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on the Iron and Steel Industry

Moscow, USSR, 19 September – 9 October 1968

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PRE-INVESTMENT INFORMATION FOR DESIGNING IRON AND STEEL[1] PLANTS IN THE DEVELOPING COUNTRIES

by

J. Hlávaček
CSSR

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[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted, without re-editing.

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SUMMARY

The basic data on projects for iron and steel plants are obtained by feasibility studies.

Developing countries may be divided into two types:

1. Potentially weak countries, namely, those that either do not possess raw materials of economic value and power resources or will not have a considerable market for iron and steel products in view of the inadequate size of their populations. In this case, exportation does not arise.

2. The potentially strong countries, which have large populations and whose market for iron and steel products might be expected to expand in the future, even with low specific consumption.

* This is a summary of a paper issued under the same title as ID/WG.14/18.

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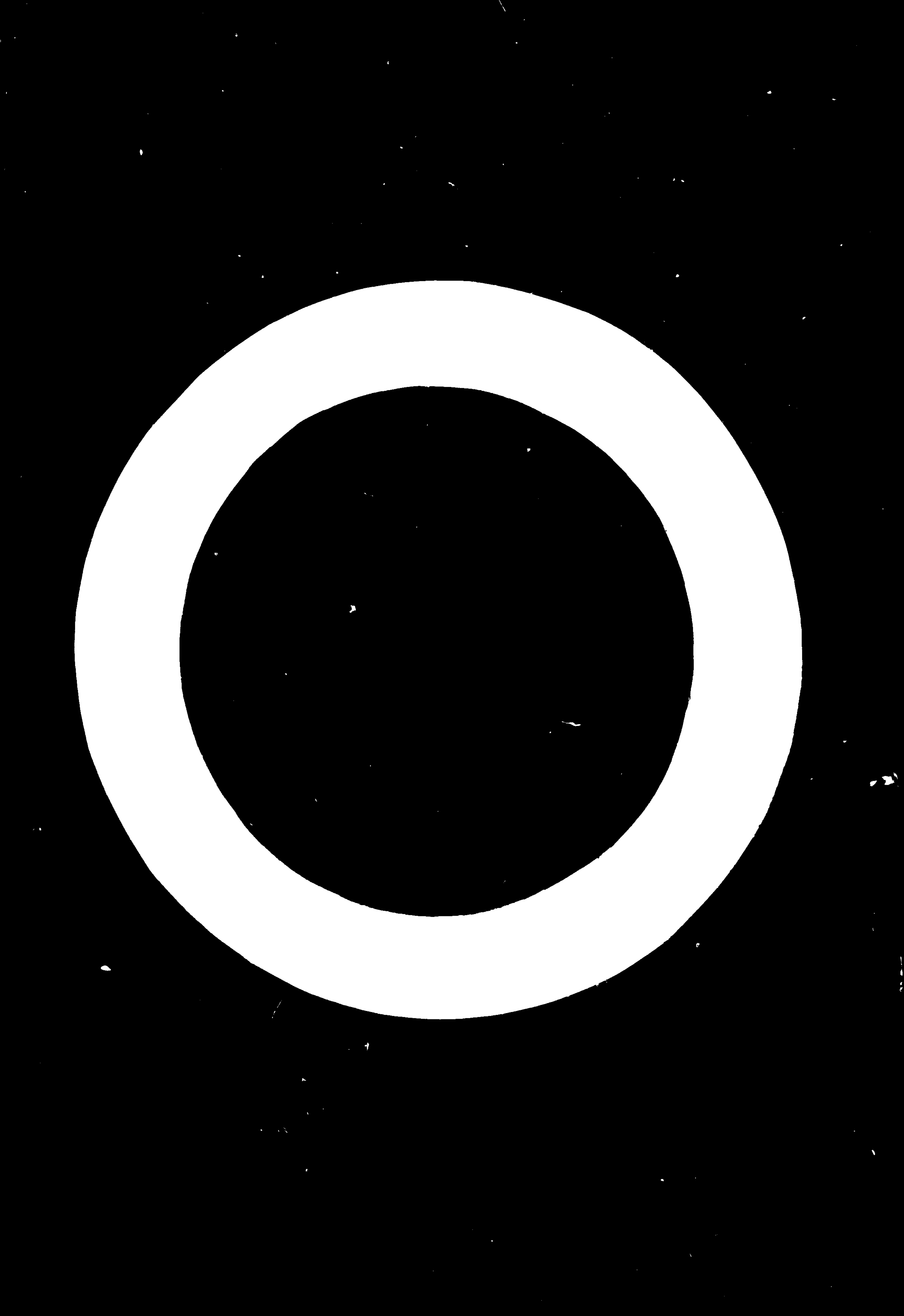

