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Agenda item 3

MINI-STEEL MILLS AND THEIR IMPORTANCE FOR STEEL PRODUCTION IN DEVELOPING COUNTRIES[1/]

by

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S U M M A R Y

The paper presents estimations of future steelmaking in the world by regions and based on this the role of mini-steel mills for the developing countries is described.

A comparison of the advantages and disadvantages of the mini-steel mills with those of the conventional steel plants is presented.

The paper provides information on the opportunity of the developing countries for establishing mini-steel mills in the frame of the market development, raw-material potentials, and energy conditions.

The author concludes that, due to lower investment expenditures per annual ton of steel as well as due to lower manufacturing costs and energy and raw materials situation, mini-steel mills will have an important role to play in the developing countries.

(1) PROSPECTIVE EVOLUTION OF STEELMAKING THROUGHOUT THE WORLD AND ITS DISTRIBUTION BY THE VARIOUS CONTINENTS AND PROCESSES

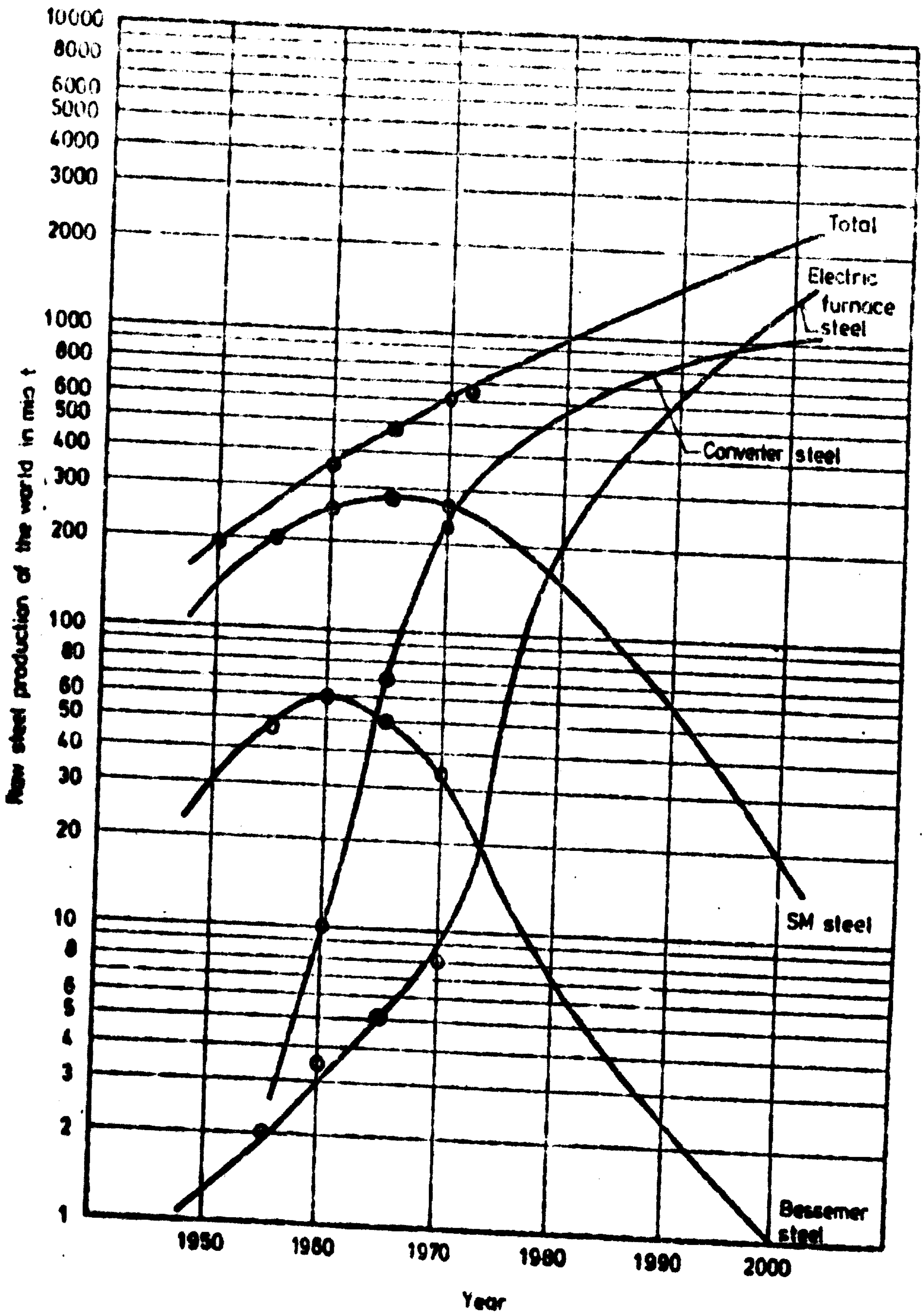
Trying to evaluate the importance of mini-steel mills for steelmaking in the Third World requires some deliberations on the evolution of future steelmaking in general. An important part is played by the fact that up to date mini steel mills have found their broadest application in industrialized countries such as the United States, Japan, Germany, and Italy, whereas their existence is given in a few developing countries only so far. Forecasts of a series of worldwide renowned experts in this area make available to us data anticipating a volume of production in the range of approximately 800 million to 1 billion tons by 1980. For 1985, J.R. Miller [1] indicates a probable production figure of 1,025 million tons.

Taking into consideration that for the erection of completely new steelmaking plants between the moment of making the decision and the steel mill startup, normally a period of time in the range of two to five years will be necessary, and considering further that at present we are approaching already the mid-Seventies, it is astonishing that most of these forecasts just cover this short interval.

In reference to some factors which are essential for the determination of the growth possibilities in the area of steelmaking throughout the world, such as the growth of the world population, the growth of the per capita consumption of steel, and the intensely increasing industrialization of developing countries, it has been tried to forecast the evolution of world steel production by the year 2000.

Figure 1

This has led to figures of world steel production by 1980 in the amount of 914 million tons, by 1990 in the amount of 1.4 billion tons, and by the year 2000 in the still unconceivably high amount of 2.2 billion tons.



KRUPP ZENTRALE TECHNIK

Raw steel production of the world

Figure 1

If one regards the potential growth rates of population by the year 2000 against the background of these very optimistic sounding figures, the above data appear to be essentially more realistic.

