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04856

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.146/86
21 June 1973

ORIGINAL: ENGLISH

Third Interregional Symposium
on the Iron and Steel Industry

Brasilia, Brazil, 14 - 21 October 1973

Agenda item 5

ECONOMIC ASPECTS OF USING A GASEOUS DIRECT-REDUCTION PROCESS IN A DEVELOPING COUNTRY[1]

by

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id. 73-4591

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SUMMARY

This paper discusses the iron and steel industry in relation to the life and human enterprise of a country under development, with particular emphasis on the broad human and economic aspects of using a gaseous direct iron-ore reduction process in a developing country.

At the beginning of the paper, the authors focus upon a wide viewpoint of siderurgy as the art of extracting, transforming, and working iron and steel to useful products.

To obtain a wide framework within which to discuss the subject, the authors sketch out the role of iron in nature in the broadest sense, mentioning its biochemical role and contrasting this role to that of the industrial role of iron and steel in the present human habitat as a material essential to modern man's development.

Within this wide conceptual framework, the authors then focus upon the subject of energy and ecology as it relates to the theme of siderurgy. Also, the concept of possible limits to world siderurgical activity is mentioned, as well as certain tendencies in modern thought which have a bearing on the subject of managing or coordinating the planet and how these may possibly reflect themselves into the future siderurgical panorama.

From this point, the scope of the discussion is then narrowed to the characteristics of a country under development and what has to be done to foster development, which then leads to considering what is required to create basic industries and the modern infrastructure of the country. This, in turn, leads to consider the general problems of the steel industry in a developing country and the advantages of the use of a gaseous direct reduction process to make steel.

In view of the wide ranging theme of this paper, the discussion is of necessity conceptual and broad; the authors have attempted to illustrate the

theme rather profusely to aid in sketching out such a broad approach to the subject and to provide a flow of ideas and images throughout. It is hoped that this approach will be stimulating for subsequent reflections, discussions, and communication.

INTRODUCTION

It is an honor and a significant event to have received the invitation from UNIDO to present to this, the Third Interregional Symposium of the Iron and Steel Industry, a paper on the economy of employing a gaseous direct iron-ore reduction process in a developing country. This theme is especially fertile in the present context of rapid change that is occurring globally and that impacts with particular characteristics each of the different countries (Ref. 33).

fig - 1

In the last decade, the integrated knowledge of man has led him to ponder the orientation and the consequences of his technological development (Fig. 1) from a very wide-ranging point of view that encompasses the planet that he populates (Ref. 3-10, 34, 35, 37-50). The iron and steel industry is not exempted from this wide viewpoint, as may be deduced from the agenda of the other conferences in this series (Ref. 1,2) and with special emphasis, the present conference (Fig. 2). Interesting contrasts are evident and major and minor problems of a challenging nature exist in different countries of the world (Fig. 3).

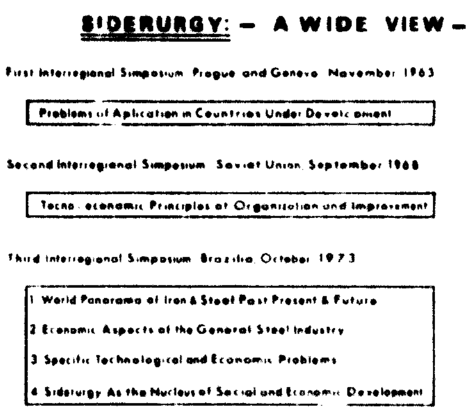


fig - 2

SCOPE OF THIS MESSAGE

Unfortunately, at the moment of writing this message we do not have within reach all the documentation which UNIDO and other agencies of the United Nations and other organizations have published thru the years on the iron and steel industry. However, even if we had this material at the reach of our hand, it would have been quite difficult to have read and assimilated it completely. Thus, we will not pretend to report herein statistics and numerical data that most probably others have published for the consideration of those interested in the broad theme of the iron and steel industry.

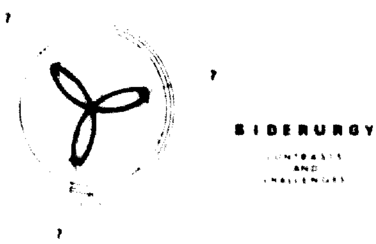


fig - 3

Also, we will not try to give a laborious numerical example of a hypothetical case to try to ilustrate a particular point. This would be more the labour of each expert or group of experts that would consider in detail the viability of a specific industrial project.

Rather, our message is oriented to contribute certain points of view, experiences, or observations about the economics of the use of a gaseous direct iron-ore reduction process in developing countries, for we believe that this is what we could most usefully contribute to this conference.

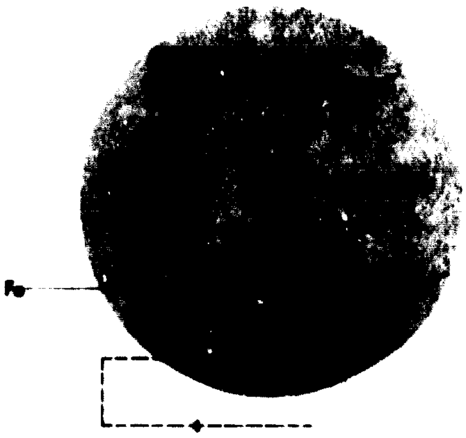


fig-4

We wish to begin our message with an ample reflexion that will situate the theme of the iron and steel industry in a wide conceptual framework within which certain points of view can be highlighted which we would consider important and which at the same time are often lost sight of when attention is focused with excessive detail upon the iron and steel industry.

Siderurgy (Fig. 4) is the art of extracting, transforming, and working iron and steel to useful products. Within this art there exist science and technology which are pertinent to it and which have been the object of the labor of innumerable people around the world. We wish to expand this point, for it will give us a useful view.

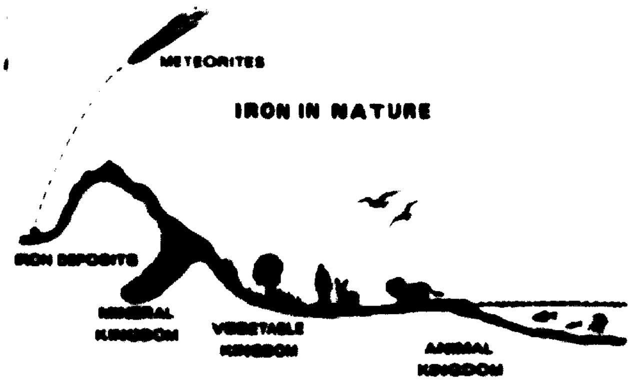


fig-5

IRON IN NATURE

Let us consider the theme of iron itself, as an element of nature (Fig. 5). Before iron figured in the art of man known as siderurgy, iron as such figured in the biochemical processes within the biosphere (Fig. 6). Thus, we now know that before man existed as a species, there existed initially forms of life much less developed (Ref. 37), there being an initial epoch in the evolution of cellular life (Ref. 11) in which cells existed that were anaerobic, that is, they did not possess the capability of utilizing oxygen in their biochemical processes (Fig. 7). The face of the earth was very different from the present (Fig. 8). The atmosphere contained little oxygen, the biosphere was populated by primitive organisms that did not utilize oxygen, indeed oxygen was a dangerous contaminant, a byproduct of then existing biochemical processes.

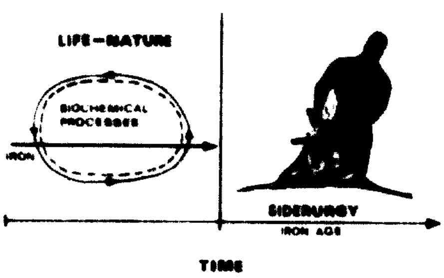


fig-6

Gradually, aerobic cells evolved and within these a key protein, essential for the cell to utilize oxygen (Fig. 9). This protein is of those called cytochromes. In the center of the cytochrome-c protein (Ref. 11) is an atom of iron which changes valence between two states of greater and lesser degree of oxidation, from trivalent to divalent and viceversa. These proteins in effect reduce and oxidize iron cyclically.

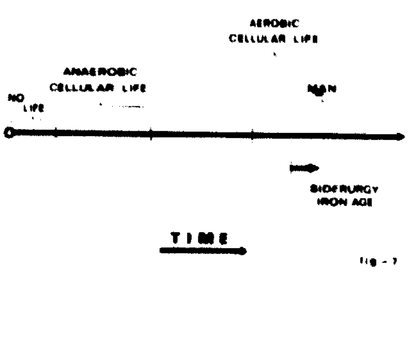


fig-7

Citochrome-c is contained in all aerobic cells of nearly all species living presently in the biosphere, including man (Fig. 10). The face of the earth would be radically different whithout this protein.

Fig.- 8

Within the human being, iron appears as well in other biological forms, including the hemoglobin of the blood (Fig. 11). Each adult normally has 4 to 5 grams of iron in his organism, which is a small amount of the order of 0.01% of the weight of the body. All the actual population of the world represents about 13,000 metric tons of biological iron (Fig.12). A human being normally ingests in his daily food about 10 to 15 milligrams of iron, the world population ingests about 37 metric tons of iron daily, that is about 13,000 metric tons annually. The weight of all human beings in the planet is of the order of 130,000,000 metric tons (Fig. 13).

