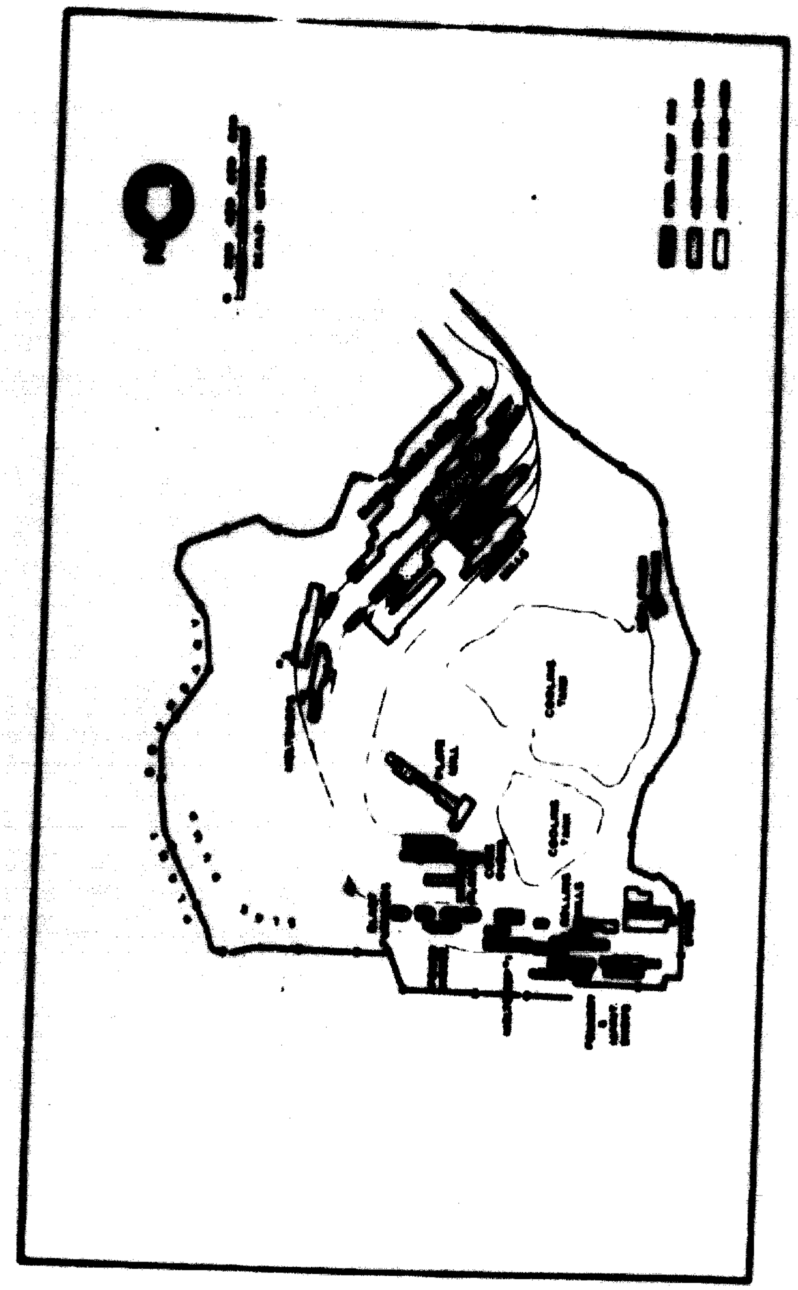


Figure 4 - Schematic Layout of Chimbote Steel Plant, Peru.