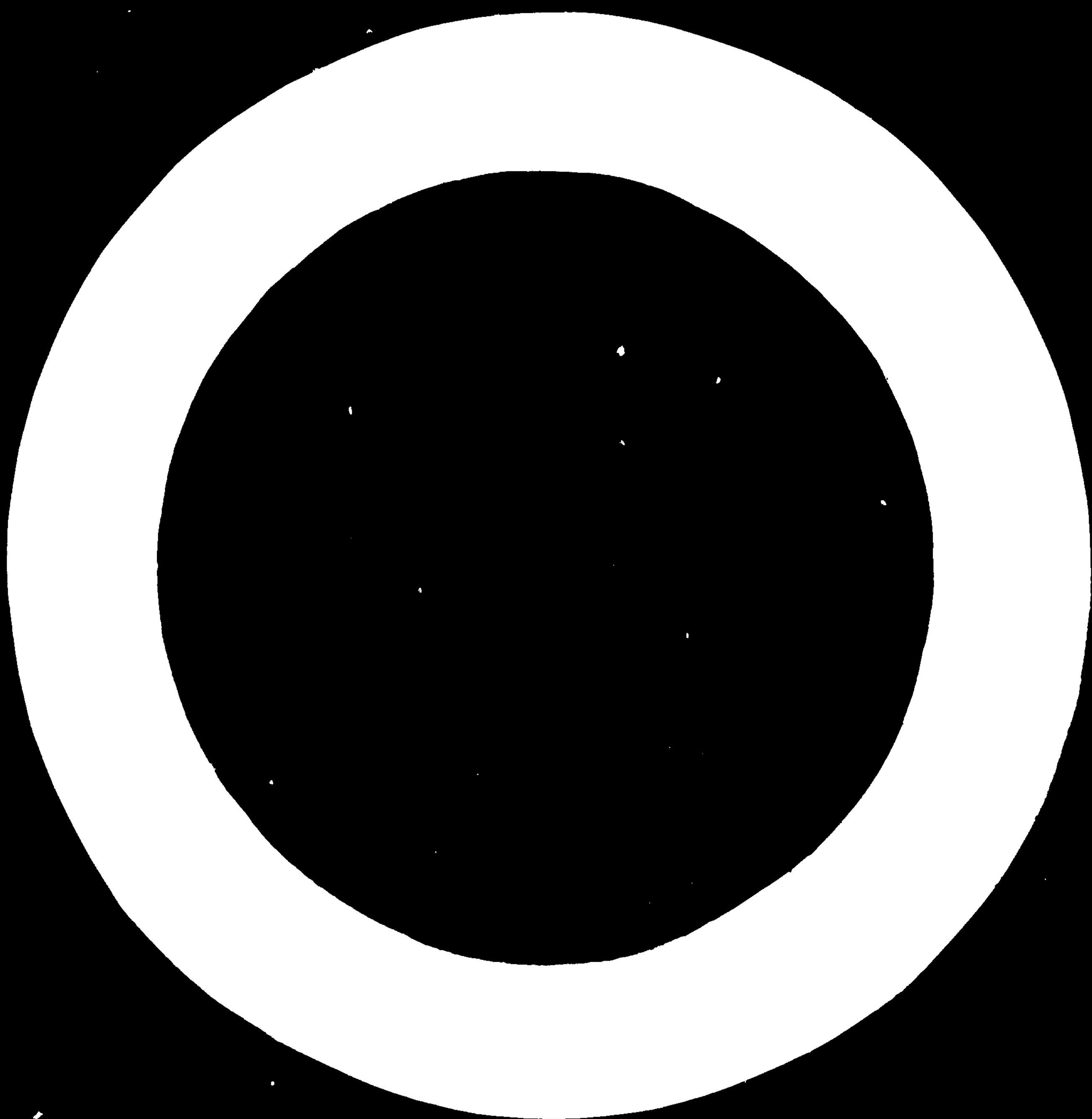

Before a decision can be made on the question whether to construct a non-integrated or an integrated iron and steel plant, the following research must be carried out:

Geological research (raw materials, fuel)
Research into power resources (including water resources)
Research into demand (also from the perspective point of view)
Demographic research
Research into finance

An overall economic plan should be drawn up on the basis of the results of research and their assessment:

Short-term for 5 - 10 years

Long-term for 10 - 20 years

The construction of both types of iron and steel plants should be considered in these plans.

Non-integrated plants - without coke ovens and blast furnaces - produce rolled products either from their own steel or from steel purchased from outside.

The integrated plants produce coke, pig-iron, steel and rolled products.

The difference in the production capacity of these two types of plants is considerable, the non-integrated plants having about 10 per cent of the capacity of the integrated plants.

Both types of countries may without notable risk begin to construct non-integrated plants. At first it would be possible to use imported billets and to roll them in a small rolling mill for semi-finished products provided such is available, or in a medium-sized mill and a small-sized mill of different capacities, producing articles such as reinforcing and other bars, small and medium sections, wire etc. Capacity might lie between 100,000 and 300,000 tonnes a year. For this purpose it would be possible to use partially modernized European or American rolling mills that had been withdrawn from service.