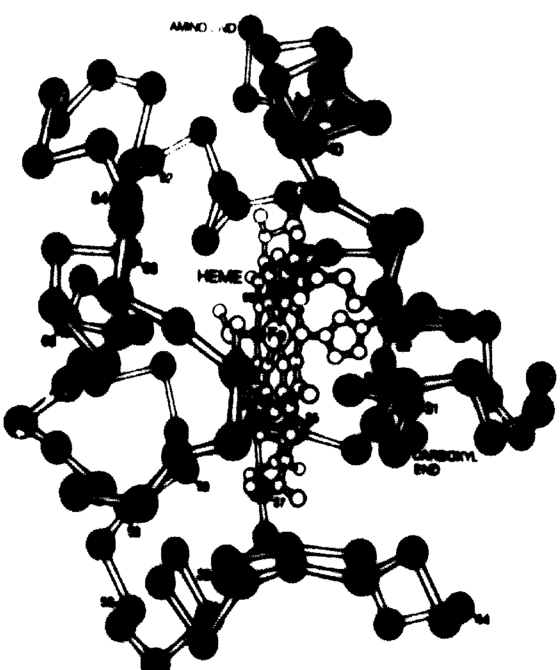


Fig.- 9

The world annual steel production is of the order of 800 million metric tons. We see that man, on a world average, annually produces about six times his weight in steel within the terrestial biosphere. No other species carries out such a task of producing and "movilizing" iron within the biosphere. In highly developed countriee, man produces 20 to 30 times his weight in steel; in developing countries, man produces on the order of two times or less, his weight in steel, annually.

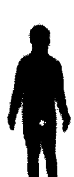
Modern man is, to coin a phrase, the small ant of steel. Under existing criteria, his index of modernity or development depends on how many times he produces his own weight in steel, annually. Undoubtedly, there are models of development that stongly question this criteria (Ref. 15, 16, 34, 35), such as for example, the Tanzanian model (Ref. 14) of development, which basically rejects this criterion in a certain way.

CITOCHROME C IS FOUND IN NEARLY ALL AEROBIC CELLS OF NEARLY ALL ACTUAL SPECIES

- MAMMALS
- OTHER VERTEBRATES
- INSECTS
- PLANTS

Fig. 10

We see then, that iron in nature was crucial in transforming (Fig. 14) the biosphere of the world in which we live and that it participates interiorly in man - - - his organism used iron internally before he knew what it was. Iron figured innately in the interior life of man (Fig. 15) and as time passed man discovered the use of iron externally to his organism, entering thereby into the iron age, according to the anthropologists (Fig. 16).



Each Adult Has 4 to 5 grams Of Iron In His Body 0.01% Of Body Weight

All World's Population Has A Total Of 13,000 Tons Of Iron.

Fig.- 11

When man introduced the art of the use of iron into his daily life, he radically changed his way of life and with this the face of the

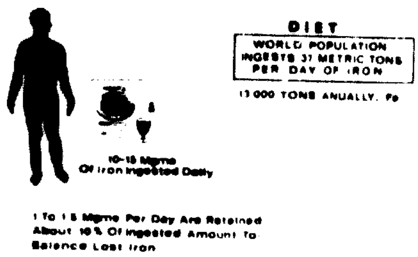


Fig. 12

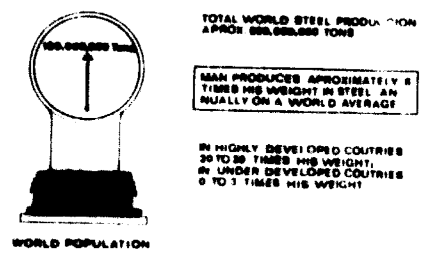


Fig. 13

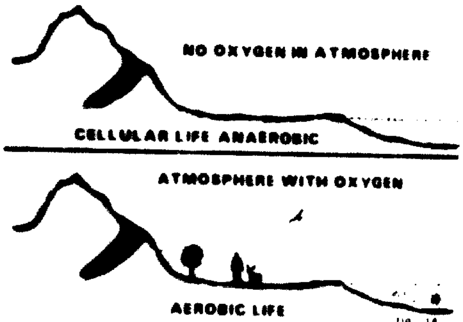


Fig. 14

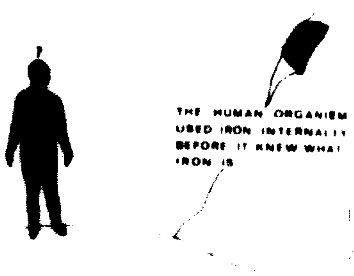


Fig. 15

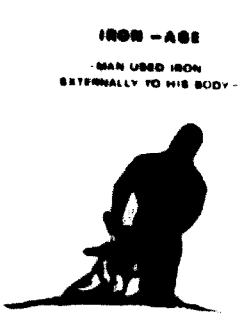


Fig. 16

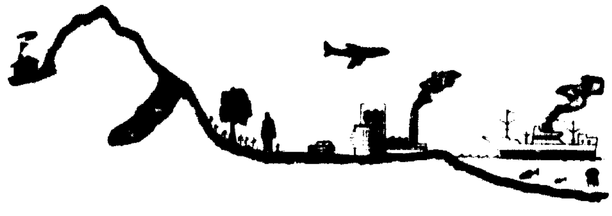
earth was changed again a second time (Fig. 17) by the effect of the use of iron within the biosphere. We all know the historical scheme (Ref. 19) thru the ages from the Stone Age to the present (Fig. 18).

We have wished to sketch this perspective of iron in the biosphere to highlight the trascendent role of iron in the human habitat and activity. Man is a soft creature within whom iron carries out a key role in his internal biokinetics. Externally to himself, man requires the use of iron in the development of his modern enterprise. He requires it as a metal in his structures, edifices, dwellings, in the highways and in the machines and objects with which he carries out his modern doings.

For modern man or man on the road to becoming modern, iron does not represent just a basic industry but rather an over-riding necessity in the modern human condition (Fig. 19). Siderurgy is an art that encompasses science and technology essential for man's development.

This point is very important for, if we wish to consider the concepts of economics with respect to the siderurgical industry of countries under development, it turns out that economic factors are not of themselves the only determinants of the siderurgical activity (Fig. 20). It is not very probable that a people would choose to depend totally on foreign siderurgical activity (Fig. 21) and this observation, by itself, would tend to place the decisions relative to the steel industry, not entirely in the domain of economics but rather somewhat in the socio-political plane (Fig. 22), or simply in the plane of private genuine self interest.

To expand this point, it is important to consider what is the proportion of the Gross National Product (GNP) that is generated directly by the steel industry in a country (Ref. 53). We find that to the surprise of some, in countries such as the United States of America and other of about equal development, the siderurgical industry represents only about 2 to 3% of the GNP. In developing countries, the figure may be about 0 to 2% of the GNP. There are other sectors within the GNP that are often many times greater, depending on the country in question. We see then that the siderurgical activity is primarily important because of its important effects within the human enterprise of a country, because it is a basic industry that feeds other industrial activities, more than because of the economic activity which is directly atributable to it as a percent of the GNP.



IRON IN HUMAN ENTERPRISE CHANGED THE FACE OF THE EARTH A SECOND TIME

fig. 17

It is well to point out, however, that the siderurgical activity generally figures more prominently in the commercial balance of trade than in the GNP, with percentages of the order of 5, 10, 15% of the trade flow involved in the commercial balance (Ref. 53). From the economic point of view, this is one of the principal aspects of a purely economic nature in the siderurgical picture, more than as a fraction of the GNP. Thus, the siderurgical activity should be fostered to as great a degree as possible within the private sector of the economy in developing countries, so that it may effectively catalyze the total human enterprise of those countries. In some cases, this may involve some type of subsidy at the most, in order that such an activity be sufficiently attractive to assure private participation. Though this is only our opinion, we feel that, when the siderurgical activity is placed entirely in the public sector (i. e. state owned and operated), then an important part of the catalytical effect of the steel industry upon human enterprise may be lost. We would, of course, recognize that different opinions and exceptions may exist as to this point, but we feel it is generally a correct assessment of many cases in the world steel picture and we know that we are not at all alone in this opinion (Ref. 33). We would recommend that governments of developing countries adopt as a policy the criteria of fostering the steel industry in the private sector rather than in the public sector. Certainly the fraction of the GNP involved will not of itself imply a great change in economic policy but it will assure that the catalytic effect of the steel industry upon human enterprise will be most effectively incorporated into the economic activity of the country.

THE AGES

Stone: - 8000 Years B.C.

Copper 8000 B.C. - 3000 B.C.

Bronze 3000 B.C. - 1500 B.C.

Iron 1500 B.C. - present

fig. 18

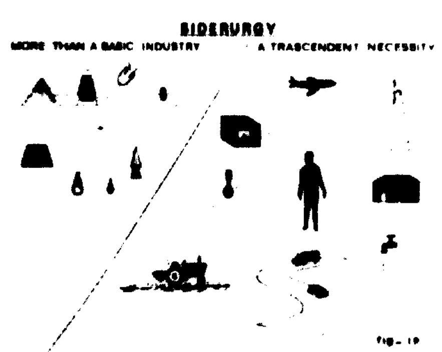


fig. 19

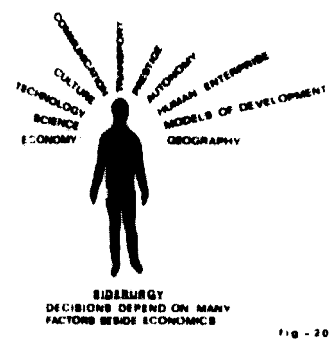


fig. 20

In this connection it is interesting to note that, as reported in Scientific American (Ref. 13), the 1972 Nobel Prize in economics was awarded to Kenneth J. Arrow and John R. Hicks "for their pioneering contributions to general economic equilibrium theory and welfare

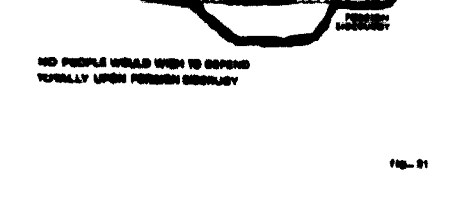


fig. 21

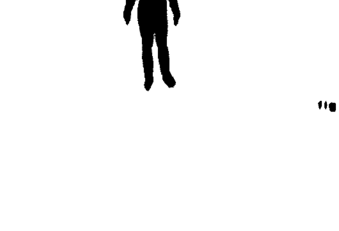
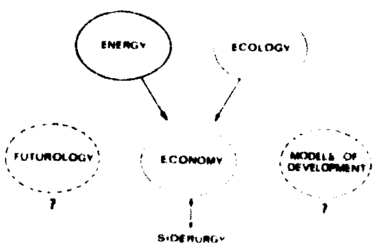


fig. 11

theory ... In welfare economics one would like to show that an economic system can be designed to satisfy the needs and wishes of the majority of people. One might think that one could ask individuals to rank various possible economic states and arrive at a consensus. Arrow's work show that such a consensus is technically impossible". Thus, we can only point out our opinion and try to explain it best we can to those who would consider it, with due mutual respect to those who would disagree.

