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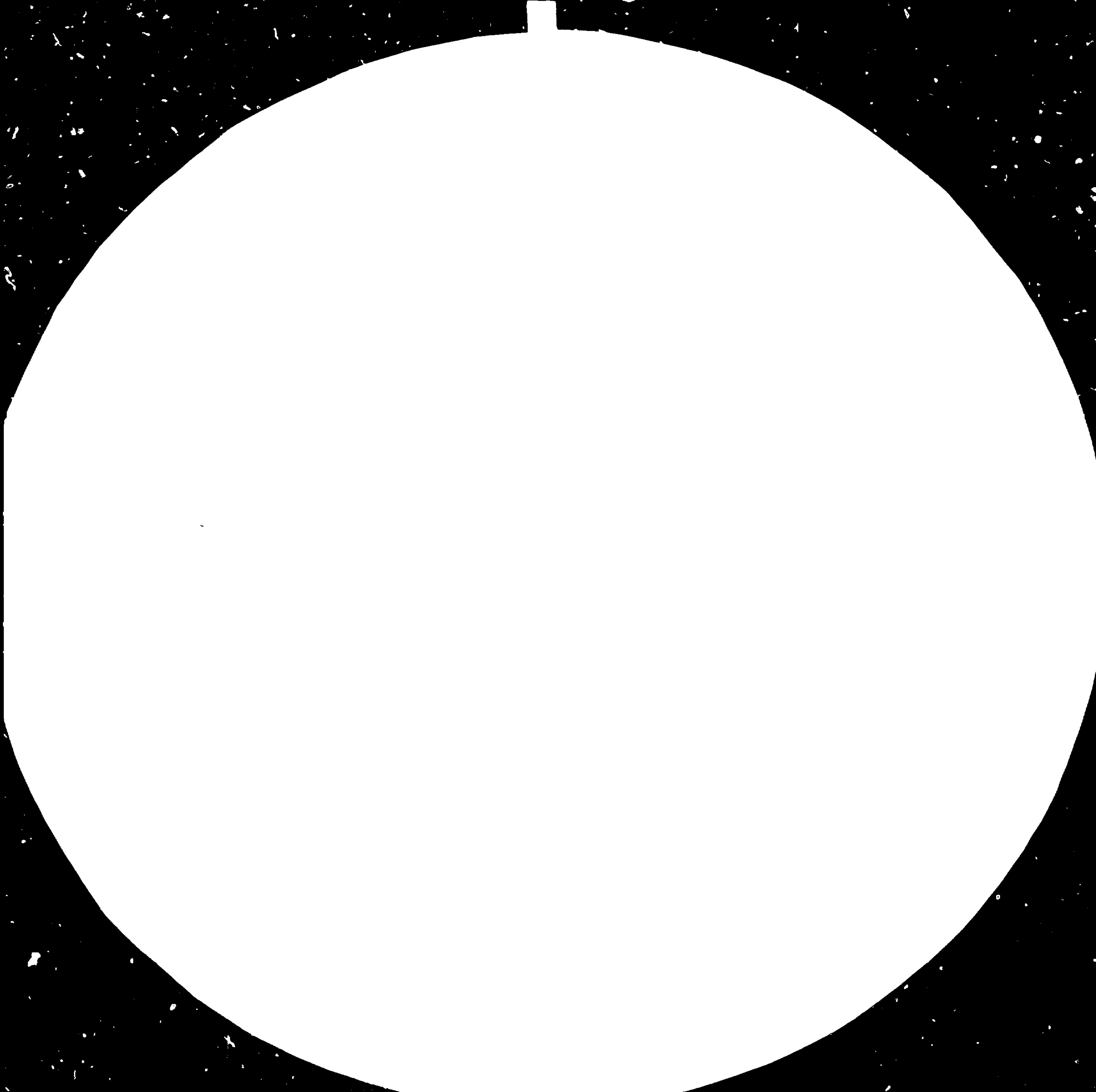

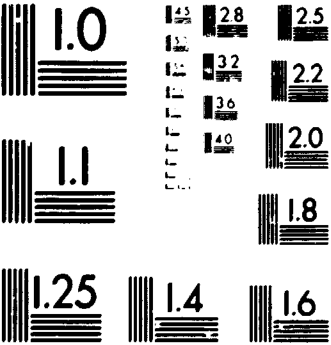
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REGIONAL CENTRE FOR TECHNOLOGY TRANSFER

OF THE ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

13949

STUDY TOUR AND WORKSHOP TO PROMOTE TECHNOLOGY DEVELOPMENT AND TRANSFER IN THE AREA OF SPONGE IRON MANUFACTURING IN DEVELOPING COUNTRIES OF THE ESCAP REGION

Indonesia and India 29 March - 8 April 1983

PROCEEDINGS. (Workshop on sponge iron).