After the construction of a small steelworks, either of the MB open-hearth type or the electric furnace type with approximately 50 t furnaces, or small 10-20 t oxygen converters, with continuous casting, it is possible to manufacture rolled products from ingots produced in the works itself. The possible construction of a roughing-down mill and also of a two-high 850 mm or three-high 700 mm finishing mill is quite advantageous, as it may make possible both the expansion of the production programme and the simultaneous introduction of continuous casting. Such expansion would reduce the economies resulting from the high quantities of inputs. Where there is cheap and abundant labour, labour productivity is unimportant, which is why the proposed rolling mill solution would be advantageous.

Charging scrap, of which the developing countries have an inadequate supply, may be replaced by sponge-iron (85-90 per cent Fe) manufactured by reduction with decomposed natural gas or oil.

It is a relatively simple matter to increase capacity in such a steelworks, particularly in the version with two oxygen converters, either by increasing the volume of the converters or by the construction of a third. By an increase in capacity it is possible to raise production to 600,000 t of crude steel a year with relatively low capital investment expenditure. The latter might be $100-120 per tonne of crude steel.

The increased output of steel would even make possible the production of thin sheet, and perhaps even of plate by the construction of two-high or three-high mills for hot rolling; these could be obtained in the same way as the rolling mills for sections.

Integrated plants may be built later but only in the potentially strong countries. The potentially weak countries would have to associate for this purpose in order to create an adequate market. The decisive factor in construction is not resources of raw materials, except where their transportation would be economic (on the coast or the banks of navigable rivers). Before a decision is made to construct a non-integrated plant it is necessary to carry out a complete marketing study concerning the demand for the iron and steel products.

Geological research should be undertaken to ascertain the location of resources of raw materials, fuels and energy as well as to study transport from the economic point of view. It is necessary to ascertain the chemical and physical properties of the ore, the method of mining, beneficiation, preparation as well as reserves of ore. Losses in pelletization and agglomeration should not exceed 2 per cent. It is also necessary to discover the chemical composition and volatility of fuels, and, in the particular case of coal, the cokability, ash content and composition. The same must be done for oil and natural gas.

After a decision on the location of the plant an economic study should be prepared on the transportation of the raw materials as well as the final product. This study should confirm whether, in the light of resources of raw materials or fuel, it is most economic to construct the plant on the sea coast or on the bank of a navigable river and whether it is most advisable to prepare the raw materials (pellets or concentrates) at the deposit or to transport them to the plant, when this is located on the sea coast or on the bank of the river. These remarks apply to both types of plant.

It is necessary to determine the carrying capacity of the soil on the site, the hydrological situation and also to ascertain whether a complete town should be constructed for the staff. The structure, age and skills of the population should also be established.

It is advisable to study the advantages of foreign and domestic capital participation as well as participation by the State and the extent to which the State intends to grant the new plant economic advantages in the form of preferential prices and protective duties, particularly during the initial period. It should be ascertained whether advantageous long-term credit is available, and, if so, from whom.

The construction of an integrated plant always represents a considerable risk because large capital investment and considerable capacity are involved, with high labour productivity and minimum costs of production per tonne of rolled products. The greatest risk occurs when the marketing of the product is hampered by the impact of objective conditions.

To achieve maximum economy, large-scale production units should be chosen for integrated plants: batteries of high-capacity coke ovens with bulk loading ($30m^3$), blast furnaces ($2,000m^3$) with high concentration of Fe in the charge and minimum coke consumption, which can be reduced by injecting oil or natural gas through the tuyères to the level of 450 kg of coke per tonne of pig iron. When the coke is imported, it is better to locate the plant on the sea coast or on the bank of a river.

As the developing countries have not enough scrap and will not have enough for a long time yet, the process chosen for the production of steel should have a minimum consumption of scrap; therefore, steel should be made in oxygen converters. Coolant scrap may be replaced by sponge iron.

Another point in favour of oxygen converters is capital investment costs, which are lower than for MB open-hearth steel furnaces (about 70 per cent) and the treatment costs, which are lower than for any other steel-making process.

Rolling mills, with their present enormous capacities, in fact determine the total capacity of the plant. In view of the expected demand, a non-integrated plant should have the following structure in the first stage:

Output of 2.3 million tonnes of rolled products per year, in the following mills:

Blooming mill, diameter 1150mm - charge	2,800,000 t/year
Continuous billet rolling mill - billets	2,400,000 t/year
Cross country rolling mill diameter 65-150mm	700,000 t/year
Rolling mill for small and medium sections, diameter 18-65mm	700,000 t/year
Strip mill, diameter 400mm	400,000 t/year
Wire rod rolling mill, diameter 5-16mm	500,000 t/year
Two oxygen converters of 300 t	2,800,000 t/year
Two blast furnaces 2,000m^3	2,800,000 t/year
Production of sponge iron	400,000 t/year
Production of coke, 3 batteries	1,600,000 t/year

This integrated plant can produce sections, sheet, girders, wire rod, U irons, angle irons, reinforcing bars, rails for mines, rounds etc. To this there can be added, vertically, the production of bright drawn steel, wire, tubes and pipes of up to 200mm, screws and bolts, chains, nails, cables and wire netting as well as structural metalwork. The blast furnaces can manufacture hematite iron for foundries during part of the year.