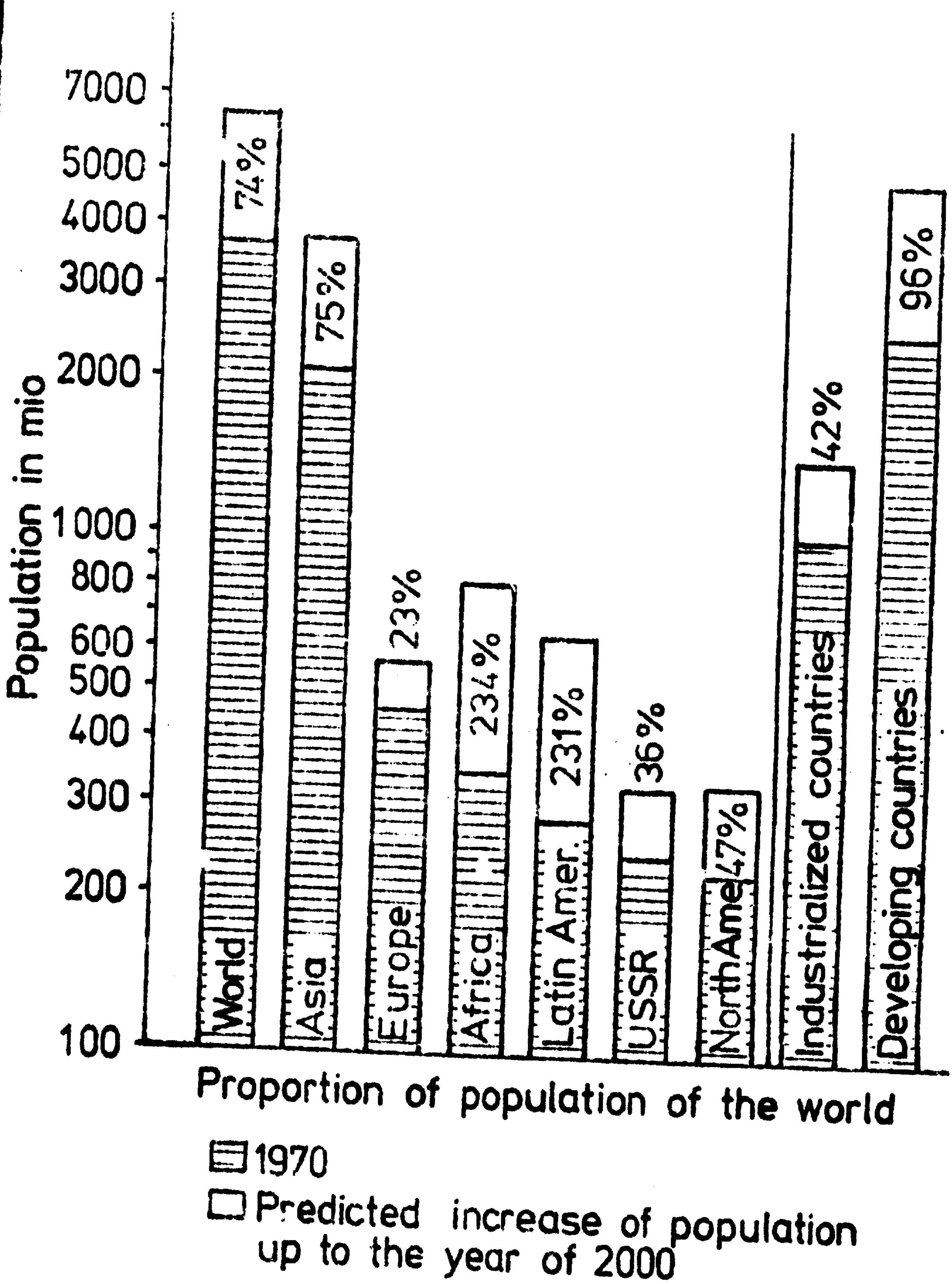
Figure 2

The ordinate of this figure shows logarithmically the number of population in millions, the hatched beams giving the number of population in 1970, and the zones above them, which are not hatched, the potential population growth by the year 2000. The population of developing countries will have nearly doubled at the beginning of the next millennium, the Latin American and African countries being likely to have the largest growth with 200 pct. The population growth of the traditional industrial countries, however, will be relatively small with about 40 pct, Northern America reaching a proportionally high growth, viz. 47 pct, over the USSR with 36 pct and Europe with 23 pct.

Following these statistical figures, the population growth of the world will be 7.4 billion by the year 2000. The fact that within the scope of these figures the growth of Asia has also been assessed with 75 pct only makes clear that the above value appears to be rather low-rated.