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UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO)
ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC (ESCAP)
REGIONAL CENTRE FOR TECHNOLOGY TRANSFER (RCTT)

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OF THE ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

10

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UNDP/UNIDO/ESCAP/RCTT

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Study Tour and Workshop to Promote Technology
Development and Transfer in the Area of Sponge
Iron Manufacturing in Developing Countries
of the ESCAP Region
Indonesia and India
29 March - 8 April 1983

REPORT OF THE WORKSHOP

This report has been reproduced without formal editing.

1. BACKGROUND INFORMATION AND OBJECTIVES OF THE WORKSHOP

In view of the growing importance of direct reduction processes in the ESCAP region, several technical advisory missions and meetings have been carried out under the auspices of UNDP and UNIDO to focus attention on problems and potentials of developing viable iron and steel industries in the developing countries of the world. In recent years promising technological changes have taken place in the iron and steel industries and it is now possible to establish viable plants on a much smaller scale, based on sponge iron production and its melting in electric arc furnaces to produce commercial grades of steel. Ways and means of increasing regional steel production by means of application of modern steelmaking technology, and, in particular, the direct reduction process, remain yet to be explored.

Within the UN family, ESCAP and RCTT (Regional Centre for Technology Transfer, Bangalore) have also been active in promoting activities in the planning, establishment and operation of direct reduction units. With assistance from UNDP and the Government of Netherlands, UNIDO, ESCAP and RCTT organized during 1979 a workshop on problems of technology transfer for promotion of sponge iron industry in the countries of the ESCAP region, in Bangkok, Thailand. UNIDO organized in Jamshedpur, India, in December 1981 a workshop on regional co-operative research among metallurgical research and development centres in Asia and the Pacific where the importance of exchange of information on direct reduction was also discussed.

In order to further promote regional co-operation and continuous exchange of information on the subject, UNDP, UNIDO and RCTT have organized the present Study Tour and Workshop in Indonesia and India to discuss latest technological advances in direct reduction processes and use of sponge iron and discuss possibilities for further development of this industry in the region.

Two plants were chosen for the study tour:

1. P.T. Krakatau Steel (PTKS), Indonesia, a large DR plant utilizing natural gas, established at Cilegon, with HYLSA (Mexico) technology. The plant has an ultimate capacity of 2 million tons of sponge iron per year.

2. The Pilot and Demonstration Plant of Sponge Iron India Ltd. (SIIL), at Paloncha Kothgudem, with a capacity of 30,000 tons per year, using the SL/RN (LURGI) direct reduction route based on non-coking coal as a reductant.

Apart from the above plant visits to study the solid reductant and gas based reductant direct reduction technology, the Workshop had the following objectives:

1. To discuss the status of the DR industry in the ESCAP countries (current state, future projections and possibilities in the global context of the iron and steel industry);
2. To review the current state of the DR technology based on various reductants (solid, gaseous);
3. To study the introduction of a regional project for the promotion of sponge iron production for different technological groups in the ESCAP countries;
4. To consider a request for UNDP assistance in the development of sponge iron industry through direct reduction technology for mini-steel plant operations in those countries which express interest and have the potential for such an industry;
5. To consider other regional activities in this field including the establishment of a network of institutions engaged in the area of sponge iron.

2. PROGRAMME OF THE WORKSHOP

The following programme was observed:

29 March 1983	Arrival of participants in Jakarta, Indonesia
30 and 31 March 1983	Travel to Cilegon, visit to Krakatau Steel Plant, briefing by plant authorities and discussion and return to Jakarta
1 - 3 April 1983	Travel to Hyderabad, India, via Singapore and Madras
4 April 1983	Arrival at Paloncha and visit to Sponge Iron India Limited followed by discussions
5 April 1983 to 7 April 1983	Arrival at Hyderabad for Opening Session, presentation of Country Papers and Discussions including observers from HYLSA, LURGI and MIDREX
8 April 1983	Concluding Session with adoption of the report and approval of project document for the proposed regional project.

Visits were undertaken to the Pilot Plant of the National Mineral Development Corporation in Hyderabad and to the Nagarjuna Steels Ltd., at Patancheru, with cold rolled steel strip production.

3. ATTENDANCE AT THE WORKSHOP

The Workshop was attended by participants from 13 developing countries of the ESCAP region. The list of participants is contained in Annex I.