This plant should also include power houses, railbound and other transport vehicles, a firebrick refractory plant and maintenance installations of all kinds, plants for oxygen and acetylene, compressor shops etc.

For the production of sheet, this factory could be expanded in all fields, the rolling mills section could be equipped with a semi-continuous wide strip rolling mill for the production of sheet and plate of thicknesses up to 12mm and a 3 - 3.5m four-high rolling mill for heavy plate. The construction of an integrated plant will involve an expenditure of $150-160 per tonne of crude steel.

Conclusion

For the developing countries it is recommended that non-integrated plants be constructed, located if possible near seaports or on navigable rivers.

Contents

1. Introduction

1.1. Steel is and will long remain one of the main needs of our civilization. Despite all the changes in technical and economic development brought about by the application of new technology, steel is in ever greater demand, particularly in countries with highly developed industries, even though it is sometimes replaced by other materials.

The increase in the demand for steel products is usually a direct function of the growth of industrial production. As a rule, however, the growth index of industrial production is greater than that of steel output. For example, in the Federal Republic of Germany, the growth index of industrial production in the period 1966-1967 was 7.4 per cent, while the growth index of steel output in the same period was 4 per cent; in the years 1950-1959, it was 5.9 per cent. In the United States, the growth index of industrial production is higher than that of steel output, owing to the different structure of industrial production. In the industrially developed countries, the electrical engineering and energy industries grow at rates of up to 12 per cent a year, whereas mining, construction and the transport industry do not show any large increase, or are even on the decline. As a result, the amount of demand for steel products and the range of products in demand will also differ, especially between the economically developed and the less developed countries.

It is a general rule that in normal peace time programmes the degree to which the economic needs of the countries are covered is related to the increase in steel consumption.

The growth index of steel output represents a higher proportion of the growth index of industrial production in the socialist countries than in the capitalist countries.

The growth indices of industrial production and steel output can be expected to be higher in the socialist countries because they engage more intensively in construction, particularly of heavy industry. The type of steel products in demand will also be different. The socialist countries can be expected to have greater needs of structural steel, permanent way materials, rails, tubes etc., as the proportion of infrastructural construction projects is greater than in the capitalist countries.

When the establishment of industry is under way and provided that the proper conditions are created, the growth index of demand for steel products in the economically less developed countries can be expected to be even higher than in the capitalist and socialist countries, in view of current specific steel consumption, which has so far also been an index of the level of living.

After a process of political consolidation, the developing countries will have to achieve rapid and efficient development of their economies, that is to say, mainly the branches of industry for which they have favourable economic conditions.

Iron and steel is one of these fundamental branches of industry, as other industries depend on it: agriculture, mining, construction, transport, energy, mechanical engineering etc., which are the backbone of the market.

2.1. Analysis of the possible establishment of the iron and steel industry in developing countries

On the whole, developing countries fall into two categories:

(a) Those that are potentially capable of constructing complete integrated iron and steel plants;

(b) Those that are not potentially capable of constructing integrated iron and steel plants themselves and that will have to join forces before they can carry out such a task, e.g. some countries in Africa, South America and Central America.

The potential capacity of a country follows from the value of its resources of raw materials and energy, on the one hand, and its general demand for metallurgical products, on the other hand.

In the potentially capable countries it is possible to begin immediately to construct integrated plants, after research into resources of raw materials, energy, demand and finance, and after preparing long-term plans.

In the potentially less capable countries it is possible to begin the construction of non-integrated plants after carrying out the same research as in the potentially strong countries, and as soon as short-term development plans have been formulated. These countries, which are potentially weaker either in reserves of raw materials or in demand, must pass through transitional stages in which they should consolidate and modernize existing branches of industry before they construct smaller plants: Small steel works, equipped with electric or März-Böhlenz furnaces with continuous casting, foundries, press shops, plants for rolling light and medium sections, welding shops, mechanical engineering plants and repair shops for agricultural, construction and transport equipment.

The construction of integrated plants in the potentially less capable countries will call for the association of several of these countries, which will require considerable political effort.

The potentially capable countries can also begin to construct non-integrated plants before integrated plants, under the same conditions as the potentially weak countries; after the construction of the integrated plants, the non-integrated plants will be reserved for special products (quality steels).

Both categories of countries will have to formulate short- and long-term economic development plans and to divide up their general development into stages, with clearly defined targets for each particular stage.

Short-term overall economic plans must be based on an assessment of the existing situation; in these plans an inventory should be made of the resources of raw materials, fuels and energy, demand and financial resources; demographic research should also be included and the plans should cover a period of five to ten years.

The long-term overall economic plans should take the short-term plans as their point of departure, or should overlap with them; they would be based on particular branches of the economy, have a far greater economic compass and cover a much longer period (ten to twenty years).

Research should be made into resources, demand, finance, manpower etc. to make it possible to formulate the overall economic plans and thus prepare for the establishment of the iron and steel industries in the two types of developing countries (those potentially capable and those potentially less capable).