Figure 3

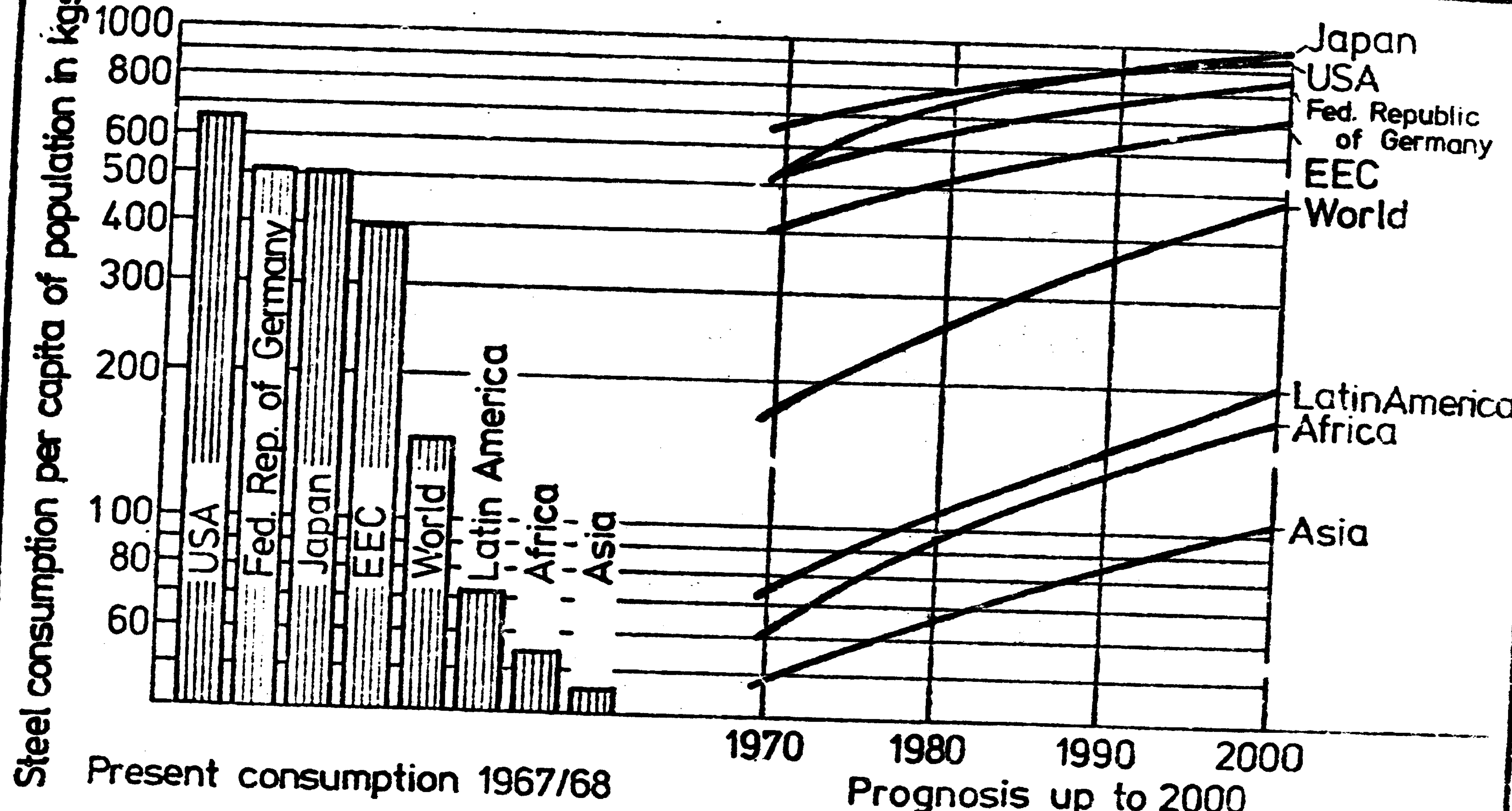
The next Figure represents the per capita steel consumption in various countries and continents. The hatched beams on the left-hand side of the graph show that the steel consumption of industrial zones such as the United States, the European Community, the Federal Republic of Germany, as well as Japan, have been in the range of an average 500 kgs per capita during the years 1967/1968, whereas the consumption of developing countries was far below 100 kgs of steel per capita. This leads to an average world steel consumption of approximately 150 kgs per capita of the world population.



ZENTRALE TECHNIK

Increase of population up to the year 2000

Figure 2



ZENTRALE TECHNIK

Development of steel consumption per capita of the population

Figure 3

On the right-hand side of the graph,, the potential growth rates of the per capita consumptions by the year 2000 have been represented in the form of curves. According to them, the per capita consumption of steel in the industrialized zones will increase from approximately 500 kgs to approximately 800 kgs per capita, whereas forecasts say that an increase of steel consumption in the developing countries will take place from approximately 50 kgs to 80 kgs to an average of 150 kgs per capita.

From these figures regarding the per capita consumption throughout the world which is below 200 kgs, an increase to more than 400 kgs, perhaps even up to 500 kgs per capita of the world population, may be derived.

So doubling the per capita consumption and the potential doubling of the population might lead, within the next decades, to a possible quadruplication of steel consumption and steel production.

Forecasting the evolution of the individual steelmaking processes existing in the world appears to be essentially more difficult. J. R. Miller anticipates by 1985 the following proportions:

Oxygen steel production	65	pct
Electric steel production	28	pct
Open-hearth steel production	6.5	pct
Bessemer steel production	0.5	pct

Taking into consideration already well known trends of certain phenomena such as the decline of open-hearth steelmaking and the Bessemer process as well as the probable meeting of world energy requirements in the long run, particularly by means of nuclear energy, the following evolution may here be forecast:

Electric steelmaking	1980 appr.	180 million tons, appr..	20 pct
	1990 appr.	600 million tons, appr.	42 pct
	2000 appr.	1.4 billion tons, appr.	58 pct.

Basic oxygen steelmaking	1980 appr. 560 million tons,	appr. 62 pct
	1990 appr. 800 million tons,	appr. 56 pct
	2000 appr. 1.0 billion tons,	appr. 42 pct

When considering these figures, which at present appear to be still unconceivably high, it must be realized that in the long run an over-proportionate increase of costs is to be expected in the area of manpower and coking coal, and that the growth rates for the haulage of liquid hydrocarbons will show a declining tendency. The use of low-quality fossil fuels will have to meet still tighter criteria in view of heavier restrictions in the area of environmental pollution, whereas the growth of nuclear energy towards being the predominant energy source should be anticipated. Developments through the use of nuclear energy to the direct production of steel from ore, presently pursued among others by study commissions in Japan and the Federal Republic of Germany, will reach their large-scale practical application within some 10 to 15 years, and, in view of generally increasing energy costs, this will lead to the situation that the gasification of the above-mentioned low-quality fossil fuels for the generation of reducing gases will result in commercially competitive cost prices of such synthetic gases. This will bring about another significant growth of direct reduction, the decisive breakthrough of which may be expected within the next 2 to 3 years. While I do not intend to make here forecasts as to the anticipated production of sponge iron until the year 2000, it appears to be thinkable that, by the beginning of the third millennium, production figures of some hundred million tons of sponge iron may be achievable.