The Workshop was officially inaugurated on 5 April 1983 by Mrs. N. Buch, Joint Secretary to the Government of India, Ministry of Steel and Mines, Department of Steel. UNDP was represented by Mr K.J. Priestley, Resident Representative, UNDP, New Delhi, and Mr P.N. Pathak, Programme Officer. Opening speeches were also given by Mr B.R. Devarajan, Director, Regional Centre for Technology Transfer, Bangalore, Mr B.R. Nijhawan, Senior Interregional Adviser, UNIDO and Mr S. Vangala, Managing Director, Sponge Iron India Limited. The international organizations were further represented by Mr C.V.S. Ratnam, Adviser on Science and Technology Policy, Regional Centre for Technology Transfer, Bangalore, Mr V.I. Korchkov, Economic Affairs Officer, ESCAP Secretariat, Bangkok, and Mr A.B. Krasiakov, Senior Industrial Development Field Adviser of UNIDO, stationed at New Delhi. Mr F. Iqbal, Senior Industrial Development Field Adviser of UNIDO stationed in Jakarta only attended the study tour to the Cilegon P.T. Krakatau Steel Plant.

During the opening session the efforts of UNDP, UNIDO and RCTT in organizing such a Workshop and Study Tour were highly appreciated and hope was expressed that these would result in a regional project of cooperation.

4. ELECTION OF CHAIRMAN AND VICE-CHAIRMAN

Mr S. Vangala, Managing Director of Sponge Iron India Ltd. was elected Chairman. Messrs. Wi Juxian, Engineer, Central Iron and Steel Research Institute, Beijing, People's Republic of China and Mr Fazwar Bujang, Direct Reduction Plant Superintendent, P.T. Krakatau Steel were elected as Vice-Chairmen. Mr M.Z. Qazi, Principal Scientific Officer, Pakistan Council for Scientific and Industrial Research, Lahore, was elected Rapporteur of the Workshop.

5. STUDY TOUR TO DIRECT REDUCTION PLANTS

(a) Visit to P.T. Krakatau Steel on 30 and 31 April 1983

The plant tour with emphasis on the DR plant and the billet plant took place on 30 April whilst participants were provided with general information, followed by discussions on 31 April. Two papers were presented to the participants which provide detailed information on the plants: "Direct Reduction Plant as Part of the First Indonesian Integrated Steel Plant" by Mr Fazwar Bujang, Superintendent, Direct Reduction Plant, and "Aspects of High Ratio DRI Melting Practice for the Production of Weldable High Tensile Reinforcing Bars in the Electric Arc Furnace" by Mr Chosdu Sai' in, Superintendent, Process Engineering and Quality Control - Primary Operation. These papers can be made available upon request. The welcome speech and introduction to the plant was made by Mr Djoko Subaigo, Associate Production Director.

Participants were informed that the second stage of the DR plant of one million tons which brings total installed capacity of the plant to 2 million tons had been completed in August 1982. A hot strip mill, of semi-continuous type, with a capacity of 300 tons/hour, had also recently been commissioned (February 1983). This mill, together with the sheet strip mill will have a total capacity of about 1 million tons/year.

The P.T. Krakatau Steel Plant further comprises a billet making plant equipped with 65 t EAF, 4 stands, 2 continuous billet casters, with 500,000 tpy capacity. The bar and section mill which were originally supplied from USSR have undergone expansion and modernization, with a present capacity of over 200,000 tpy, and also the wire rod strip mill with a capacity of 200,000 tpy made by a German company. The spiral pipe manufacturing plant has a capacity of 65,000 tpy, with the maximum size of 2 m pipe diameter. The cold rolling mill complex is a joint co-operation with the private sector, PTKS has a share of about 40%. Most of the hot coil to be produced will be taken by the cold rolling mill. The construction of the mill will start during 1983 to be completed by 1986. The plant also disposes of a training centre for vocational training. After presentation of the papers by Messrs. Fazwar Bujang and Chosdu Sai'in a number of technical and economic questions were raised, such as the possible affect of the recent devaluation of the Indonesian Rupiah on the steel price. Participants were informed that the price was Government controlled through import control and orientation on world market prices. The high energy consumption 4.85 Gkal per ton of iron in the sponge produced was also pointed out. This could possibly be brought down by adapting the plant which is of HyL I type to more recent developments in the process, such as HyL III. It was admitted that the plant was designed before the oil crisis and that in the light of world economic developments revamping would become desirable.

The labour force at PTKS is about 5,000. Training for the direct reduction plant took place in Mexico and for the slab steel plant in the Federal Republic of Germany. Of the 2 modules of the plant one is always in operation, a minimum amount of gas has to be taken under contract. With the billet plant operations reach about 48 weeks per year.