ENERGY AND ECOLOGY



Siderurgical economics can not be discussed without considering the panorama of energy and ecology

fig - 23

Today it is not possible to discuss the economy of siderurgical processes without considering the world panorama of energy sources and ecological aspects (Fig. 23). When considering the possibility of installing or increasing the siderurgical activity of a country, it is necessary to consider the procurement of energy and raw materials, be they from internal or external sources (Fig. 24). Besides the consideration of marketing and finances, these are basic data for any siderurgical project (Fig. 25). We will not go deeper into these points because many and diverse studies and opinions exist with regard to these.

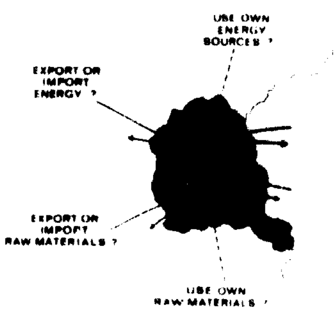


fig - 24

It is significant, nevertheless, that it is estimated (Ref. 9) that if all the countries of the world were to achieve a standard of living equal to that of the most industrialized countries (Fig. 26), the world's commercial grade reserves of iron ore would not run out in the near future, but on the other hand, within 1 to 3 decades the reserves of other commercial-grade ores vital to industrial activity would run out, such as chrome and nickel (stainless steels), tungsten, copper, lead, zinc, tin, molybdenum, mercury, and silver (see Figure 26). This implies that there are natural limits to the growth of industrial activity and population (Fig. 27), which can not but translate itself into the concept of limits to the world steel market, which in turn represents, in the last analysis, the concept of limits to the world siderurgical activity. This concept of limits is not derived from the Club of Rome's report (Ref. 5) and is quite independent of the controversy that surrounds that work (Ref. 54).

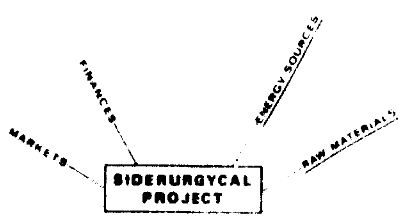


fig - 25

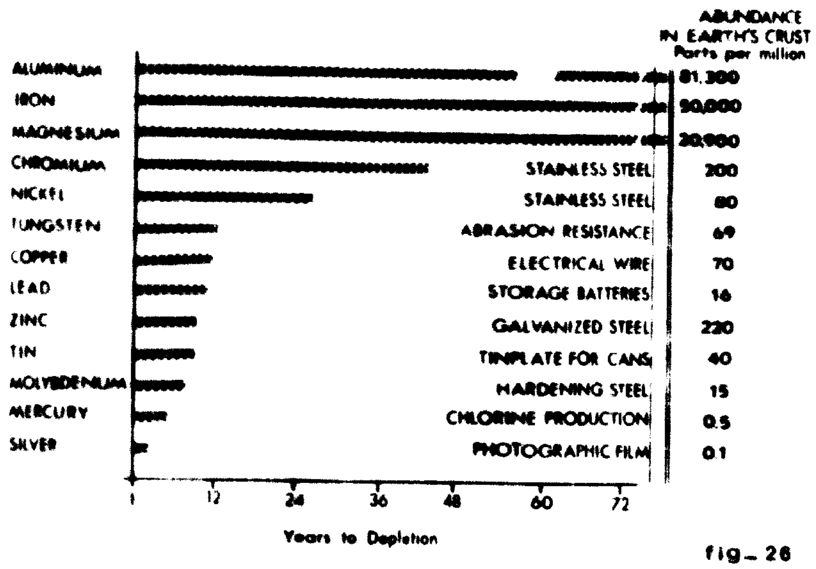
Actually, the concept of limits to growth is an important concept, even though no general agreement exists as to time and magnitude. In general, we would say that the concept of limits characterizes the siderurgical sphere.

As we shall discuss later in more detail, when discussing the siderurgical industry of a country, the concept of conserving nonrenewable resources comes into play (Fig. 28), be it in terms of raw materials or energy sources. At the same time, this involves the balance of payments of a country (Fig. 29).

We see, then, that generally, when discussing the siderurgical industry of a country, both internal as well as international and global factors must be examined.

If one is to discuss the possible, existent, or nascent siderurgical activity as a function of local conditions as regards raw materials, energy sources

DEPLETION OF WORLD RESERVES OF COMMERCIAL GRADE ORES IF WORLD POPULATION HAD U S LIVING STANDARD



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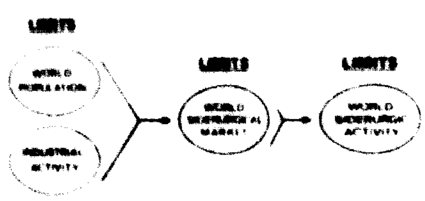
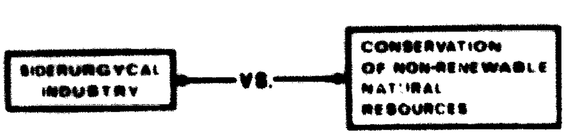


fig_27

and markets (Fig. 30), we find that the discussion turns to considering the appropriate technology for the optimum benefit or economic result. The siderurgical industry (Fig. 31) is an activity in which science and technology have been the object and result of the extensive application of research and development to obtain the most appropriate processes in terms of size, energy, and raw materials.



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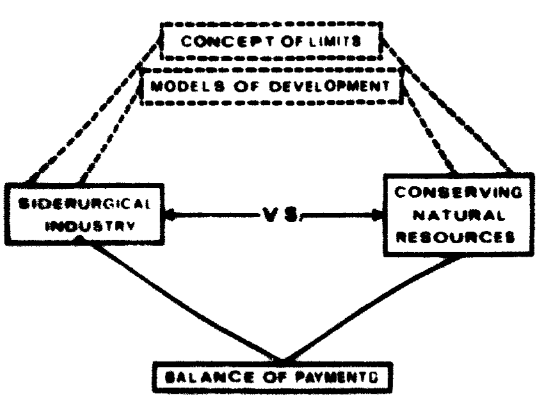

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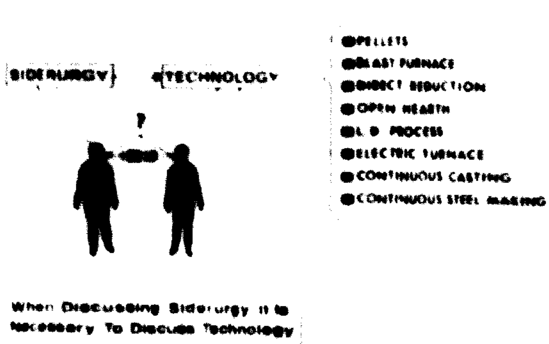

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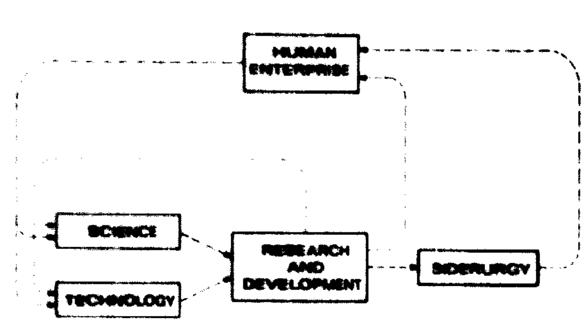

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FOUR STRATA OR LEVELS OF THINKING

This carries with it several implications and consequences.

It is not possible to delve deeply into these matters because the subject is too extensive. However, we would wish to point out what to us represent certain interesting tendencies of modern thought which we could call the "Four levels of thinking" (Ref. 24):

Level of Research and Development
Level of Technological Forecasting
Level of Technology Assessment
Level of Planetary Management or Coordination

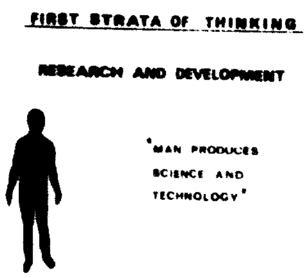


FIG. 32

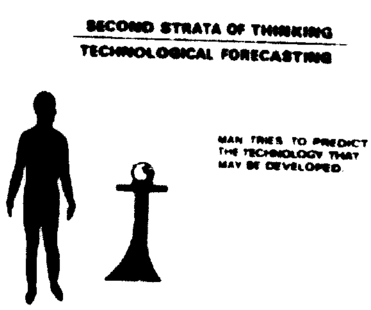


FIG. 33

In general, in the first level of thinking (Fig. 32), that of "Research and Development", man evolves science and technology. In the second level of thinking (Fig. 33), man attempts to predict the technology which he will or he may develop in the future. In the third level of thinking (Fig. 34), man enquires concerning the effects, positive or negative, that will envelop a country or the world if such technology were developed and applied in the future. That is, he makes an "assessment" of technology, considering many factors including ecological, economic, and social factors. In the fourth level of thinking (Fig. 35), man enquires concerning the orientation that he should give to his affairs and to technology to avoid the negative effects in a country and ultimately in the planet as a whole. This is the level of Planetary Management or Coordination, i. e., managerial action, coordination, or concordance on a planetary level. Rather than a constituted authority on a planetary level, planetary management is a phenomenon of communication and a shared decision process, as are essentially all management processes.