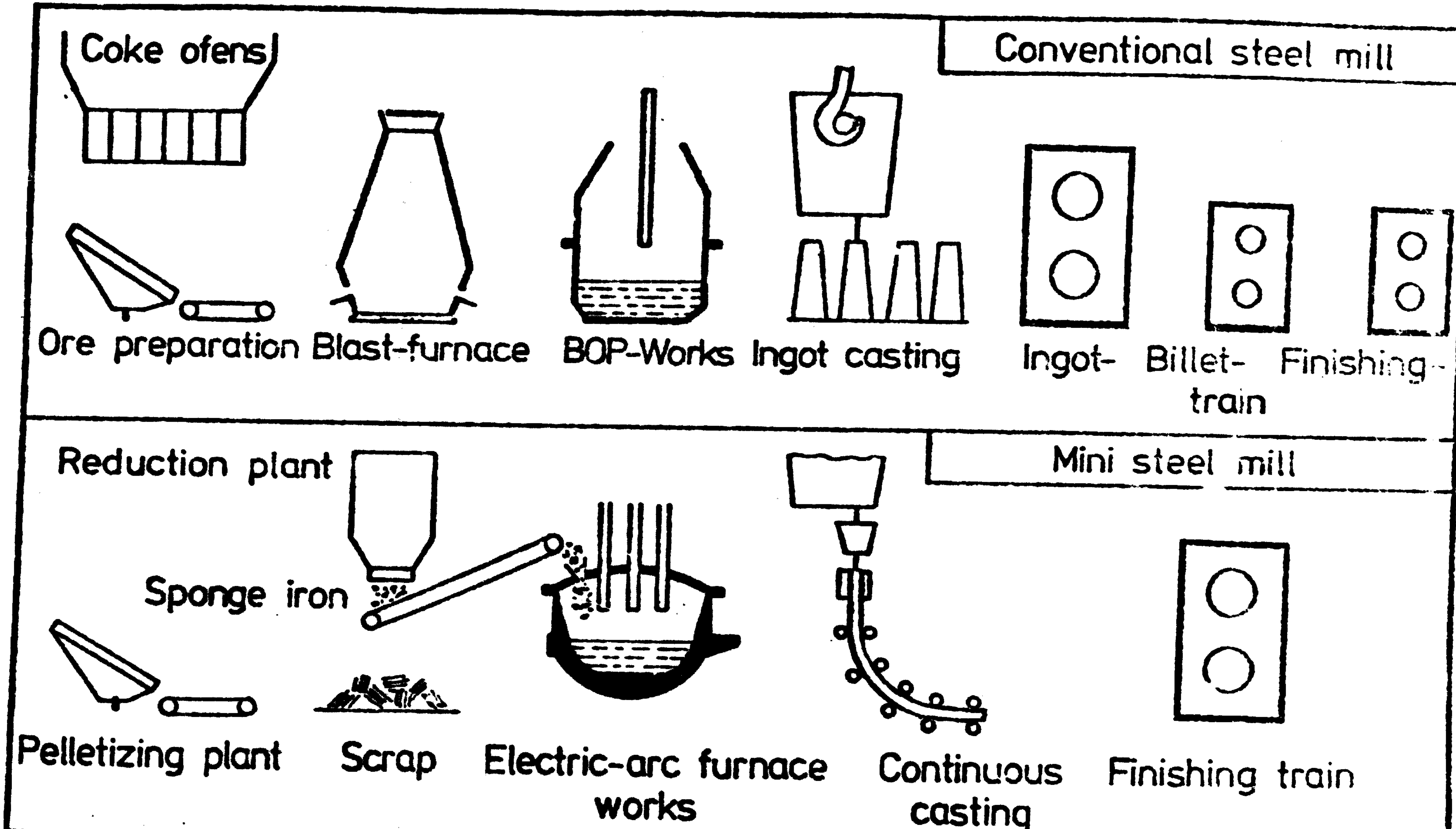
2. MINI-STEEL MILLS, MARKED OFF AND CONSIDERED IN THEIR HISTORICAL EVOLUTION

After the just bullish figures resulting from the forecast of the potential evolution in the long run, it is almost sobering to go back to the order of mini-steel mills as they have presented themselves so far to the observer. So there exists a general tendency of describing the mini-steel mill as a semi-integrated steel works specialized in the area of producing one or two relatively simple kinds of steel product (such as concrete reinforcing bars, wire rod, small structurals, and the like), of relatively uniform quality and in quantities up to some hundred thousand tons per year.

The technical basis of such a mini-steel mill is the availability of electric arc furnaces, continuous-casting facilities, and efficient small rolling mills, the products of which will be sold in a market relatively adjacent to the plant. Mills of this concept exist in large numbers, in some countries of the world, as for instance in the United States with approximately 35 to 40, in Italy with far more than 20, and in Spain with as good as a dozen. All these plants are finally based, from a technical point of view, upon two successful developments made during the recent decades, viz. continuous casting of billets and the UHP electric arc furnaces. This latter is an electric arc furnace in which the installed transformer efficiency per ton of tapping weight reaches a value of at least 350 to 500 VA, thus enabling it to achieve, with this high efficiency, tap-to-tap times of less than 2 hours. Taking into consideration that the first electric furnace of this efficiency was put operational some ten years ago only, it is amazing in what short a time the UHP electric arc furnace had its breakthrough.

With these achievable and relatively short tap to tap times it became possible to feed a billet continuous-casting machine in a way to facilitate a reasonable ratio between the operating time and the total time available. Taking into consideration that with normal carbon steels a maximum casting time, on a continuous-casting machine, in the order of approximately 1.5 hours is acceptable and that an extension of this time, for reasons of the steel temperature in the ladle and consequently in the distributor, is not yet recommendable, there remain still approximately 0.5 hours for the preparation of such a facility for the next casting operation, a time which, in practice, may be reduced without any difficulty. On the other hand, numerous plants have substantially shorter casting times due to the tapping weights of relatively small furnaces and the casting quantity per time unit of casting machines with several strands, so that frequently, for instance, two furnaces serve one casting machine in order to improve the operating time of this facility in view of the relatively short casting times just mentioned.

The development of the direct-reduction technology into operationally proved and economically reasonable plant sizes has made possible for mini-steel mills, until then semi-integrated, the final step towards full integration, i.e. exactly like conventional steel works they are in a position to produce a product — by using ore and the supply of energy for the reduction and melting of this material — which qualitatively does not at all differ from that which is being obtained over the so-called classical way of coking metallurgy. The following figure which opposes in principle the process routes of the conventional steel works and those of a fully integrated mini-steel mill clearly shows that in such a fully integrated mini-steel mill, as compared to a conventional works, quite a series of process steps can be saved. **Figure 4**



ZENTRALE TECHNIK

Comparison process steps
conventional versus-mini steel mill

Figure 4

As shown in this figure, the conventional steel works has essentially the following process steps:

- Upgrading of raw materials
- pig-iron production in the blast furnace
- oxygen converter steel plant
- ingot casting
- blooming train
- billet train
- finishing train

The following process steps may be attributed to the fully integrated mini-steel mill corresponding to the definition already given the process routes of which appear in the lower part of the graph:

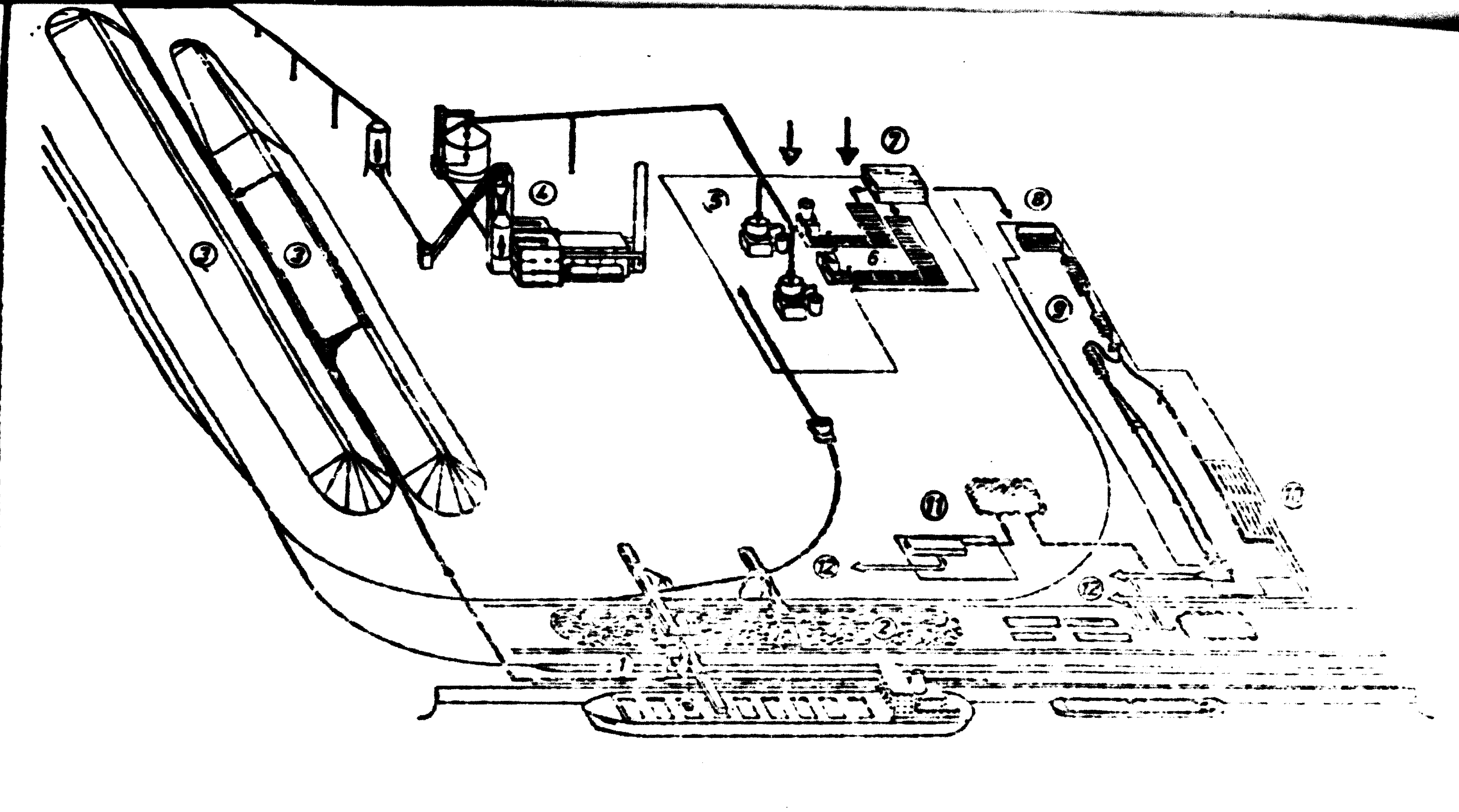
- Upgrading of raw materials
- sponge-iron production
- steelmaking in UHP electric arc furnaces
- billet production in continuous-casting machines
- finishing train

It must be remarked, in addition to the above comparison, that in both plants the same kind of finished product has been assumed in order to make it fairly reasonable. In doing this, round materials in the form of steel bars, concrete reinforcing bars, and wire rod as well as light and medium structurals have been taken into consideration. While the conventional steel works requires a series of interruptions in the material flow, with the fully integrated mini-steel mill the old vision of the metallurgists, viz. the development of a continuous process for steelmaking, may already be realized in substance.

Until the finished product, there remain two boundary positions only, viz. the ladle for furnace tapping and operation of the continuous-casting machine as well as the billet yard ahead of the rolling-mill finishing train.

The next graph shows a perspective drawing of the material flow of the youngest and most modern fully integrated mini steel mill of the world, Hamburger Stahlwerke GmbH, Hamburg, Federal Republic of Germany. **FIGURE 5**

In this graph, the both remaining boundary positions have been indicated by corresponding arrows.



ZENTRALE TECHNIK

Production flow of Hamburger Stahlwerke

Figure 5

3. PROFITABILITY CRITERIA OF A FULLY INTEGRATED MINI STEEL MILL

As to the essential factors involved in the profitability of a mini steel mill on the basis of scrap, quite a series of publications has already been made, so that just now it does not appear to be necessary to enter into this matter in more detail. The preeminent economic advantages of such mills as compared to conventional steel works are to be found especially in the area of the comparably very low investment cost.

Since during recent years no completely new conventional steel works have been erected worldwide, only two examples are left for a numerical valuation of the expense. According to Japanese sources, the expense of specific investment cost of conventional mills are to be rated to approximately 800 to 1,200 DM per annual ton of capacity, in the second half of the sixties, and as to the metallurgical plant presently under construction at Fos-sur-Mer near Marseilles, specific investment costs are being expected which are by far in excess of. this figure. At the 6th Annual Meeting of the International Iron and Steel Institute, S. Galluzzo reported that the cost of a mini-steel mill in Northern Italy was in the range of less than $ 80 per ton,assuming the prices of 1969/1970 referring to a mill with an annual capacity of 100,000 tons. Adding still approximately $ 60 per annual ton of capacity, of specific investment cost, for a direct reduction plant,this leads to a figure of about $ 140 per annual ton of the fully integrated steel mill which, let us say, is in accordance with the figures required for the investment of Hamburger Stahlwerke GmbH, in the greenfield. There a total amount of some DM 450 per ton of annual capacity have been invested.

Another cost advantage of mini steel mills is to be noted particularly in highly developed countries with their correspondingly high standard of living, where personnel expenses incurred by conventional mills are in some cases in excess of 40 pct of the total sales volume, bearing in mind that in conventional mills the production per man and year reaches some 200 to 300 tons. On the basis of the figures mentioned by Galluzzo for the above plant in Northern Italy, a productivity of 500 to 550 tons per man and year may be determined, and the same figure of productivity results from Hamburger Stahlwerke GmbH even involving the personnel for the operation of the direct-reduction plant.

The productivity figures per man and year of similar steel mills such as Badische Stahlwerke AG and Georgetown Steel Corporation are also in the range of this typical scope of mini mills.