Asked about the possibility of providing assistance to other developing countries PTKS expressed their willingness, with the consideration that they themselves were very young steel producers. Staff for training could be accepted for short periods in the plant as such or 1 - 2 staff members from PTKS may visit the plant to assist in a limited field such as in the method of melting sponge iron and in the production of sponge iron itself, taking into consideration that the process used in PTKS plant is based on HyL I. Questioned about the approximate investment cost participants were informed as follows: including infrastructure the plants' investment cost were about 2,5 billion US dollars. Before completion of the slab mill the ratio was 65% for infrastructure and 35% for production facilities. With the completion of the slab mill the production facilities now account for 70% of the total investment. The UNIDO representative referred to plants in Iraq and Venezuela using the same process and an investment cost of about 110 US$ per ton of installed capacity was recorded in the early 70's for Iraq and about 200 US$ for Venezuela. He pointed out that latest figures were given in a recent publication by Father Hogan, USA.

With a combination of 80% coal and 20% oil the DR plant with 150,000 tpy capacity in Orissa will have an energy consumption of about 3 Gcal per ton of sponge produced.

The licence agreement of the company is based on a lump sum payment for ten years, independent of production.

In the experience of PTKS the consumption of electrodes in a plant using 60% of sponge iron in the charge was not increased.

At the inquiry of PTKS UNIDO expressed its readiness to provide technical assistance that might be required such as in the revamping of the plant.

Further information on the plant is available in Mr Fazwar Bujang's second paper entitled "Some Notes on the Commissioning of the Direct Reduction Plant" which he presented during the Workshop deliberations in Hyderabad.

(b) Visit to Sponge Iron India Ltd., on 4 April 1983

Sponge Iron India Limited (SIIL) is located about 280 kms from Hyderabad, at Paloncha, Kothagudem, in the State of Andhra Pradesh. The plant was established with assistance from UNDP/UNIDO and cost sharing by the Indian Government, both convertible and non-convertible contribution. The plant is a pilot and demonstration plant with a test centre intended to test various raw material combinations mainly iron ore and coal from India and abroad to their suitability and techno-economic feasibility of producing sponge iron from lumpy iron ore and non-coking coal. The Test Centre is specifically designed for catering to plant production and process control, bench scale and semi-commercial test work and for carrying out fundamental and applied research work in the field of coal-based direct reduction processes. The plant uses the SL/RN process know-how of LURGI Chemie, FRG. Details of the 30,000 tpy plant are contained in the country paper of the Indian representative, Mr S. Vangala, Managing Director, SIIL, which provides data on Indian raw materials for iron and steel making and present developments in India. At the time of visit of participants to the Test Centre testing of reducibility was under way using coal from Pakistan and iron ore from the Indian deposit of Hospet. The technical details about the test programme were explained. Some of the main features of the Test Centre are:

a) Plant process control (chemical laboratory, X-ray fluorescence spectrometer; magnetic balance; Leitz heating microscope);

b) Bench scale test work (laboratory salvis rotary kiln, static reducibility apparatus, apparatus for reactivity of coal; short rotary kiln tester);

c) Semi-commercial demonstration test runs;

d) R and D facilities including differential thermal analysis; vacuum emission spectrometer, X-ray fluorescence spectrometer and metallurgical microscope. Engineering and consultancy services in basic and detailed engineering of coal based direct reduction sponge iron plants can be provided from the conception stage into the commissioning of the plant.

For those participants who joined the Group later in Hyderabad and could not visit the plant, a 18-minute movie was shown. Various technical questions were raised and information provided is summarized as follows:

The plant is operating at 95% of rated capacity of 30,000 tpy and is selling its sponge to mini steel plants in different parts of India. In view of the successful operation which was achieved right from the start, expansion is envisaged and construction work is under way to establish an identical unit with the same capacity. Equipment for second plant will be produced mostly in India. Operation is expected by end 1984. The same capacity was chosen for reasons of identical equipment, spare parts and maintenance and ready infrastructure facilities available for the plant layout.

For this purpose, independent feeding circuits for iron ore, coal and limestone will be introduced.

Solutions will also be found for waste material and UNIDO is presently assisting with a study on the processing of sludges into value added products such as using them for production of roof and wall tiles.

The process is working on 100% coal. Initially the rotary kiln was heated up with oil whilst now coal tar is being used. The kiln is 40 metres long and has a diameter of 3 meters. Energy consumption of 5.5 - 5.6 Gcal. per ton of iron is rather high due to poor quality of coal with a high ash content. A 20% decrease could be achieved with a better quality coal.