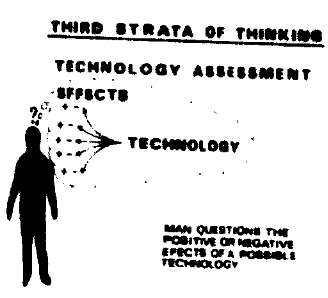


FIG. 34

We have wished to define these four strata of thinking (Fig. 36), not for philosophic reasons but for a practical reason: this Third Interregional Symposium of the Iron and Steel Industry can be said to be a part of this communication process on a world scale and as such is of itself an element of planetary management in its actual state of development. In this forum, limits and possibilities will be discussed as well as markets, technology, and strategies of development. Those communications will no doubt influence the thoughts and decisions of people in different parts of the world and as such the managerial decisions of different echelons in the private and governmental sectors.

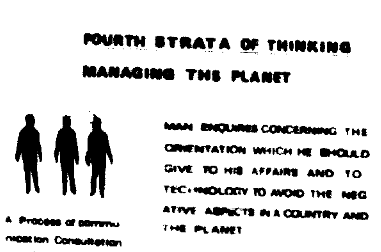


FIG. 35

Thus, it is a practical consideration to visualize the four levels of thought which we have pointed out here, for they serve to highlight in a wide framework the meaning of this type of symposium.

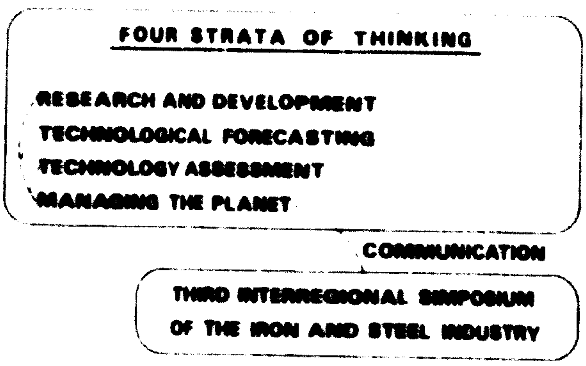


fig - 38

We expect that much of what we will subsequently comment will be relevent to this framework. It is not possible to fully expand any of the levels of thinking, only to bear them in mind as a reference framework.

The theme of our message is centered on the economics of a gaseous direct-reduction process in the context of a developing country.

To develop this subject, we first wish to discuss briefly certain things such as:

The characteristics of a developing country.
What has to be done to foster development.
What is required to create basic industries and the infrastructure.

And then we would discuss:

The general problems of the steel industry in such a context.
Advantages of gaseous direct iron-ore reduction processes.

CHARACTERISTICS OF A COUNTRY UNDER DEVELOPMENT

What do we understand by the term "A country under development"? Basically, the following:

1. A country in which the gross national product is low.
2. A country in which the industrial sector does not exist or is being formed.
3. A country in which the economic activity is not balanced and which generally depends strongly on agriculture, forestry and fishing.
4. A country in which the percapita income is not well distributed, there being generally a great majority of poor persons and a small minority of very rich persons, with a very small middle class.

We recognize that this definition of a country under development is somewhat arbitrary; nevertheless, we believe that it represents the typical image which many people usually consider.

WHAT HAS TO BE DONE TO FOSTER DEVELOPMENT?

If the four preceding characteristics are considered as typical of a country under development, then what has to be done to foster development is essentially to invert the terms so as to:

1. Increase the gross national product.
2. Form or increase the industrial sector.
3. Guide the economic activity in such a way as to balance it in terms of industrial activity, agriculture, forestry and fishing, adequately stimulating each.
4. Improve the distribution of the percapita income by the creation of jobs and the progressive formation of an economically and socially healthy middle class.

This implies that the following is required:

1. Establish an independent economic policy.
2. Rapidly achieve a profitable economic scale.
3. Improve the balance of payments.
4. Create jobs.
5. Make the best use of local national resources.

WHAT IS REQUIRED TO CREATE BASIC INDUSTRIES AND THE NECESSARY INFRASTRUCTURE?

The creation of basic industry requires the following:
Iron and steel
Energy
Cement
Chemical
Petrochemical

The creation of the infrastructures requires the following:
Transportation
Communication
Highways
Health and hygiene facilities
Irrigation
Schools
Banking systems

GENERAL PROBLEMS OF THE STEEL INDUSTRY IN A DEVELOPING COUNTRY

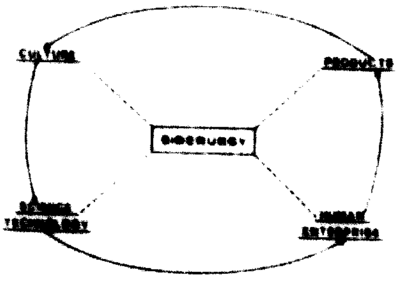


fig.- 37

As we mentioned earlier, the siderurgical activity (Fig. 37) is an essential activity within the general human development, both in terms of the products which are generated and applied as in terms also of the exercise of science and technology within the siderurgical and industrial arts. Thus, in the development policy of almost any country the solution of the siderurgical problems of the country will occupy a prominent place. Depending on the country (Fig. 38), this may be lead to situating the siderurgical question either in the private sector or in the public sector of the economy, or perhaps simultaneously in both sectors.

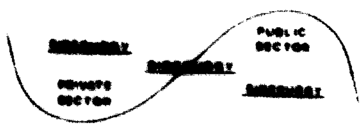


fig.- 38

It is possible to visualize that a country under development will evolve across the entire spectrum (Fig. 39) from total importer of siderurgical products to the level of self-sufficiency and even to export capacity. Within this spectrum of conditions, we may distinguish the following cases of interest (Fig. 40):

Total importation of siderurgical products.

Non-integrated steel industry: rolling of imported steel in the form of billets or melting cold charge to make steel.

Integrated steel industry: reduction, melting, refining, and rolling to satisfy local market.

Steel industry for exporting: excess capacity is exported.

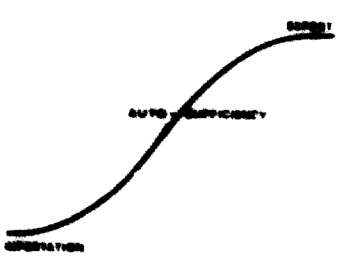


fig.- 39

Because of the excess capacity (Fig. 41) in the large steel-producing countries (Ref. 1), it is common in the initial stages of development of a country to solve the need of steel products by importing.

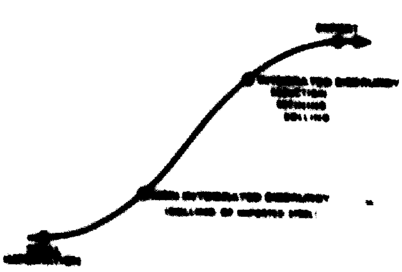


fig.- 40

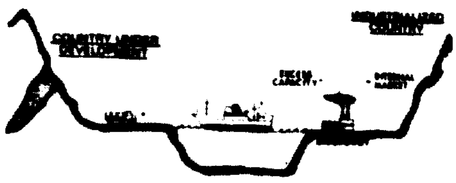


fig-41

However, when the consumption of steel products become significant, it is attractive to substitute the importation of such products by producing them locally on a non-integrated basis (Fig. 42), usually by rolling imported billet or ingot.

When production and consumption of steel products increases further (Fig. 43), it becomes attractive to think of integrating the siderurgical activity by including ore-reduction processes — in a blast furnace, in an electric reduction furnace, or in direct-reduction processes. Semiintegration may also be achieved by using electric furnaces and local or imported scrap. The adequate technology depends on the scale of the internal demand, the tolerable internal prices versus the imported product, the availability of local or external sources to supply energy, ore, raw materials, refractories, etc., as well as the availability of capital and adequate personnel, services, etc.

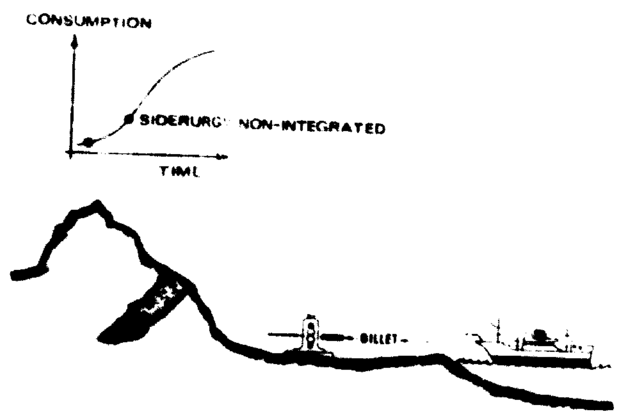


fig-42

The decision to expand the steel industry of the country to the level of achieving export capacity is a decision which depends as much on siderurgical factors as on other general factors of the economic policy of a country. In some cases, because of a small internal market, this may be an early decision (Fig. 44) imposed by the consideration that the minimum installable capacity exceeds the local demand. The tendency to establish local steel industry and to export the excess capacity has been a popular trend to the present. It is not easy to conclude that in the future such a point of view will be sustainable versus the concepts of limits to growth, for if many countries concur in the same formula, then the effect could be to depress prices of the international market, thus making it less attractive to escalate the steel industry to export levels. This could tend to favor the importation of steel products to developing countries instead of their trying to install or expand their own steel industries. From the point of view of the concepts of managing or coordinating the planet, this could be considered as a favorable utilization of the excess world steel capacity, which on the other hand could be a positive objective if it could be carried out under equitable or convenient commercial basis for the countries under development.