An extensive comparison regarding the conditions when setting up a statement of materials and energy, on the one hand for the mini-steel mill, and on the other for a conventional works, has already been made by Maschlanka et al. at the International Symposium on Direct Reduction, in Bucharest. By this paper it has been made clear that for the production of 1 ton of wire rod or bars, in the conventional mill, 1,985 kgs of material will have to be handled, whereas in the fully integrated mini steel mill this quantity will amount to 1,500 kgs only. Even for the net energy consumption figures of the individual different process routes, an advantage has been assessed for the fully integrated steel mill consuming with 4.85 million Kcal less energy than the conventional steel works with 4.97 million Kcal to produce the same ton of wire rod or bar.

With the rates of DM 150/ton of coke, DM 6.30/million Kcal of natural gas, DM 0.04/kWh of power, and DM 2.36/kg of electrodes, it has been verified that the energy cost of the mini-steel mill amounts to 82.5 % only of that of a conventional works.

The last remaining cost advantage of mini-steel mills over conventional mills is related to lower freight rates of finished products. This applies especially to mini-steel mills on the basis of scrap located in major consumer markets. While such a mill is in a position to sell a major proportion of its quantitatively limited output within one of these outlets, it is indispensable to the essentially higher production rate of a conventional mill to serve also other markets with a less favorable freight cost.

However, this quantitatively unproved advantage of the mini-steel mill disappears if either the local scrap availabilities of the market to be served are not large enough to supply the mini-steel mill with scrap, or if the raw materials for the fully integrated mini steel mill have to be delivered from far away. In this case, however, it must be taken into consideration that with freight rates calculated in conformity with market conditions the transport way of bulk materials to the plant site such as iron ores may be four times the distance of the shipment of finished goods, at equal cost. Eventually necessary intermediate handling when transporting the input materials to the plant site, maybe of ore or scrap, however, will affect on its part such distance-cost ratio.

This may lead to the conclusion that a sales-orientated location of a mini-steel mill should rank before a raw-material optimized location. However, if there is a possibility of serving the main outlets directly by means of water-borne transport, the above locational criteria may approximately be equated with each other, and only the question of cost degression by larger transport volumes of the input materials would mean an advantage to the sales orientated location.

Apart from this transport cost of raw materials and finished materials, mention must be made of the energy transport cost which, however, cannot be forced into such a plain system. Generally speaking, some 20 to 30 km of a separate high-tension line leading to a mini-steel mill should charge the energy cost in the order of about 1 mill, and the pipeline transport of natural gas over a distance of 10 to 20 km might cause an additional outlay of US$ 0.01 per million thermal Kcal. The latter figures, however, are normally almost not being taken into consideration when determining the minimization of the transport cost since the fluctuations of energy prices are essentially larger than the figures mentioned hereunder.

4. CHANCES OF THE MINI-STEEL MILLS IN DEVELOPING COUNTRIES

A - Market Development

To begin with, it must be remarked in this Chapter that it is extremely difficult to lump together the rather different markets of the individual developing countries and then to give a plain description of the market development in developing countries. Therefore the following explanations should be understood with the reservation that in the concrete case with reference to a single and eventually small country they are of conditional evidence only; however to the entirety of the countries referred to they will be of a certain probability. In other words: The laws of mathematical statistics will have to be considered also in this case.

An analysis of the steel consumptions related to individual products in some industrialized countries shows that the proportion of rounds such as wire rod, concrete reinforcing bars, as well as that of light and medium structurals accounts for approximately 30 to 40% of the overall steel consumption. Up to 50% of the consumption fall to the sector of flat steel production, which will be represented here by the production of hot wide strip, in general terms. Taking into consideration that such products are used for processing, mainly for automotive bodies as well as industrial and household electrics as, for instance, refrigerators, cooking ovens, deep-freezing chests, and the like, it can be seen that the consumption of hot-rolled wide strip in the developing countries cannot yet account for so large a proportion. It will surely not be too erroneous to assume that the proportion of products generally attributed to a mini steel mill is in the range of approximately 50% of the total consumption of steel products in developing countries, and in this connection it should be remarked in passing that even the manufacture of heavy plates for shipbuilding and heavy industries may be successfully realized in a mini-steel mill, as shown by the example of Oregon Steel Mill in Portland, Oregon, USA.

With an assumed steel consumption of 150 kgs per capita and a proportion of rounds and light st ucturals of 50%, in a country with 4 to 5 million inhabitants a consumption of approxima-tely 300 to 350,000 tons per year would already exist for the-se products. Assuming beforehand that the export possibili-ties are nil, against this background the output of a hot rolling wide strip mill designed with the most modern technology would already supply a population of 50 million. Such a mar-ket within reasonable economical transport routes and conse-quently also reasonable transport costs is likely to exist in only very few countries coming here into question, so that only the alternative of exporting a high per-centage of this output would be attractive. This, however, can only be economical if the location of such a plant is as favorable for exportation as, for instance, the large Japanese steel mills, which are in a position to handle the finished product directly over ocean-going vessels of larger and largest tonnages.

While with the figures of steel consumption forecast per ca-pita in the longer run this ratio would change, only very few plants would then be in a position to sell that kind of produc-tion with reasonable returns. For the typical product line of a mini-steel mill, however, already doubling the steel con-sumption a market of approximately 1 million people is enough reason to think over the erection of such a plant with an an-nual capacity of some 250 to 300,000 tons. Even if a 100 % ship-ment per truck of the finished product of such a mini-steel mill is taken into consideration, market inlets with a ra-dius of about 200 to 300 km adjacent to the plant site can be well served at favorable cost. In view of the population growth and due to the trend that in some favored regions of certain countries overcrowded settlements are coming into existence, the own supply of a large part of such regions through a local mini steel mill will really be economic sense.

B - Raw material potentials

The importance of developing countries as raw material suppliers for the large industrialized countries of the world is sufficiently known. So for instance in 1971 the share of Brazil in the world iron-ore supply was in the order of 4.22 %, that of Venezuela 2.92%, that of India (Goa) 4.11%, that of Liberia 3.34%, to make mention of the most important ones only. The countries of the Northern American Continent only (Canada with 5.94%, and the U.S. with 11.25% of the haulage worldwide) as well as the USSR meet the largest part of their iron-ore consumption by means of supplies from national deposits, and beyond that they are able to export significant quantities (Australia and Sweden as additional important exporting countries shall not be referred to in this connection). Assuming in addition that the iron-ore deposits of developing countries are to a large extent ores with a relatively high Fe content and that by using the most modern upgrading techniques it is possible to bring these ores to an iron content of 65 and more per cent, reducing particularly the acid gangue proportion in a corresponding manner, this will lead to a number of favorable supply possibilities for the production of sponge iron in developing countries. This is of special importance because countries of this type generally have available relatively insignificant old scrap risings since the average life of machinery and equipment in developing countries tends to be essentially longer than that in large industrialized countries. The output capacities of iron and sheet processing plants are also still relatively low, so that generally speaking small quantities of recycled scrap only will arise.