The refractory lining of the kiln is about 200 mm in thickness. It was assumed that the lining would last at least 4 years and would at no time have to be replaced in toto. The kiln has refractory brick lining and high alumina refractory in the reduction zone. Critical points were only the reduction and discharging area. The RPM of the kiln may be selected between 0.3 and 1, depending on the feed. Operating days are about 300 per year with breaks every 90 - 95 days. The cooler is of similar construction as the rotary kiln, with 20 m length and 2.2 m diameter.

The carbon content of the sponge iron ranges between 0.15 and 0.5%, mostly around 0.25 - 0.3%,and is free graphitic carbon type.

The separation of the sponge iron depends on the efficiency of the magnetic separation which may lead to contaminants in the product. Initially such contaminants counted for 5 - 6 % which is now down to 2% with the objective of bringing them down to 1% only. The lack of carbon may create a problem in steelmaking; a carburizing product could be added to the EAF charge that would offset such a shortcoming.

The sponge presently produced is sold to mini steel plants in India which are using it in various proportions with scrap charge. In the transportation and storage, the low carbon sponge [illegible] a much higher resistancy to re-oxidation. In fact, when exposed to rain in wagons only the outer material had lost some 5% of metallization. Sponge such as from PTKS was more liable to re-oxidation, which had reportedly occurred.

On an inquiry SIIL informed about the charging proportions and consumption per ton of sponge produced: Iron ore run-of-mine 2.5 tons, from which after crushing 1.5 tons of screened ore are used, coal 1.4 tons and limestone 0.15 tons. The quality of iron ore tried ranges from 62% minimum Fe to 66 - 67% Fe content. The plant is based on 62% Fe containing iron ore, with acid gangue of 7%. Other common ores used have an Fe content of 64% with acid gangue of 5 - 6%. S content is about 0.01 and P content 0.05%.

The investment cost of the plant could be taken at around 400 US$ per ton installed capacity. The production cost is around 1200 - 1400 Rs.per ton including raw material cost, fixed costs, operation costs.

The generation of iron ore fines during crushing was considered large and one of the participants suggested autogenous grinding of ore to reduce the fines. The Managing Director informed that steps are being taken to cope with this shortfall and development work is under way to utilize them through sintering. The initial trials produced sinters of sufficient mechanical strength. Samples were shown. However, after the sinter was reduced the iron content was still found to be low and may not be suitable for the EAF charging. They may however be used for ironmaking by melting in hot blast cupola furnace. Work is going on to find a satisfactory solution. Further testing was considered necessary.

Retention time of the charge in the rotary kiln was reported at 5 - 5.5 hours, including time in the cooler about 7 hours.

Limestone used was about 5% of the total feed. Initially limestone to an extent of 10% was used. Due to the quite low S content of the coal (about 0.7%) the limestone consumption could be reduced. Instead of limestone dolomite could also be used. In case of very low S content of the coal no limestone may be needed and it is advisable to avoid use of limestone as it increases the tendency of sticking in the kiln. Asked about the size distribution of sponge iron, SIIL informed that 1 - 8 mm fraction accounts for 20 - 25% and the balance is 8-18 mm. Buyers preferred the +3 mm size range in order to avoid any risk of sticking of the fines in the EAF. In India most of the furnaces do not have continuous charging systems. Such material of -1 to - 3 mm range could be briquetted.

The maximum storage capacity of the plant is about 1,500 tons or 1 1/2 to 2 months.

Asked about slag volume generated in the EAF this was reported to be about 15 - 25% in the case of 50 to 60% sponge iron charge. The product required by the EAF plants should have a minimum of 88% and a maximum of 92% metallization.

6. PRESENTATION AND DISCUSSION OF PAPERS

On 5 April 1985 the Workshop started with the presentation of country papers. Papers were presented by all the participating ESCAP countries. The list of papers is contained in Annex II. Summary of the papers, or in case of short papers, the entire papers are reproduced in Annexes III to XV. Presentation of papers were taken up in alphabetical order. Short summaries of the discussions are provided as follows:

Democratic Republic of Afghanistan

The country has plans to build a mini steel plant based on scrap and asked for UNIDO assistance in the practical implementation of such a project. It was informed that UNIDO, although not financing investment, may provide all necessary technical advisory services that were required, arrange for training and supply certain items of equipment of laboratory and investigation type. Iron ore deposits are reportedly of high quality. Total steel requirement is about 10,000 tpy only. Infrastructure is lacking which causes a serious problem. The summary of the country paper is given in Annex III.