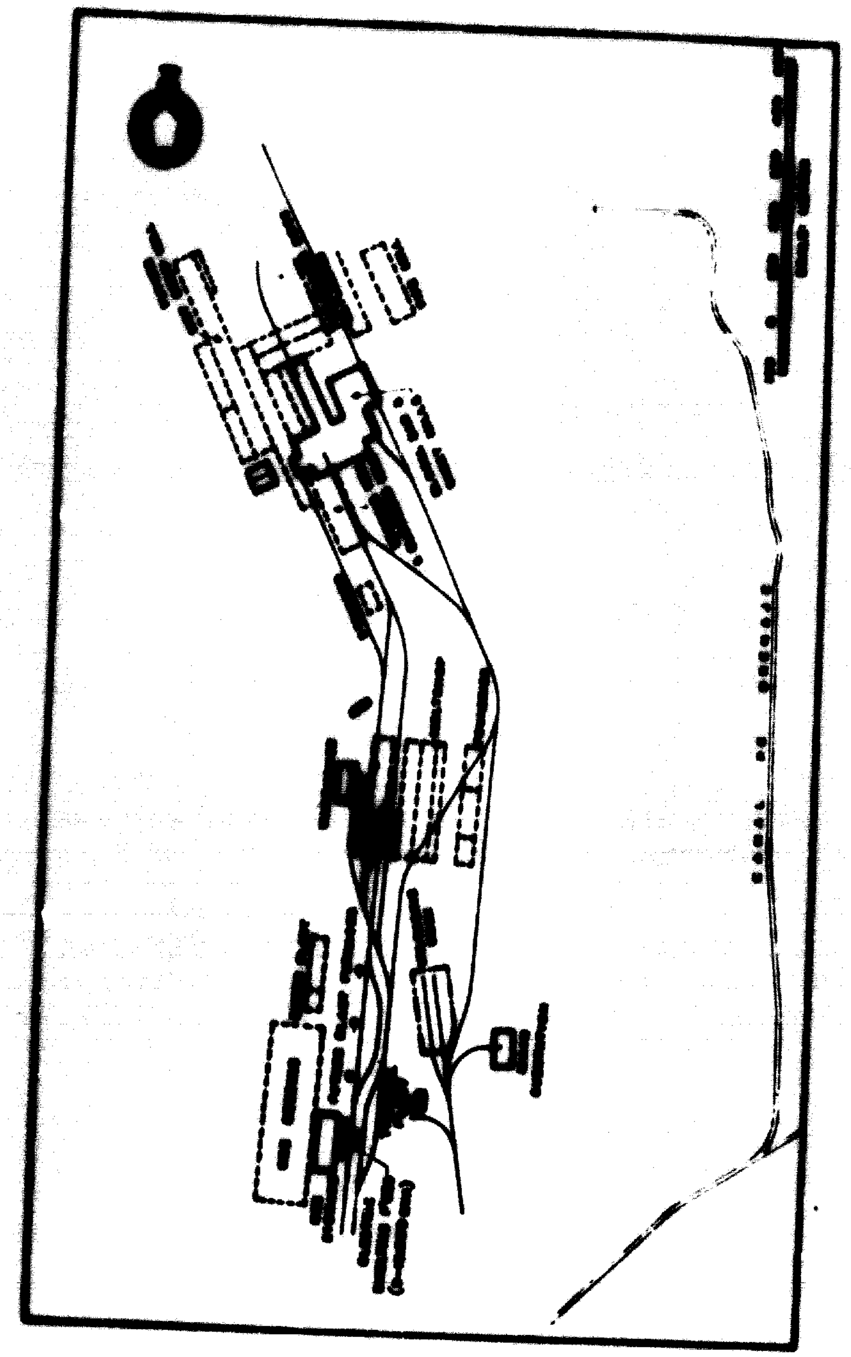
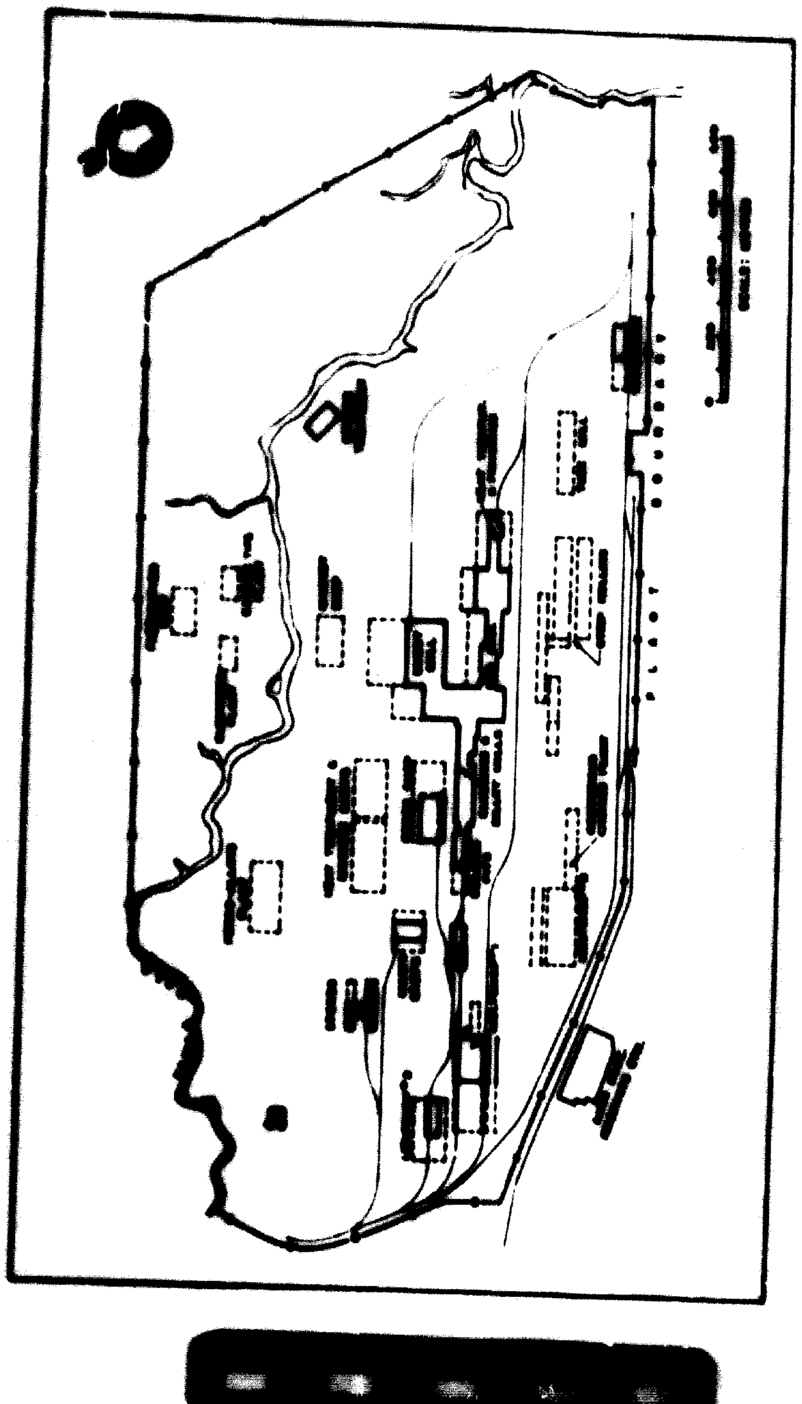


Figure 5 – Schematic Layout of Alloy Steels Plant,
Durgapur, India.



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