This means that in developing countries the supply of a scrap-melting mini-steel mill would be given at a few locations only.

While in principle the alternative possibility of importing scrap for the supply of this kind of plants would come into question, such possibilities are very scarcely practicable, partly due to very long transport routes, and partly for reasons of national economy, since on the one hand scrap prices in the free world market are subject to heavy fluctuations so that the profitability of a scrap-melting mini-steel mill cannot be given at any rate, and on the other hand there does exist the potential danger that, due to increasingly more protectionist attitudes of countries exporting scrap, still today a general restriction imposed to scrap exports is no longer unthinkable. It is just from this point of view that the recently strengthening efforts of various mini-steel mill operators have to be seen to evade this danger by the installation of, or the participation in, joint sponge-iron producing ventures. As a matter of fact, however, it appears to be hampering within this trend that the direct-reduction processes actually offered have been operated on a large scale during a relatively short period of time only, and on the other hand certain sponge-iron plants have not yet achieved the success they had been expected to. Nevertheless, it should be mentioned here that the reasons therefor are manifold and that in many cases plant difficulties have been decisive, whereas the processes for themselves have proved to be reliable, as this must be stated here representatively of the Midrex process.

While due to reasons of national economy in some countries considerations have been made as to calculate the existing but not so suitable ore reserves for upgrading and processing in direct-reduction plants, it must be generally considered that the available raw material potentials in developing countries, as compared to those of industrialized countries, are considerably more favorable, thus pleading for a major number of mini-steel mills on the basis of local sponge-iron production.

Backing such efforts, the UNIDO grants help very liberally as was shown in detail by Mr. Nijhawan [4] on the occasion of the Symposium on Direct Reduction, in Bucharest.

Coking coal, also in future important for steelmaking in the conventional way, is being considered for certain reasons when analyzing the energy conditions, and has been mentioned here on account of completeness only.

In the same way, mention shall be made on account of completeness of raw materials and supplies for steelmaking such as particularly refractory materials, additives, etc. Since these materials account for a small proportion only of the overall manufacturing cost of steel, either in the blast furnace/oxygen converter steel plant route or in the direct reduction/electric steel mill route,it is not necessarily required to manufacture them in the respective countries themselves. So, for instance, the erection of an own refractory industry will only be given if several steelmaking operations will justify such an investment within the scope of their demand.

C - Energy conditions

Since the largest part of the operational processing cost incurred from ore to steel both in the way blast furnace/ oxygen steel plant and in the direct reduction/electric steel mill route is energy cost, an evaluation of the energy conditions prevailing in developing countries is of utmost importance to the question of an own steelmaking industry. The deposits of suitable coking coal are, generally speaking, rather insignificant in developing countries, and the main producers of this kind of products are the United States, the Federal Republic of Germany, Australia, and the U.K. in the Western as well as Poland and the USSR in the Eastern hemisphere. The cost price of coking coal should be subject to a relatively heavy increase in the years to come, just due to their geographical distribution, so that its importance for world steel production will show a declining tendency. Not or hardly coking coal deposits in large quantities and at favorable cost conditions are raising anew at many places the question of their possible application in the iron and steel industries, considering on the one hand the use in solid-material direct-reduction processes, but on the other hand also pressure gasification for generating reducing gases and their use in gas reduction processes. This latter variant would take advantage, on the one hand, of the widely completed development of the Koppers-Totzek process, but on the other hand of the intense investigation on the use of high-temperature reactors within the compound system of an integrated steel works on the basis of direct reduction.

It may be expected that just the trials to use nuclear heat for the generation of reducing gas from fossil fuels will lead, within some years, to large-scale successfully useable compound plants offering the advantage that already further improved and sophisticated gas reduction processes on a continuous basis will facilitate the secured and economical utilization of those gases.

The use of liquid hydrocarbons for ore reduction has been limited so far to the addition of crude oil to the tuyères of the blast furnace at a maximum rate of approximately 70 kgs per ton of pig iron. The use of crude oil as melting energy source has been linked until now to the open-hearth process, presently dying out, and no other ways are noticeable which might permit essentially the utilization of this primary energy source for conventional steelmaking. The importance of crude oil as an energy source, generally speaking, will increase, however, in future and might be affected only if for reasons of trade or business policy certain quantitative restrictions were imposed by the producing countries. Since this, however, should influence the availability of crude oil in the main consumer countries only, but not in the other developing countries, such a bottleneck cannot be further considered, but the question arises as to which are the possibilities of using crude oil beyond the ways already mentioned. Here the gasification of crude oil by means of the Shell or Texaco processes for the generation of gaseous reducing agents might also provide for a further strengthening of the gas reduction processes. While it may be technically realizable without difficulties that such a gasification of heavy fuel oil generates reduction gas of the required analysis for gas reduction processes, the economics in comparison with directly available methane gas is given only conditionally due to several process steps and the cooling down required between them as well as reheating.

Locally available crude oil, the exploiting and sale of which in the international market is not possible due to extremely unfavorable transport situations, in conjunction with favorable neighborhood iron-ore deposits as well as a market also extremely unfavorable for steel imports, with regard to transport costs, might, however, facilitate the creation of mini-steel mills in future at such places provided that the generation of electric power could also be realized at a favorable cost. In connection with some large energy-winning projects in developing countries mentioned further below, this variation should also materialize in the long run.

A direct-reduction plant in the neighborhood of a major refinery capacity being in a position to use part of the usually burnt-off refinery tail gas for purposes of reduction will come off more favorably than with the use of crude oil in itself. In view of the essential expansion of the refinery capacity in crowded centers to be anticipated in the near future, in different developing countries, great importance must be attributed to fully integrated mini-steel mills on the basis of energy stemming from liquid hydrocarbons, either in original or derivative form. The corresponding development work for large-scale use of these energy sources for the manufacture of sponge iron has achieved considerable progress already at places known to the author.

If from the actual point of view chancer of realizing fully integrated mini-steel mills on the basis of liquid hydrocarbons as energy sources can be seen under certain conditions only, for countries disposing of own natural-gas deposits and either national or foreign ores with a high Fe content to be favorably imported, an excellent chance of development in the field of steelmaking may be forecast in general terms.