Socialist Republic of the Union of Burma

Burma operates a 20,000 tpy Kinglor-Metor DR plant. Several questions were raised and information was provided as follows:

The cost of production of sponge cannot be compared, in the case of Burma, with scrap based steelmaking since scrap is very cheap there (war surpluses). The need of the country is around the 20,000 tpy level. The EAF has to be stopped during peak hours because of lack of electricity. Storage facilities for sponge are available for about 6 months.

Some mechanical maintenance problems had occurred when taking out the sponge to the cooling hopper water jacket. The cooling zone and reduction zone is subdivided. The P content in sponge iron is 0.04. The plant can operate 330 days per year as claimed by the process supplier. Due to energy supply and maintenance problems they had to stop for about 6 weeks. A rate of 60 tons/day can be achieved. The total cost of the project including EAF and sizing plant was about 17 million \$. Operating temperatures at the top zone are 800°C in the reaction/reduction zone 1050°, 1st stage of cooling hopper 400°C, second cooling hopper this will be decreased to 80°. Cooling time is about 2 hours. An expansion of another 20,000 tons is foreseen which will bring total investment to about 40 million \$. UNIDO considered the investment to be a very high one and suggested that Burma should also look into other possibilities, i.e. alternative routes. UNIDO assistance may be required in this aspect. The summary of the country paper is contained in Annex IV.

People's Republic of China

A number of laboratory and pilot plant work has already been undertaken towards the operation of DR route. UNIDO participant referred to assistance that had been provided to China in a number of other metallurgical projects. UNIDO had also proposed a project for establishment of a pilot and demonstration plant and this had been taken up during the recent visit of UNIDO representatives to China. Steel production in 1982 was well over 37,8 million tons. The summary of the country paper is contained in Annex V.

Republic of India

The summary of the Indian country paper is presented in Annex VI. As all participants were fully aware of SIIL activities and had been given opportunity to discuss all questions earlier, no discussions took place.

Republic of Indonesia

Mr Fazwar Bujang's paper "Some notes on the commissioning of direct reduction plant" provoked a number of comments and questions outlining as it does, all the difficulties encountered when establishing the first module of the HyL I plant. A summary of the paper is contained in Annex VII. It was recommended that the raw materials proposed to be used for such a plant should be carefully tested, at least on a semicommercial, if not a commercial scale. Such work should be undertaken by the Contractor, as the source of raw material supply was usually known before establishment of the plant. Adequately trained personnel in a sufficient number should always be available as counterpart during the construction and erection stages. It was questioned whether the HyL I plant could be transformed into an HyL III one and energy consumption decreased. The process supplier's representative confirmed that this could be done would however be a large size project. As in Monterrey a moving bed reactor could be installed to replace the 4 reactors.

It was felt that the process and equipment suppliers should give performance guarantees on sound techno-economic parameters. In the case of Indonesia the technology may have to be modified to prevent clustering and sticking and bring energy consumption down.

The Midrex representative informed that his company undertakes complete testing of the ores proposed to be used, laboratory, tumble and sticking tests and basket tests and commercial trials before guarantee for running the plant is given. He suggested that in some cases it was advisable to send a representative to the mine site and observe shipping to make sure the agreed type of ore is received. Testing was usually low in cost compared to overall investment, laboratory and basket tests would cost around 2,000 to 3,000 $ each.

Training was considered a very important factor. It should however be tailored to the needs of the country and the Contractor should work out what training is recommended rather than to offer what they have.

The SIIL representative again referred to the possibilities for countries having their raw materials tested in India, if the DR coal based route is envisaged.

Islamic Republic of Iran

When the HyL and Midrex plants will be commissioned then the experience may be reported. The representative felt that companies after having supplied the first engineering and equipment they were not willing to inform readily on improvements to the process. It was suggested that UNIDO and RCTT gather enough information about raw materials and products like sponge iron oxide pellets and steel for the countries of the ESCAP region.

The UNIDO representative referred to his previous visits to Iran and that testing of ores also took place, years back. Work for Isfahan and Ahwaz project was presently under way with large contractors on bilateral basis. For Isfahan, bidding is taking place. The LURGI representative mentioned that the pelletising plant is being finalized while the Ahwaz plant was under construction. The Dastur and Co representative inquired how revamping of the Purofer plant was foreseen. He was informed that Iran plans to operate it with their own experts, having gained the experience. The only problem was the briquetting plants were the segments are breaking very often and a lack of spare parts.

The process suppliers pointed out that improvements were taken place continuously. Introduction of such improvements in relatively new plants can be done but is expensive. Since the plant in Iran has not yet started the Iranian representatives asked that latest technology be introduced, they are willing to pay the cost. The text of the paper is contained in Annex VIII. The Iranian Delegate made a closing statement which is presented in Annexure VIII-A.