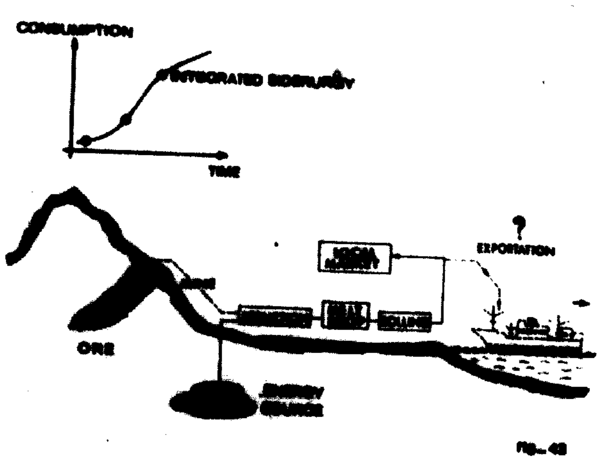


fig-43

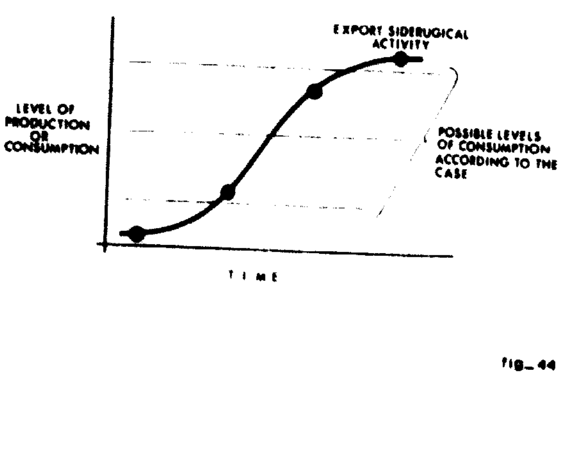


fig-44

LIMITS TO:

POPULATION
CONTAMINATION
ENERGY SOURCES
RAW MATERIALS
SOURCES OF CAPITAL

FIG. 45

For on the other hand (Fig. 45), the concepts of limits to growth indicate not only limits to population, contamination, energy sources, and raw materials, but also limits to sources of capital. Thus the question arises as to whether it is logical to favor in the whole world the application of capital to the creation of steel industries with excess capacity in countries under development when in other countries excess capacity also exists. This could be an important question if one considers that the steel industry is quite intensive of capital, for the second question would be if it were not preferable for a developing country to invest such capital in another industrial branch less intensive of capital or in additional infrastructure.

As may be observed, these are truly problematic questions which we would not pretend to solve here, only to indicate them as characteristic questions which envelop the subject of the iron and steel industry in countries under development. It is not very probable that the countries under development would desist from wishing to establish or expand their siderurgical activity as part of their economic policy, for in general they would seek a certain degree of autonomy and independence in the field of siderurgy, if at all possible. Nevertheless, considering the concepts of limits to growth, it could be thought that the tendency towards independent economic policies in this and other fields (Ref. 12, 17, 18, 36), probably would finally lead to economic policies not of greater independence as such, but rather to greater interdependence or coordination, which would be expected from the points of view of the concept of managing or coordinating the planet which we mentioned earlier.

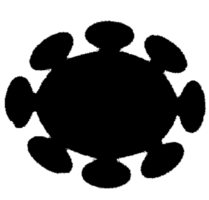


FIG. 46

The managerial action (Fig. 46) would probably evolve in the field of siderurgy on the basis of recognizing the limits to growth or the limits to the rate of growth, as well as on the basis of communication and analysis of the tendencies and possibilities for the immediate future. Such communication and analysis will lead the management spheres in the public and private sectors of different countries to consider the alternatives and the world and local panorama, present and future. One possibility that could be examined is that the countries under development form a block to negotiate and purchase the siderurgical products which can be produced with the excess capacity in other countries.

However, even in spite of the concepts of limits to growth, additional worldwide steel production and consumption will continue to be necessary during the immediate future and it is not at all evident that additional capacity should be installed in developed countries already producing huge quantities of steel. It is, in fact, somewhat contraindicated as potentially undesirable to do so, both on ecological as on economic terms. This is, of course, subject to a large range of opinions, difficult to reconcile.

Nevertheless, we would take as a basis that an independent economic policy (Fig. 47) is characteristic of a country under development. Projected into the siderurgical sector this would reflect itself principally in the way

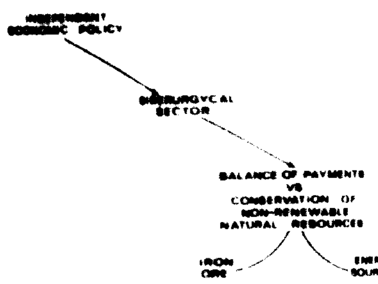


fig. 47

it affects the commercial balance of payments of a country as a consequence of this sector. Depending on the available natural resources, a country could adopt different policies with respect to the balance of payments and to the conservation of the non-renewable natural resources, which in the siderurgical sector would basically be the iron-ore and the energy sources. Thus, if the iron-ore resources are very large (Fig. 48), it may be attractive to export the ore rather than to subject it to local siderurgical processes. The balance of payments would be favored directly by exporting the ore, but this non-renewable resource would be progressibly exhausted. Something similar would occur in the case of the energy sources, assuming that large resources exists. When natural resources are not abundant (Fig. 49), then it may be attractive to import part or all of them for the local siderurgical activity. In the case of the iron units, these may be imported as iron ore or scrap, assuming that siderurgical processes are selected accordingly. The balance of payments in such a case is favored to the degree that imported siderurgical articles of high price are suppressed or to the degree that equivalent steel products are exported.

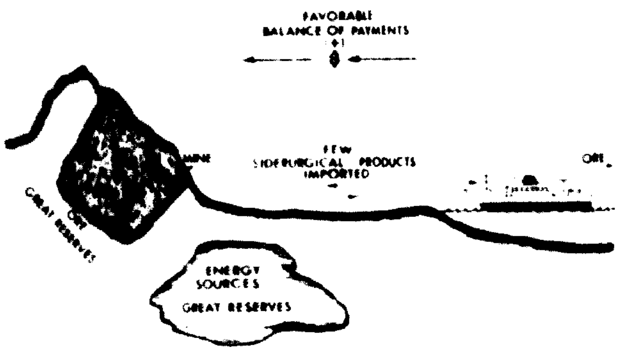


fig. 48

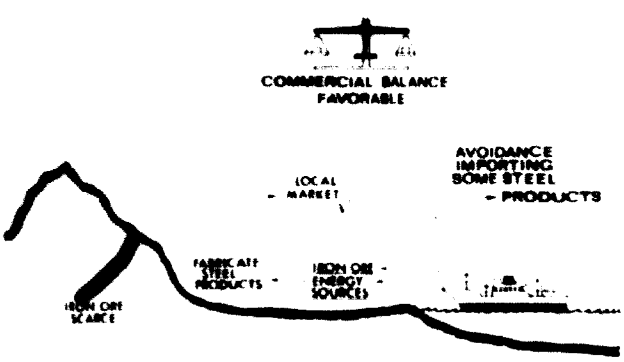


fig. 49

The evolution of mini-steel plants (Fig. 50) in different countries, especially including those of long-standing siderurgical tradition (Ref. 25), has been another factor which makes it attractive to countries under development to establish their own siderurgical industry, even on a modest scale.

Thus, we see that the general problems of the siderurgical industry in countries under development is immersed in a context of great change and uncertainty. Nevertheless, the present tendency is definitely toward the establishment or expansion of the siderurgical industries in countries under development (Ref. 28) and it is in this tendency in which it is particularly attractive for many countries to establish siderurgical industries based on gaseous direct iron ore reduction processes.

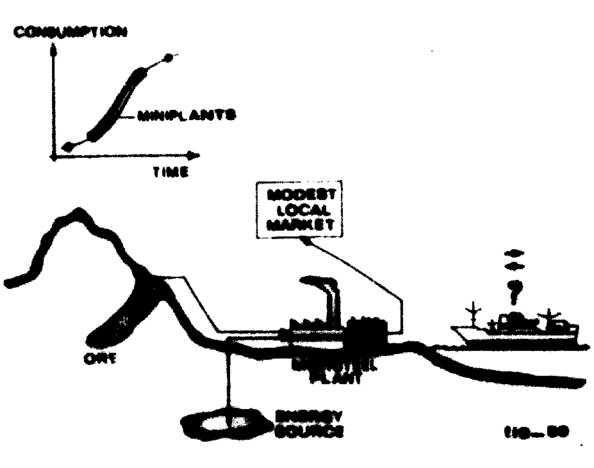


fig. 50

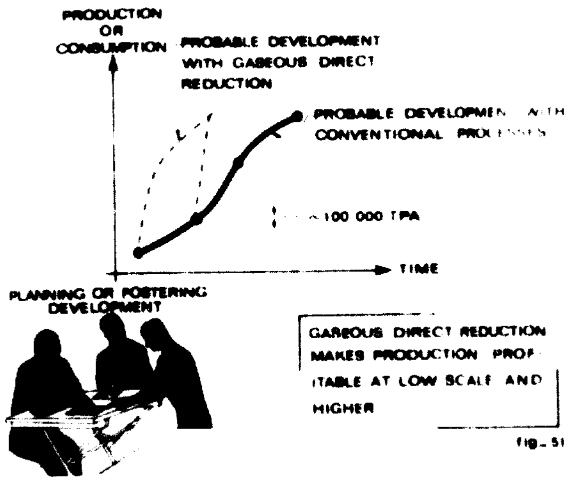
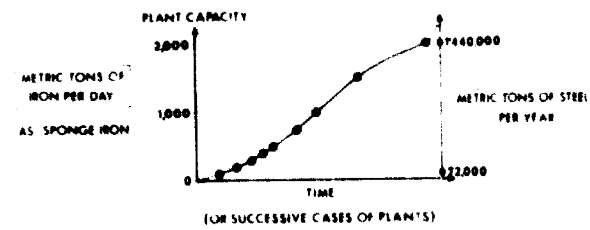