This does not only apply to the proper definition of the mini steel mill in view of quantities and products, but rather to steelmaking on the basis of direct reduction/electric furnace process, generally speaking. Evolutions of this kind can be observed already today in Russia and Iran, and it may be considered as absolutely sure that other States with similarly favorable energy cost conditions will follow up soon with the installation of this kind of plant. Projects which appear to be favorable as to cost and competitiveness against international comparison will, in any case, lead to the realization of a number of steel mills on the basis of direct reduction/electric arc furnaces/continuous-casting machines, at least up to the manufacture of semi-finished materials, and the further growth of steel demand in the neighborhood regions of such novel plant facilities should leave it merely up to time when the respective investments will be realized for the further processing of at least part of the semi-finished material manufactured at those places into finished products. It is rather probable that the availability of natural gas will favor such projects, not only at the place or in the neighborhood of their being extracted, but also that with improving techniques and cost reduction of the transport of liquefied gas, Mini-steel mills should generally be installed in the immediate neighborhood of a regasification plant of major capacity. It will be decisive, in this respect, that correspondingly long-term supply possibilities exist which would have to be secured as to prices, justifying economically this kind of investment.

In view of all these observations as to energy economics, the question of the availability of electric power and its cost, as well as the necessity of correspondingly strong electric networks for the operation of mini-steel mills, must not at all be disregarded. Taking into consideration, however, that on the basis of all above-mentioned primary energies the generation of electric power will be possible at approximately the same cost, no heavily diverging conditions have to be expected for the melting energy of such electric furnace mills.

It goes without saying that the availability of hydro-electricity offers the most important advantage, as to cost, and the water quantities and supplies therefore necessary are to be found almost exclusively in developing countries. The investment required for the development of such potential hydro-electric power is, however, tremendous in some cases, passing by far beyond the financial power of the individual States owning those supplies. Joint ventures of several neighborhood countries, eventually in conjunction with generous international funds for financing of such investments, will contribute to meet at least partially the increasing requirements of electric power worldwide. Most recent examples such as the joint Yugoslavian-Rumanian Danube power station, the Brazilian-Paraguayan project, the once politically hard-disputed construction of the Cabora Bassa high dam, and the Tarbela project in Pakistan, as well as the Euphrates high dam and the completion of the Aswan dam, may be sufficient in this connection.

The development of nuclear power generation by means of different processes will provide for an improved uniformity of the power cost price worldwide. The marked tendency even in nuclear energy generation towards cost degression by increased installed power rates might shift substantially if the development of the high-temperature reactor also in units of several hundred MW of performance brings the anticipated practical results. Correspondingly strong and strongest distribution nets as well as an increasing compound system of power supply also in developing countries will facilitate the connection of electric arc furnaces with transformer efficiencies of 30 to 50 MVA, with easy supply and acceptable net reactions, and also the technical improvement of the transfer of highest tensions far beyond of 380 kV are indicative that the percentage power distribution cost will increase as irrelevantly as the power cost price in comparison with the forecast growth rates of other energies.

D - Conclusions

Following a number of opinions and comments on the further evolution of steel industry recently published, the tendency may be derived that in the great industrialized countries an essential growth of capacity will no longer take place in future. Taking into consideration the efforts of major steelmakers, in part already materializing, to carry through additional capacities in countries with privileged locational criteria, instead of the expansion in their own countries, the essentially stronger growth rate of steelmaking in developing countries can already be anticipated. It is only the kind of process to be used which will determine whether thereby the growth of steelmaking capacity in developing countries is to be equated with the growth of mini-steel mill capacities.

The ideas pointed out in connection with the evaluation of energy conditions indicate that on the basis of coking metallurgy no overwhelming chances will exist for the realization of projects in the order of magnitude then becoming necessary, since the investment volumes required in those cases would reach an order which is likely to surpass the financial power of even the largest steel companies. A contribution to this will surely be the fact that, generally speaking, the steel industry has had relatively small earnings during recent years, so that the available and useable funds are also limited on this side. Investments in the range of about US$ 100 million should represent an order of magnitude which might be raised by such a company group within one to two years for a project in developing countries, of its own strength. This would create, then, the basis of such an economically reasonable mini-steel mill of the fully integrated type which in subsequent years could be expanded by modules of capacity, offering the possibility of further financing in part already by means of re-invested depreciations of the first constructional stage.

Considerations similar to those on the financing power of large groups of steel companies aiming at the creation of additional capacities in developing countries should also apply to a series of smaller countries which intend to build up a steelmaking industry of their own in order to meet at least part of their domestic requirements by national production. Just in view of the fact that countries of this type cannot afford the erection of economically not working copies of large metallurgical plants with limited output, the increased switching to the concept of the mini-steel mill can be anticipated. If plants of this kind prove repeatedly their competitiveness in the hardest disputed markets of the world, even a rivalry between state-controlled and influential private groups can be expected, and it will remain to be seen to whom the erection of such plants will be definitely conceded.

The fact that the main factors of manufacturing costs of such mini-steel mills are ranking quite favorably in most developing countries, even within the scope of international competition, has already been pointed out so that investments of this kind most probably will influence the national economy of the respective countries in a favorable way. However, it should be definitely decisive to reach quite a high productivity and operation to capacity of such plants. The willingness of successful mini-steel mill operators to create here, with the sale of know-how and the granting of technical assistance the necessary prerequisites, deserves to be underscored. In view of the future impetuous development to be expected both in the area of economy potentials and population in most developing countries, the most successful fully integrated mini steel mills will further expand gradually reaching an order of magnitude which according to actual definitions does no longer justify this name in itself.

However, if the technical concept continues - which appears to be self-evident according to all statements made so far - the big growth-rates mentioned at the beginning of this paper for electric steelmaking will have been confirmed in essence. Perishable consumer goods, due to increasing prosperity in growth markets of this kind, will also be a guarantee for the continuing existence of the concept of the scrap-melting electric arc furnace with continuous-casting facilities and small rolling mills, corresponding to the original definition of a mini-steel mill. And finally, the increasing environmental consciousness will be a guarantee in countries of that kind that the essentially more favorable prerequisites for pollution-free steelmaking will lead to further growth rates for a more modern technology. If one remembers, to conclude with, the forecast at the beginning of this paper which appeared to be rather audacious, concerning the future way of steelmaking, it may at least be hoped that the greatest part of the doubts caused by those figures will have vanished.

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3. 9. 74