Malaysia

A DR plant will be established with Nippon Steel as the Contractor. That will be Nippon Steel's first commercial plant to operate. The other contract, for a plant in Sabah is with Midrex.

The Japanese plant will cost about Malaysia $ 833 million.

The Malaysian representative asked if UNIDO assistance could be provided in the training programmes that are envisaged and was advised to submit an official request from the Government through the UNDP office.
The Country Paper is given in Annex IX.

Islamic Republic of Pakistan

A DR plant is under consideration. At present Pakistani coal together with Indian iron ores are being tested at the SIIL plant. The coals are of high S content. The tests are not yet completed and will take another 3 months.

UNIDO had at many occasions provided assistance to Pakistan such as in the establishment of Metals Advisory Services and in preparing a Master Plan for the Iron and Steel Industry until the year 2000.

The natural gas that is available is used for household and fertilizers. Until new deposits are discovered this reductant would not be available for sponge iron production.

The summary of the country paper is contained in Annex X.

Republic of the Philippines

A sponge iron plant is under consideration. All the necessary raw materials are available. Technology and a financing scheme are needed. It seems that the plan for establishing the plant has been postponed and emphasis will be laid on modernizing existing iron and steel production facilities.

The summary of the country paper is given in Annex XI.

Republic of Korea

The country paper is contained in Annex XII. No comments were made, since the country has no plans of establishing DR plant at the moment.

Democratic Socialist Republic of Sri Lanka

The country paper is contained in processing of heavy mineral beach sands (ilmenitic) for which investigation work was successfully carried out by UNIDO. No fuel, apart from coconut shell is available. Coconut is the third largest export item.

Kingdom of Thailand

UNIDO has been very actively involved in assisting Thailand. A Master Plan for development of the iron and steel industry until the year 2000 has been prepared with the help of a UNIDO sub-contractor.

Iron ore will have to be imported. Lignite coal is available. The price of natural gas is rather high. They might now consider the SL/RN process. They would like to procure sponge iron as a secure supply for the EAFs in the country. Half of the scrap demand is now imported. This could be substituted by locally produced sponge iron. Above all, scrap prices are fluctuating. India reported that a 10 - 20 kWh increase in power consumption was noticed using 20 - 25% sponge iron in the EAF instead of 100% scrap. In an ordinary

EAF a charge of 50-60% sponge iron could be used. In super and ultra-super power furnaces the sponge iron portion could be increased to as much as about 80%. The rest could be made up by scrap from the internal generation of the steel plant.

A summary of the paper is given in Annex XIV.

Socialist Republic of Vietnam

The country paper is contained in Annex XV.

The representative from Vietnam expressed desire to obtain training, through UNIDO, for specialists abroad. They have one rotary kiln, of local manufacture, operating.

7. INTRODUCTION OF PROCESS TECHNOLOGIES BY REPRESENTATIVES FROM HYLSA, MEXICO
LURGI Chemie and Huttenwerke, FEDERAL REPUBLIC OF GERMANY
MIDREX CORPORATION, USA; and
IPITATA SPONGE IRON LTD, TATA STEEL, INDIA

Leaflets and brochures and papers were handed out by LURGI on SL/RN coal based direct reduction - The state of the Art.

A paper was presented by the MIDREX representative "MIDREX Direct Reduction Process "State of the Art Technology"

The HYLSA representative will send brochures to the participants.

The representative from IPITATA Sponge Iron Ltd. presented a paper on "An appraisal of the current status of DR processes with particular reference to their adaptation in developing countries of the ESCAP region" and informed on the TATA DR process. The paper is available upon request.

Many technical questions were raised and discussed during the Workshop. These will be contained in the Proceedings which SIIL intends to compile.

The primary conditions for selection the DR route were considered to be:

1. Adequate reserves of high grade iron ore in the form of lump ore or pellets
2. Lack of matching availability of reserves of coking coal, otherwise the conventional BF route could be chosen more economically.
3. Adequate quantities of alternative reductants should be available (gaseous, solid, liquid).

The quality of DRI should be measured by the degree of metallization and the carbon content.

Questions specifically centered around the presence of non-metallics in the product (with special rerence to LURGI). A certain amount of such non-metallics was always present, about 4.5% with pellets, 1 - 1.5% with lumpy ore, depending on the iron ore. In the LURGI process the carbon content was around 0.2 - 0.4%. It can be raised up to 1 or 1.2%, with oil injection. The economics of such injection would have to be investigated in terms of liquid steel produced. Sponge iron with a higher carbon content was certainly better for EAF feeding but has a hihger tendency for re-oxidation during storage and transport.