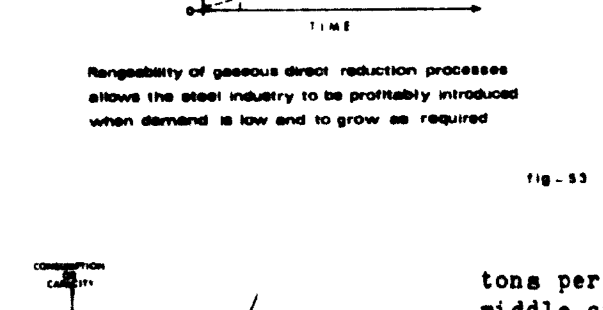
fig-51



RANGEABILITY OF FIXED BED GASEOUS DIRECT REDUCTION PLANTS

Plants may be designed between 100 and 2000 tons per day of iron

fig-52



Rangeability of gaseous direct reduction processes allows the steel industry to be profitably introduced when demand is low and to grow as required

fig-53

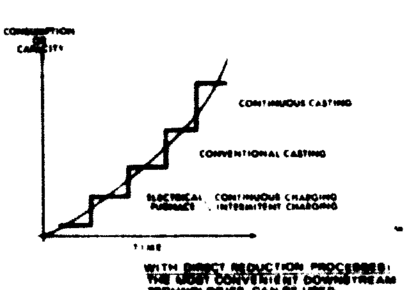


fig-54

ADVANTAGES OF GASEOUS DIRECT IRON-ORE REDUCTION PROCESSES

From the point of view of fostering the economic development of countries under development, the gaseous direct-reduction processes present various advantages to those who participate in the coordination and decision functions.

In the first place (Fig. 51), the gaseous direct iron-ore reduction processes make it possible to produce steel economically at low capacities, even for local markets of the order of 100,000 metric tons per year; for example, the fixed-bed gaseous direct reduction processes are scaleable in the range from 100 to 2,000 metric tons per day of iron in the form of sponge (72,000 to 1,440,000 metric tons per year of refined liquid steel). This rangeability (Fig. 52) is of great interest for fostering the development of countries or regions, because conventional processes show minimum economic capacities of the order of 200,000 for non-flat products and 500,000 metric tons per year for flat products (Ref. 1). It is evident that this rangeability, particularly of the fixed-bed processes (Fig. 53), is an important characteristic of the direct-reduction processes, for it gives the facility of introducing the siderurgical industry to a country when the consumption is still at a very low level. Also, it permits the industry to grow with the same reduction technology up to the production levels of blast furnaces; it is also possible during the scale-up of production (Fig. 54) to progressively use the most convenient technologies in the departments downstream of the reduction step.

Another way of viewing the advantage of promptly achieving economic production of steel, even for local markets of the order of 100,000 metric tons per year, is illustrated in Fig. 55. The middle curve, a, is the demand as a function of time assumed for a country under development.

The lower curve, b, is the probable production of steel or the capacity of production, assuming conventional processes to fulfill the demand. It is most probable that the installation of conventional capacity will usually be delayed until the demand grows above the minimum economic size for conventional processes. This results in a deflection of the production curve with respect to the demand.

The upper curve, c, represent the possibility of production with gaseous direct reduction, which can be used to introduce the siderurgic activity at levels lower than conventional. This gives as a result a favorable deflection of the production curve with respect to the demand and it leads to [illegible] consumption of steel and the overall development of the country because of the availability and price of steel products; there exist also the possibility of participating in the export market.

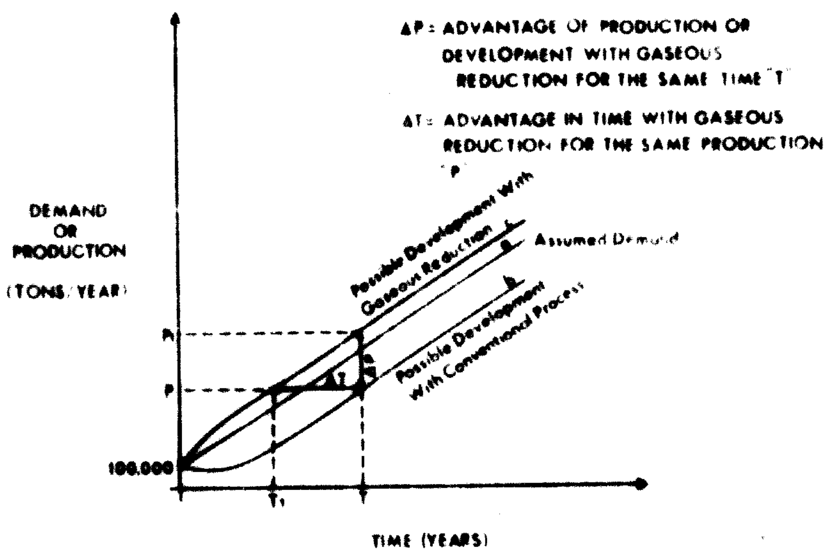
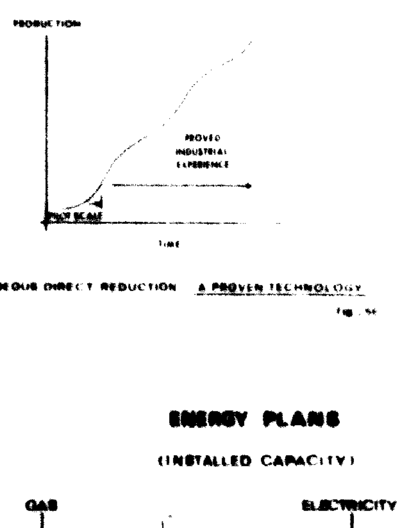


fig – 55



GASEOUS DIRECT REDUCTION A PROVEN TECHNOLOGY

fig. 56

In the case of conventional processes, the deflection of the curve tends to discourage consumption and to cause the importation of steel products. It is possible that this may represent a particularly unfavorable deflection of a country's development, in some cases.

Comparing the curves we see that for a given time, t, there is a difference of production ΔP which is favorable and which represents an advantage in the industrial development when direct-reduction processes are used. Similarly, to achieve the same level of production, we see that there is a difference in time, Δt, between the two cases. Both factors ΔP and Δt, are favorable for the assumed case of gaseous direct-reduction processes versus conventional processes.

A second advantage (Fig. 56) which is derived from using or considering the use of gaseous direct reduction processes in countries under development is that the techno-

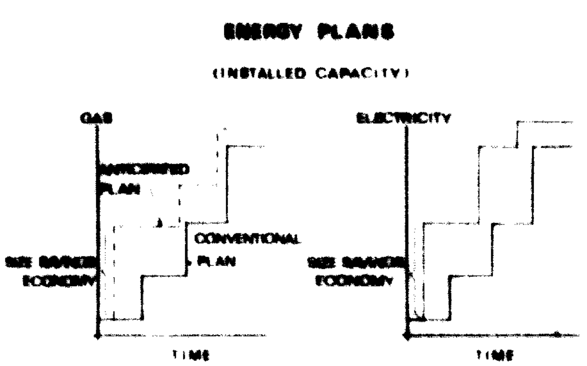


fig – 57

logy of some of these processes has been proved commercially on an industrial scale by many years of experience. It is not an unknown element to be tested. It is possible to determine with industrial-scale data the characteristics and performance.

From this second advantage, there is derived a third advantage (Fig. 57) which it is well worth pointing out in particular, for by counting on this proved technology it is possible to advance on a firm basis the development of energy sources (gas and electricity) within the overall industrial development. It is well to conceptually explain this aspect to a certain degree.

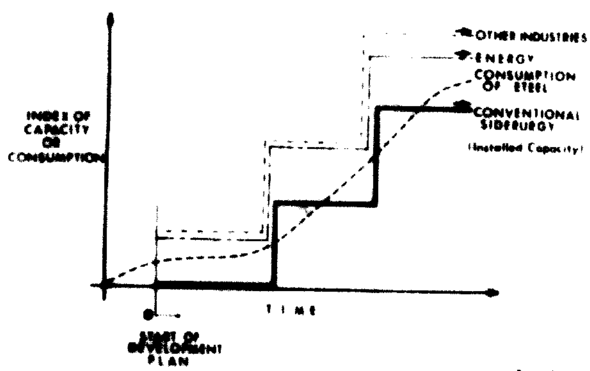


Fig-58

Normally, or at least in an exemplified case of a country under development with low initial consumption of steel products, the course of development would usually lead to introducing the steel industry at some point beyond the beginning of industrialization (Fig. 58) to correspond with a phase in which it would be expected to supply a local demand above the minimum economic capacity for conventional processes (200,000 metric tons per year non-flat, 500,000 metric tons per year flat products). Thus, the usual course of industrial development would lead to a reduced energy plan at the beginning.

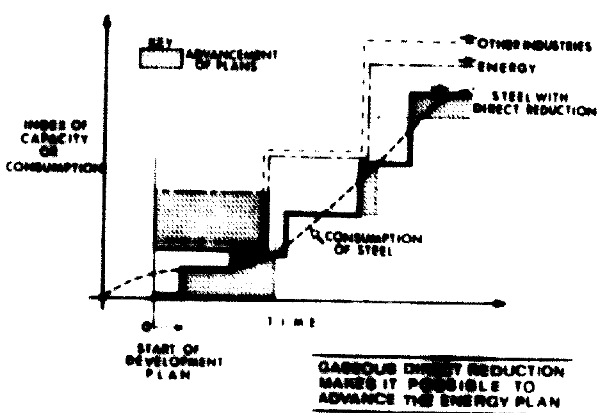


Fig-59

On the other hand (Fig. 59), if it is considered that a siderurgical process of gaseous direct reduction is introduced from the beginning, the energy plan may be advanced, thus installing from the beginning energy capacity to supply the steel industry. This consideration introduces size savings into the energy plan which in turn may be beneficial for the group of industries featured (Fig. 60) in the industrial development and it would catalyze all of the process of industrial development. This would accelerate the growth of the economy in general.