The overall plans should be formulated on the basis of the data obtained in this way and should include the development of those branches of the economy for which there is a favourable economic climate in the individual countries.

First and foremost will come the modernization of existing industry, agriculture and transport.

It will be necessary to carry out geological research, and perhaps to supplement and assess research that has already been made, to ascertain the location and quality of reserves of ore, solid, liquid and gaseous fuels, energy resources and transport facilities and to study the economic efficiency of their use. The demand for metallurgical products in existing branches of the economy can be ascertained as early as at the stage of geological research.

On the basis of geological research, it will be possible to include the exploitation of resources in the overall economic plans - after the preparation of the respective technical and economic studies - as well as the improvement or establishment of agriculture, mining, energy, transport and public works so that the demand for metallurgical products under the short- and long-term overall economic plans can be calculated.

Until the local iron and steel industry is established, the metallurgical products required will have to be imported.

The choice of technology in the iron and steel industry will be influenced by considerations of the economic exploitation of raw materials, fuels and energy as well as of the marketing of products.

The potentially strong countries - even if the rate at which the level of living is raised remains slow and the *per capita* consumption of steel is also low - will have an adequate total demand for iron and steel products, so that, even if they do not have raw materials of their own, it will be economic for them to construct even large integrated plants. As all these countries lie on the sea, integrated plants can be constructed on the coast or the shores of navigable rivers.

The potentially weak countries, especially those that have not sufficient demand for metallurgical products, cannot economically construct integrated plants, when they have resources of raw materials in areas without economic transport facilities. The only exceptions are countries whose resources lie on the coast. Such countries are obliged to join forces so as to enlarge the base of their markets. When that is done, they will have the characteristics of potentially strong countries, and the same fundamental principles can be applied to them. However, there is nothing to prevent the potentially weak countries from constructing non-integrated plants if they obtain additional capital. Even if the potentially strong countries decide to construct integrated plants, they may also construct non-integrated plants.

The construction of non-integrated plants may be accelerated at low capital investment by constructing first only intermediate rolling mills and mills for small sections, with shops for rolling wire rod, and supplying them with imported billets. It would be possible to assign to such work some of the smaller European or American rolling plants, which, after slight adaptation, could economically execute the small orders received from the developing countries. As the economy of the country develops, it would be advantageous to treat local steel successively either in electric arc furnaces, März-Böhlenz oil-fired furnaces or tandem furnaces followed by continuous casting or in small oxygen converters.

The choice would depend on considerations of economic utility.

Should the country in question be potentially capable of constructing an integrated plant later, the non-integrated plants might manufacture rolled products in small production runs as well as special sections - even for export - and quality steels.

One of the most important factors in relation to the construction of non-integrated and integrated plants is to determine the pattern and volume of sales.

Statistics on the importation of rolled products and perhaps foundry pig-iron would be useful as preliminary information. Such information may be supplied by importers.

Future marketing possibilities will be determined:

(a) By the structure of the national economy, which will be covered by overall economic plans;

(b) By the development of the purchasing power of the population and the pattern of demand.

Historical data on the evolution of the developed countries in the early industrialization period may be of value in estimating sales of goods.

Most of the developing countries have a low consumption of metallurgical products, which in the first phase of development, will be used in agriculture, construction, transport and energy, including the development of water resources. These branches will largely determine the pattern of demand for rolled products. The centre of gravity will usually be at the coast and on the shores of waterways, that is to say, in the most densely populated regions, through which the bulk of trade also passes.

The construction of plants and the pattern of their output would in turn influence consumption, because new branches of the processing industry would be created. Approximate per capita consumption of 15-30 kg of steel might be achieved by the construction of non-integrated plants and a figure of 150 kg, in the first stage of development, through the construction of integrated plants.

As plants producing a fixed product-mix cannot be constructed immediately, it will be necessary to consider what products it would be better to import than to manufacture.

In the developing countries there will first of all be demand for reinforcing bars, sections, steel bars, rails and small sized rails, wire rod, screws, nails, tubes etc.

Rails and wire rod will have to be imported because there will not be a large demand for them and the construction of a rolling mill would not be economic. Even sheet metal would be imported because economic plants are of large capacity.

Physioal resources for industry

Resources of raw materials (i.e. ores, fuels, energy, including water) must be economically accessible and of good quality.

Ores should not have any harmful components and should be economically workable; their physical, chemical and geological make-up must be fully known. It is essential to ascertain the content of undesirable substances such as P, S, As, Cr, Ni, as well as SiO_2, Al_2O_3, CaO and MgO and the form in which they occur in the ore (oxides, silicates, hydroxides etc.). It is necessary to know the most economic method of use (as pellets, agglomerates, concentrates or in lumps) and to decide whether to introduce underground or open-cast mining. The thickness and reserves of the deposits must be known. Pelletization and agglomeration losses higher than 2 per cent should not be expected.