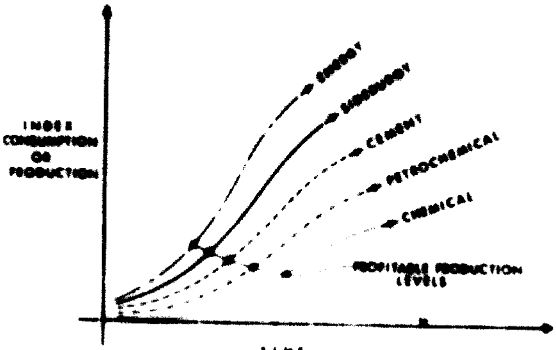


Fig-60

A fourth advantage which accompanies the use of gaseous direct-reduction processes is also related to the energy sources. This advantage resides (Fig. 61) in the fact that in joint promotion of industrial development it is possible to consider and provide for the simultaneous energy requirements of the steel industry together with the petrochemical industry, which in turn permits the optimization of the energy supply, making allowances as well for the priority and assignments of the energy uses in optimum form, with the possibility of achieving economies of scale in the energy systems, also making

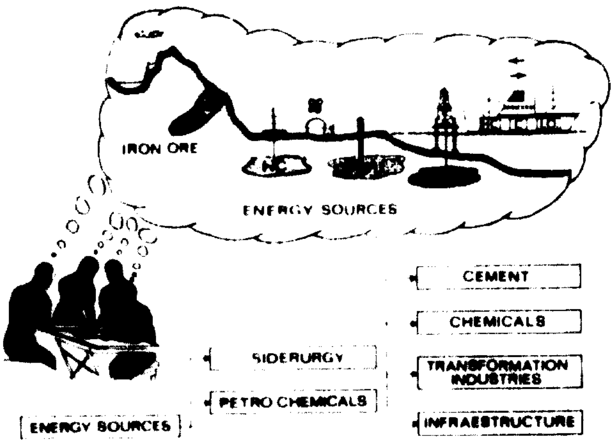


fig - 61

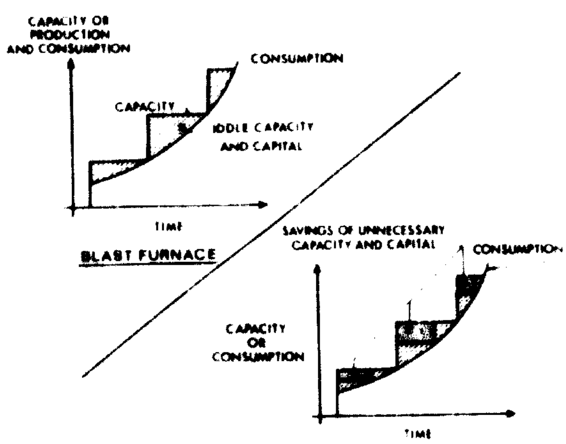


fig - 62

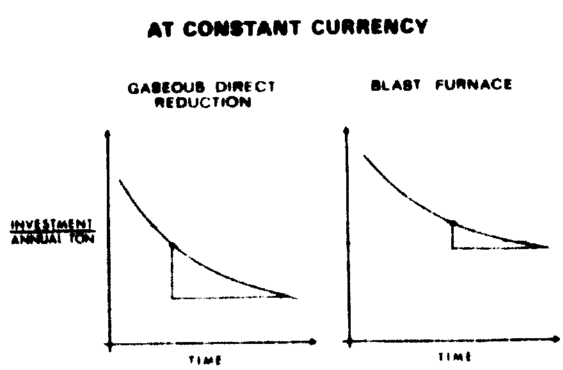


fig - 63

it feasible to avoid, in so far as possible, non-programed and costly modifications or additions to the energy systems.

A fifth advantage of the use of gaseous direct-reduction processes in countries under development is the lower relative capital investment per ton compared to coke oven-blast furnace combination (Ref. 55). This leads to an effective use of capital, which is particularly scarce in countries under development. Also, the successive investments are deferred as much as possible, thus avoiding in great part both idle capacity and idle capital (Fig. 62).

Another way of viewing the concept of capital investment per annual ton is in regard to its relationship with possible technological (Ref. 28) and capital forecasts (Fig. 63). It may be observed that gaseous direct reduction is a much newer technology which is still high on its curve of development; such a curve descends with time for most processes, as may be appreciated in the illustrated graph of Fig. 63. Thus, the direct-reduction processes have a greater potential for further cost reduction.

On the other hand, the blast furnace is very much advanced along its curve of development, so its potential for diminishing investment is less than for the gaseous direct-reduction process.

If we observe the following graph, Fig. 64, we will see that the HyL gaseous direct-reduction process, at real prices, had shown a diminishing capital investment per annual ton.

A sixth advantage of the use of gaseous direct-reduction process in countries under development is related to the possibility of achieving good quality control promptly, particularly with regard to the problem of residual elements in the melting of scrap. By using mixtures of sponge iron and scrap, the level of residuals may be diminished with great facility by the effect of dilution and slag reactions, thus making it possible to use lower-priced scrap. This is important to promptly achieve profitable production of a variety of quality steels with an effective quality control, even at low levels of production.

A seventh advantage which is derived from the use of gaseous direct-reduction process is related to certain ecological and economic aspects of the use of scrap. In melting sponge iron and scrap in an electric furnace many

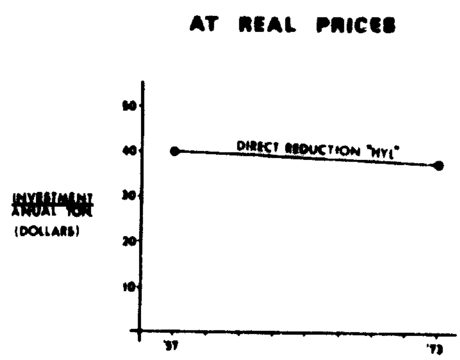


fig - 64

different proportions of sponge iron and scrap may be used, in the range from zero to one hundred percent, as a general principle. It is common to use proportions of sponge iron above fifty percent.

In any case, the possibility of using appreciable quantities of scrap has two ecological implications (Ref. 20-23) derived from recycling the iron units contained in the scrap:

-Energy sources are conserved by using scrap, because it is not necessary to again use energy for reducing the iron units of the scrap.

-Non-renewable iron-ore reserves tend to be conserved by using appreciable amounts of scrap.

fig - 65

It is well to note another ecological aspect (Fig. 65) of the use of gaseous direct-reduction processes in a country under development. Because the steel industry can be introduced at a low level of production as mini-steel plants, the successive location of these in more than one place within the country may be considered, thus avoiding the excessive industrial concentration which so characterizes developed countries as well as some countries under development. Thus, a country can disperse its centers of industrial development throughout its territory and so tend to avoid the macrocephalic phenomenon which is observed in some countries that prematurely formed megalopolises.

The location of mini-plants (Fig. 66) may be strategicaly determined according to the centers of development which it is desired to foster in the country. This may lead to the establishment of siderurgical industries in places where the usual viability studies for conventional processes would not commonly indicate as convenient. It may lead to fabricating steel in uncommon places - the middle of a desert or arid zone, in arctic zones, in the prairies of highlands at great altitude or on the coast by the sea, etc. "Steel making in unheard-of places".

In Mexico we have (Fig. 67), for example, steel industry diseminated in various parts of the country (Ref. 26, 55), consisting both of conventional processes as well as those of gaseous direct-reduction. Considering only those of gaseous direct reduction, there is the case of a steel plant along the coast of the Gulf of Mexico at Veracruz, three plants in the arid and desert zones of the northern part of the country at Monterrey and one plant in the highest prairies of the Mexican

fig - 67

highlands at Puebla, where the altitude is 2151 meters above sea level and where the barometer stands at 672 millimeters of mercury.

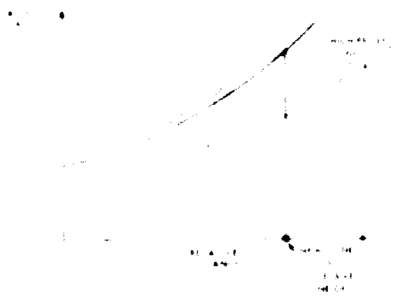


Fig. 68

In principle, it may be objected that the scheme of diseminating the centers of development is not economical. Nevertheless, it is well to observe (Fig. 68) that there are many factors which determine the economy of a project and the remotness or separation have only a relative effect; for after all, a remote center of development will in any case tend to represent at the beginning an economic activity carried out at higher cost but all local transformation tends to ultimately abate the cost and improve the balance of payments of the zone surrounding the new center of development, thus tending to finally cause the local economy to "take off" in terms of its own products and services, thus more extensively catalyzing the general development of the country.

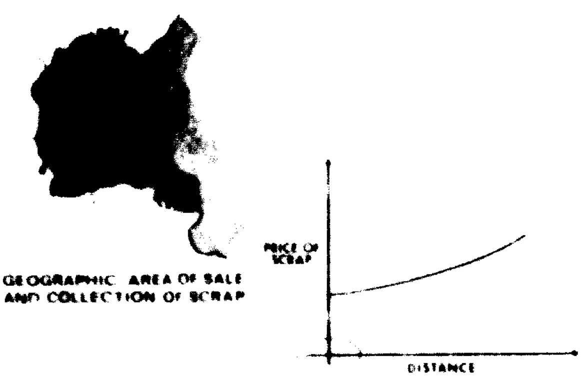


Fig. 69

This may be illustrated somewhat by the example of the scrap market (Fig. 69). In a place where local scrap is abundant, the price is usually less than at a greater distance where it is not abundant. Thus the greater price offered by the distant customer creates an economic potential which tends to favor the sale of scrap to the distant customer who pays more. At the same time, the collector of scrap may collect scrap in a larger geographic area because he may locate a distant customer and a greater price. The effect is to enlarge the geographic area for the collection and sale of scrap. The basic restrictions to this process are inherent in the transportation facilities and their cost, border crossings and other trade barriers etc.