Fuel resources are no less important, especially in the case of integrated plants, because high quality blast-furnace coke is needed for the conventional manufacture of pig-iron and is a substantial item in the cost. It is economically advantageous if a deposit of coking coal occurs in the vicinity of the integrated plant, but this is a rarity, and most advantageous of all if the resources are on the coast or on the bank of a waterway. Assuming that these resources occur deep in the interior of the country, that an economically efficient communication route does not exist and would have to be constructed specially to transport raw materials or fuel, serving no other purpose, then the importance of the non-integrated plant must be demonstrated by economic analysis, to show whether the construction of the communication route would make it economic to open up the resources. The construction of non-integrated plants on the coast or the banks of navigable rivers is economically the best solution because in this case ores, coke and fuel can also be supplied from other deposits that are more favourably placed, from the economic point of view.

When a non-integrated plant is constructed and the consumption of ore and fuel is low, the expensive construction of a special communications route for the plant is out of the question.

Natural gas and oil are less expensive to transport and can be carried either by pipe-line or in tanks.

Development plan

The land for the plant site must be cheap, the carrying capacity of the soil must be good, a minimum volume of earth-moving work must be necessary and there must be an adequate supply of industrial and drinking water. When a plant is constructed in an uninhabited area, facilities must be provided for the construction of a complete urban complex, i.e. a workers' town with all social amenities and services.

The state should subsidize the necessary public works (roads, airports, railways, communication routes and transportation) and also provide for capital investment in energy, because, in an integrated plant, the power station consumes hot water, steam, gas and in some cases even electric energy.

Under normal conditions, approximately two-thirds of the electric energy should be supplied by the public network. When the plant itself finances the construction of a workers' town, such expenditure must be included in the capital investment costs.

Demographic surveys must be carried out in the various regions, taking into account the manpower requirements of the projected plants and the skills of the population. It is necessary to ascertain the number of inhabitants (men, women, skilled or non-skilled, artisans, age structure, literacy etc.).

Another very important factor is estimation of the prospective purchasing power and the pattern of demand of the population, which will influence outlets.

The necessary foundation must be laid for the establishment of lower- and middle-level vocational training for both groups of countries. The question of higher vocational training does not arise until the later stages of economic development. During the first stage of development, specialized higher study must be carried on abroad. Participation by foreign specialists in all categories will be necessary in the stage of construction proper and for the commencement of operations in the plants.

Some of the workers in all categories will have to be trained in foreign plants at the respective technical job station.

During the construction of non-integrated plants in the first period, a certain number of skilled staff will be trained, a large proportion of whom can be employed in the integrated plant.

The financial resources, which are considerable, particularly in the case of integrated plants, must be obtained either from institutions or from private persons.

The necessary investment capital may be obtained either by establishing joint stock companies or by contracting loans from private persons, with or without state participation, or by borrowing from institutions. The state must have an interest in the establishment of the iron and steel industry and encourage it because it creates employment and saves foreign exchange.

The experience of the United States shows that, for every worker directly employed in the iron and steel industry there are eight workers employed in related industries (metal mining, coal mining, energy and transport) and in services, apart from the large consumer industries. The state should help its developing iron and steel industry by establishing reasonable stabilized tariffs and possibly taking out shares itself. It should also pursue a wise Customs policy until the newly constructed iron and steel plant can produce at world prices.

The most expedient way of financing the construction of plants is to contract long-term, low-interest loans; the loan may be granted by the suppliers or by various foreign institutions. A stable political climate in the beneficiary country is a condition for participation by foreign investors.

The most efficient equipment must be installed in the plants so that manufacturing costs are as low as possible and a profit is made.

Policy for the construction of plants

The decision to construct iron and steel plants may be based on information obtained by market research, geological research and demographic research, after the formulation of an overall economic development plan for the country.

Non-integrated plants may be constructed first because they involve less risk, are cheaper to finance, have smaller staffs and can be constructed more quickly. It should also be remembered that it is a primary requirement to conclude political agreements in order to create groupings of countries. Furthermore, the choice of the site does not depend on the location of raw materials and fuel resources, as it does in the case of integrated plants.

The construction of non-integrated plants

If non-integrated plants manufacture rolled products from their own steel and not from imported billets, they need for scrap iron the blast furnace charge and perhaps some solid pig-iron; when steel is made in oxygen converters, molten pig-iron is needed.

As a consequence of their low specific consumption of steel, the developing countries lack scrap iron (their *per capita* consumption of steel is not more than 10 kg). Scrap iron can, it is true, be imported from the economically advanced countries, but at present only the United States has a surplus of scrap iron, because even countries such as those of the European Coal and Steel Community and Japan are importing scrap. Accordingly, it would be inadvisable to base the steel industry of developing countries on the importation of scrap.

The developing countries cannot even manufacture pig-iron economically in blast furnaces by a conventional method because large-scale capital investment is required, with expensive coke ovens and preparation of the ore charge, transport and energy. It is not even always possible to contemplate the construction of a charcoal blast furnace as it should be borne in mind that this technique requires very pure ores with low sulphur, as sulphur cannot be eliminated in a charcoal furnace by the "low-temperature process". Only one method remains, viz. the direct reduction of sponge iron with 85-90 per cent Fe by means of oil or gas in reactors, shaft furnaces or rotary furnaces. Obviously the gas and the oil must be combusted with the aid of steam or oxygen.

Direct reduction may be carried out with rich or poor ores that have been previously beneficiated. The product obtained may be treated either in hot-blast cupola furnaces (acid or basic according to the chemical composition of the ore) with the addition of 12 or 22 per cent of metallurgical coke to the liquid metal for processing in oxygen converters, or in steel-making furnaces as pellets and briquettes, according to a whole series of patented processes. These furnaces may use oil, natural gas or electricity, assuming that these types of energy are available. The direct reduction installations constructed so far can produce 50,000-200,000 tonnes a year; the following production plants could probably handle such amounts:

2 oxygen converters, capacity 10-25 tonnes each, or

1-3 MB open-hearth furnaces, capacity 50 tonnes each, or

1-3 electric arc furnaces, capacity 50 tonnes each.

The arc furnaces require the lowest capital investment, followed by the oxygen converters and the open-hearth furnaces. However, the construction of oxygen converters requires hot-blast cupola furnaces, which will increase the capital investment. The construction of hot blast cupola furnaces necessitates high-quality metallurgical coke, which it will be somewhat difficult to obtain;

MB open-hearth furnaces involve the greatest capital investment, while oxygen converters have the lowest production costs. Another point in favour of oxygen converters is the ease with which capacity can be increased by increasing their volume; this fact will have to be taken into account when constructing tracks for cranes. The capacity of the oxygen converters can be raised by 100 per cent by the addition of a third converter if needed. If the oxygen steel works with two 20-tonne converters and a capacity of approximately 200,000 tonnes a year as proposed above, is converted to one of 3 x 40 tonnes, with a capacity of approximately 600,000 tonnes of pig-iron a year, the considerable increase in capacity can be achieved at the cost of a relatively low capital investment and in a short time.

The advantage of electric furnaces lies in the fact that, in countries where integrated plants can be constructed later, steel works with electric furnaces could be used for the production of quality steels.

The capital investment for such steel works may be estimated as follows (for a capacity of 100,000 tonnes of crude steel a year):

MB open-hearth furnaces	US$ 50/tonne of crude steel, i.e. US$ 5 million
Oxygen converters	US$ 42/tonne of crude steel, i.e. US$ 4.2 million
Electric furnaces	US$ 36/tonne of crude steel, i.e. US$ 3.6 million

For a capacity of 500,000 tonnes of crude steel a year:

MB open-hearth furnaces	US$ 40/tonne of crude steel, i.e. US$ 20 million
Oxygen converters	US$ 34/tonne of crude steel, i.e. US$ 17 million
Electric furnaces	US$ 25/tonne of crude steel, i.e. US$ 12.5 million

As far as the rolling mills are concerned, it would be best, as has been mentioned above, to use converted "open" or combined rolling trains of low capacity, medium-sized bar mills and small-sized section mills for the production of bars, sections and wire. Square 100-140 mm billets might be imported until the steel works is constructed. After the construction of the steel works billets might be obtained either by continuous casting or by the construction of a three-high roughing down mill (diameter 700 mm) or, better, a reversing two-high mill (diameter 850 mm) so that the production programme could simultaneously be extended by including the manufacture of rounds of up to 150 mm in diameter, sections and hot rolled strip of up to 200 mm in width. This plant could roll 3-4 tonne ingots.

The manufacture of these products might be followed by the production of wire, cold rolled strip, welded tubes, nails, wire netting, cables and screws. Welded pipes of up to 100 mm in diameter could be produced, especially for irrigation and construction work.

Czechoslovakia has some plants of this type that can profitably manufacture special sections and products to order in small production runs.

Sheet could be manufactured in the second stage, with a simultaneous increase in the capacity of the steel works by the addition of three-high rolling mills, or two-high hot rolling mills. The raw material for the manufacture of sheet and sections might be obtained from either European or American rolling mills. Mine rails might be produced in the two- or three-high roughing mills mentioned, normal rails and wire rod would have to be imported.

The non-integrated plant mentioned could most economically be constructed on the coast or on the bank of a navigable river; all forms of energy not available locally would have to be brought in from outside. If a steel works with oxygen converters is constructed, reduction to sponge iron will have to be carried out at the plant in which the steel is manufactured and the ore will have to be imported. In order to decide on the best site for a non-integrated plant, an economic study with several variants will have to be prepared.

According to one estimate, the construction of non-integrated plants would call for capital investment of US$ 100-120 per tonne of crude steel. The preparation of the project and construction would take approximately four years.

<u>The construction of integrated plants</u>

The construction of integrated plants can be contemplated only in potentially strong countries, in view of demand and the need to obtain loans. In the first stage, <u>per capita</u> steel consumption higher than 150 kg cannot be expected.

The integrated plant will then manufacture, or have a capacity of, approximately 3 million tonnes of crude steel a year.