It is well to consider that, on the edge of a geographic scrapmarket zone, an interesting economic situation occurs because of the comparison of alternatives (Ref. 27) which are available for siderurgic activity. For the siderurgist may consider fabricating steel under the following cases:

- By melting and refining scrap only, at its available price at his site,
- By considering various forms of producing pig iron or sponge iron, in which case it is necessary to incur capital costs – for coking-plant equipment, pig iron production equipment, and/or equipment to produce sponge iron; also it would be necessary to consider whether the country has cokeable coal as well as whether iron ore and natural gas are available and whether siderurgical equipment can be manufactured locally in whole or in part.

This is a very interesting set of alternatives. Let us examine them further.

A comparison of cases is presented in the table of Fig. 70 to show an example of the effect of substituting imported scrap in the commercial balance of a country for a hypothetical example (Ref. 27). Each case implies that certain terms of the trade balance are altered either favorably or unfavorably. Identifying the terms that change and the magnitude of the change, it is possible to estimate the net effect on the trade balance per ton of iron for each case. The base case for the comparison is the melting and refining

EFFECT ON THE COMMERCIAL BALANCE
OF SUBSTITUTING IMPORTED SCRAP
(US DOLLARS METRIC TON)

AFFECTED TRADE TERMS	CASE A: PIG IRON WITH LOCAL COKE	CASE B: PIG IRON WITH IMPORTED COKE	CASE C: SPONGE IRON WITH LOCAL NATURAL GAS	BASE CASE: SCRAP
IMPORTED SCRAP				40
CAPITAL COSTS OF IMPORTED EQUIPMENT AND SPARE PARTS				
FOR COKING	5			
FOR MAKING PIG IRON	6	6		
FOR MAKING SPONGE IRON			2	
IMPORTED CARBON OR COKE		21		
CONCENTRATED IRON ORE	27	27	27	
TOTAL UNFAVORABLE CHANGE IN TRADE TERMS	38	54	29	40
NET TRADE ADVANTAGE VERSUS IMPORTED SCRAP	2	-14	11	

FIG-70

of imported scrap. Thus to make steel in the alternatives cases, imported scrap must be substituted by pig iron or sponge iron. An assumed import price for scrap of $40.00 dollars per metric ton for this example. In order that the other alternatives be attrac-tive they must present a lower net change in import terms than $40.00 dollars per ton. The difference between the net change in import terms and the $40.00 dollars figure would represent the net favorable benefit for each case in the example.

Case A: Pig iron produced with local coke. In this case the changes in affected trade terms are the following:

Capital cost of imported equipment and spare parts for making local coke and for producing pig iron. These are equipments and spare parts that need to be imported under this case and as such represent an unfavorable change in the trade balance.

Concentrated Ore. It is assumed that the country possesses iron-ore resource which can be concentrated and pelletized to be exported at $27.00 dollars per ton of iron. Thus under this case, when the ore is used to produce pig iron to substitute imported scrap, each ton of iron so produced implies that a ton of iron as concentrated pelletized ore ceased to be exported. This represents an unfavorable change in a trade balance term.

The net change in trade balance terms for case A is $38.00 dollars per metric ton of iron which is $2.00 dollars less per metric ton than shown for the base case of imported scrap. Thus, case A is favorably compared to the base case in this example.

Case B: Pig iron produced with imported coke or coal. In this case the changes in affected trade terms are the following:

Capital cost for imported equipment and spare parts for producing pig iron.

Cost of imported coke

Concentrated Ore. The net change in trade-balance terms for case B is $54.00 dollars per metric ton which is $14.00 dollars more per metric ton than for the base case of imported scrap. Thus, case B is unfavorably compared to the base case of imported scrap in this example.

Case C: Sponge iron produced with natural gas. In this case the changes in affected trade terms are the following:

Capital cost of imported equipment and spare parts for producing sponge iron from locally available natural gas and iron ore.

Concentrated Ore. The net change in trade balance terms for case C is $29.00 dollars per metric ton of iron, which is $11.00 dollars less than for the base case of imported scrap. Thus case C in this example is very favorably compared to the base case.

This example illustrates the type of considerations which must be made when judging the economics of using a gaseous direct reduction process in a country under development. At the same time it illustrates a case in which it would be very favorable to use such a type of process. Each case must be judged in the light of many factors, as we have indicated before hand. Factors of installed capacity, local and foreign market, freight rates for products, etc., all must be considered. No real case is extremely simple.

It is well to note that the example of Fig. 70 relates to concentrated and pelletized ore. This need not be so in all cases, for it may be quite favorable to use a raw lump ore without need of concentration or pelletizing.

An eighth advantage which is derived from the use of a gaseous direct reduction process in a country under development is that related to the possible long-range technological forecast (Fig. 71) in the field of the energy sources of the future (Ref. 29, 30, 51, 52). It has been forecast that the energy sources of the future will adopt two forms: electricity and gas in the form of hydrogen. Both are ideal for gaseous direct-reduction processes which at the same time are accompanied by the use of electric furnaces for melting and refining.

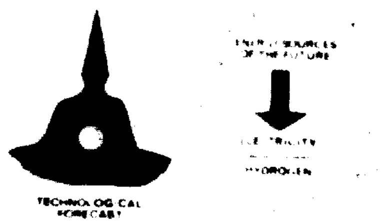


FIG-71

It is well to note that hydrogen would be an excellent reducing gas as well as a non-contaminating fuel.

It is foreseen (Fig. 72) that the future sources of energy (nuclear either by fusion or fision, thermal, or solar-space energy) will lead to the generation, transmission, and distribution of large quantities of electric energy. It is estimated that, if energy transmission were based on transmitting hydrogen, there would be marked advantages, because it is storable (Fig. 73) while electricity is not. Also it seems to be cheaper to transmit at great distances the same quantity of energy as hydrogen than as electricity.

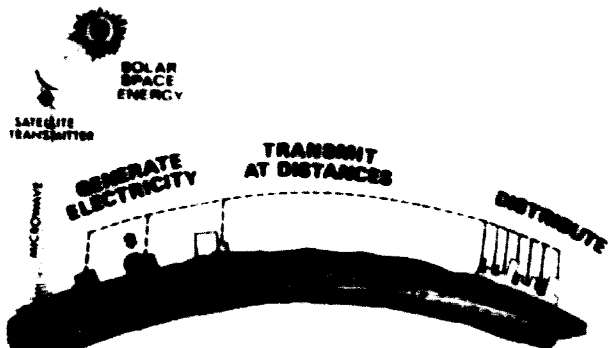
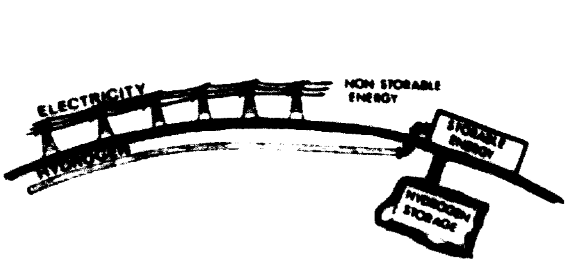


FIG-72

Hydrogen may be generated by chemical or electrical means (Fig. 74). Chemical means include reforming or gasifying a number of possible fossil fuels such as natural gas, hydrocarbon liquids, non-cokeable carbon, organic wastes (Ref. 31) from livestock, trash, etc. Electric means for generating hydrogen are basically those of electrolysis, which may be perfected greatly by taking advantage of the science and technology of fuel cells, for which efficiencies of the order of 80% are expected.



CHEAPER TO TRANSMIT ENERGY AS HYDROGEN ALSO IT IS STORABLE

FIG-73

The long-range forecast indicates, on the other hand (Fig. 75), that on a worldwide basis cokeable coal tends to be exhausted, while non-cokeable coals present great reserves (Ref. 32). It

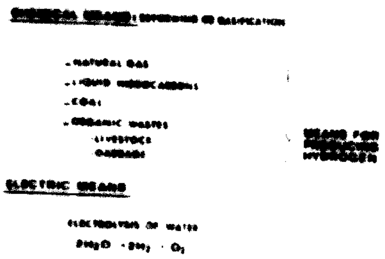


FIG. 74

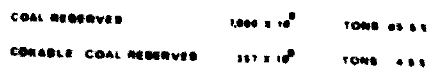


Fig - 75

is evident that such a forecast implies a limit to the technology of the blast furnace based on coke. On the other hand, it indicates favorably the possible development of methods of direct reduction which use carbon as a solid reducing agent, generally rotary furnace processes. It is not possible to delve into this here and it would have to be recognized that many different opinions exist in this regard.

Precisely, the concept that the future energy sources (Fig. 76) will lead to electricity and hydrogen is an important factor to underwrite the concept of disseminating centers of industrial development in a country by utilizing gaseous direct reduction and the electric furnace in siderurgical systems of the mini-plant type.

It is recommendable that persons engaged in coordinating energy sources and those who are responsible for fostering the development of a country take very much into account this aspect and if at all possible that they incorporate into their efforts such concepts as will be congruent with the technological forecast, looking toward achieving opportunely or anticipatedly an energy plan based on electricity and hydrogen.

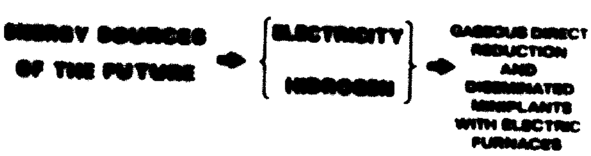


FIG.- 76

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