The integrated plant must produce at world prices and for that reason must be equipped with powerful and efficient modern plant that will manufacture with maximum economy. It is assumed that the plant will produce metallurgical coke, pig-iron, steel and rolled products by conventional methods.

The comments on the marketing of goods, metallurgical products, raw materials, energy, manpower and finance made with regard to non-integrated plants are particularly applicable to integrated plants.

To make possible production at the lowest cost, it is necessary to construct pushed coke ovens (30 m^3) as well as high-capacity blast furnaces (2,000 m^3) using charges with the highest concentration of Fe in the form of pellets, agglomerate etc. It will be necessary to obtain a coefficient of utilization lower than 0.5, which means that the above-mentioned blast furnace will produce up to 4,000 tonnes a day, or approximately 1.4-1.5 million tonnes of pig-iron a year.

Since the developing countries will not have a sufficient quantity of scrap for a long time yet, it will be necessary to adopt a steel-making process that uses the highest possible proportion of pig-iron. For this reason, pig-iron must be as cheap as possible. The main item in the cost of production is metallurgical coke, so that its consumption in the blast furnace must be reduced to the minimum. This object is achieved by means of a maximum concentration of Fe in the charge, a high blast temperature, the injection of natural gas and oil through the tuyères, the use of low-ash coke, etc. Under these conditions, the blast furnace will work more or less like a huge cupola furnace and the consumption of coke can be brought below 450 kg per tonne of pig-iron.

As mentioned above, the lack of scrap in the developing countries will also dictate which steel-making processes must be adopted.

The integrated plant mentioned, with a capacity of approximately 3 million tonnes of finished steel, equipped with oxygen converters, will require the construction of two 2,000 m^3 blast furnaces with an output of 3 million tonnes a year.

The capital investment on the two blast furnaces will be US$ 17/tonne of pig-iron, and expenses for operation and treatment will amount to US$ 5.5/tonne of pig-iron.

Neither open-hearth furnaces, tandem furnaces nor oxygen converters can be used for the manufacture of steel in a non-integrated plant, because all these techniques require a high proportion of scrap.

The LD process is the most suitable. Furthermore, it involves the lowest treatment costs and gives a good quality of steel. For the contemplated production of approximately 3 million tonnes of crude steel a year, it is possible to use two 300-tonne oxygen converters with a capacity of 2.8-3 million tonnes a year. Scrap would be used only as a coolant and could be replaced by sponge iron manufactured in the same way as for non-integrated plants. The total consumption of scrap or sponge iron would be about 400,000 tonnes. The capital investment would amount to approximately US$ 20 per tonne of steel.

The current output of rolling mills determines the general design of an integrated plant. The capacity of rolling mills has increased so fast during the last ten years that smaller units cannot be constructed if they are to be competitive. Hot rolling mills for broad strip have an output of up to 3 million tonnes per year.

During the first stage of the establishment of the integrated plant, the following rolling mills may be proposed, in the light of market demand:

Medium-sized slab mills and small section mills, 18-65 mm diameter with a capacity of	700,000 tonnes per year,
Cross country rolling mill of 65-150 mm diameter	700,000 tonnes per year,
Strip rolling mill up to 400 mm	400,000 tonnes per year,
Rolling mill for wire rod of 5-16 mm diameter	500,000 tonnes per year.
Total rolled products	2.3 million tonnes per year.

This will require 2.8 million tonnes of crude steel on the basis of a gross weight of 1,220 kg/tonne of rolled products. It is necessary to construct a blooming mill of 1,150 mm diameter and a continuous billet rolling mill with a capacity of 2.4 million tonnes of billets a year for the manufacture of these products. This plant would manufacture semi-finished products for forges and press shops, angle iron, U iron, girders, hot rolled strip, reinforcing and other bars, wire etc.

The manufacture of rolled products may be taken as the point of departure for the production of longitudinally and spirally welded pipes of up to 200 mm diameter, bright drawn steel, wire, nuts and bolts, chains, cables, nails, wire netting, prefabricated structural steelwork etc.

The factories could be expanded in the second stage by introducing the manufacture of thick and thin sheet by constructing a four high reversing semi-continuous mill for wide strip, with rollers 3-3.5 metres long.

At least two-thirds of the electric energy requirements should be supplied by the large public power stations; only a thermal power station of economic electrical capacity should be constructed at the iron and steel plant. As is known, such a plant requires an installed capacity of approximately 200 MW. The boiler room fuel might be oil, natural gas, or solid fuels, whichever is available, this being determined by economic study and geological research. At least in the first phase, it is possible to construct an electricity power station at the plant, and even a public power station if the installed capacity is not sufficient.

The integrated plant must provide for and organize materials handling maintenance of the building, the mechanical and electrical installations, maintenance by teams of bricklayers, and maintenance of the thermal plant, the measuring equipment and the automation equipment; it must construct oxygen and acetylene works, a building for compressors, a fire-brick refractory plant etc.

In the case of an integrated plant, expenditure of US$ 150-160/tonne of crude steel may be expected, which corresponds to about US$ 450 million.

The period for the preparation of projects and construction may be estimated at 7-8 years.

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