Fluctuations in the quality of natural gas supplied may cause a problem in the reformer are and it was advisable to have the quality frequently checked, even the associate gas, in order to avoid heavy hydrocarbons, etc. in the Midrex or Hyl process. Catalyst life in Midrex plants lasts some 5 - 7 years. Sulphur may cause damage. Preheating of top gas fuel to the reformer can be done and significantly increases temperature. 100% recycled gas may be used.

Generation of fines could be tackled in various ways, such as briquetting, and unconventional ones such as packing them into paper bags for charging to the EAF.

8. ACTIVITIES OF UNIDO, ESCAP and RCTT FOR THE BENEIFIT OF ESCAP REGION COUNTRIES

The activities of the Metallurgical Industries Section of UNIDO were outlined. A summary is given in Annex XVI. Many countries of the region expressed keen interest in such assistance, particularly Indonesia.

RCTT proposed a net-work on sponge iron for ESCAP developing countries which aims at promoting the continuous exchange of experience among the countries. The proposal was accepted and RCTT was requested to initiate such activities as soon as possible. An outline of the proposed network is given in Annex XVII.

The RCTT Secretariat also prepared a paper "Issues in the promotion of technology development and transfer in the area of sponge iron manufacture and use in developing countries of ESCAP region" which can be found in Annex XVIII. In addition, leaflets were handed out to the participants describing the objectives of RCTT to enhance the economic and social advancement of developing countries in Asia and the Pacific.

The ESCAP Secretariat has prepared a special paper for the Workshop on "Problems, Trends and Technology Development in Iron and Steel Making including Sponge Iron Production" which was presented to the Workshop by Mr V.I. Gorchkov, Economic Affairs Officer, Joint ESCAP/UNIDO Division of Industry, Human Settlements and Technology. The paper is available upon request.

8. REGIONAL CO-OPERATION TO PROMOTE TECHNOLOGY DEVELOPMETN AND TRANSFER IN THE AREA OF SPONGE IRON MANUFACTURE AND USE IN DEVELOPING COUNTRIES OF THE ESCAP REGION

After being fully informed about the activities of UNDP/UNIDO/ESCAP/RCTT and in the light of Workshop's deliberations many participants expressed keen interest in UNDP/UNIDO's technical assistance programme and in regional co-operation. A project document for a regional project had been prepared in draft and was introduced to the participants in all its parts. The project has the aim of regional development of sponge iron industry through direct reduction technology for mini steel plant operations; the Project Document as attached herewith was fully endorsed by all participants concerned. Within the principal context of industrial development of the ESCAP countries region, based on the exploitation of those countries' natural resources and raw materials, the major development objectives are to survey, investigate and technologically assess the possibilities of promoting sponge iron production for development/expansion of the steel industry, with a view to economically utilize raw material resources and apply the most appropriate sponge iron production technology (gas or coal as a reductant) as well as estimating the domestic market for sponge iron and consider possible exports, including intra-regional trade. The project proposal/Project Document was endorsed and fully supported by the participants and they requested UNDP/UNIDO to start implementation of the project as soon as possible. The full text of the Project Document as proposed is contained in Annex XIX.

9. ADOPTION OF THE REPORT

The Report with all its attachments including Regional Project Document (UNDP/UNIDO) and the RCTT Network was adopted by all participants on 8 April 1983 during the Closing Session.

The effort undertaken by UNDP/UNIDO/RCTT to assist developing countries of the Asia region in development of local sponge production facilities was highly commended special thanks were expressed to the Indian Government, Indonesian Government and Krakatau PT and SIIL PLant for their remarkable assistance in the organization of the Workshop and Study Tour to SIIL. What remained to be done was the implementation, at the earliest possible date, of the proposed regional project, as a first step towards regional co-operation in production of sponge iron in the ESCAP Region Countries.

ANNEX I

LIST OF PARTICIPANTS

Sl. No.	Name	Status	Country/Place/ Organisation
A.	**Delegates**		
1.	Mr Nasir Ahmad	General Director of Investment Department, Ministry of Mines and Industries.	Afghanistan
2.	Mr U Myint Thein	General Manager No. 1 Iron Project	Burma
3.	Mr Wei Jun Xian	Central Iron and Steel Research Institute	China
4.	Mr V. Subba Rao	Manager (Incharge), Sponge Iron India Limited	India
5.	Mr Fazwar Bujang	Superintendent DR Plant, PT Krakatau Steel	Indonesia
6.	Mr M.R.T.Shahrain	Deputy, Ahwaz Steel Complex, Ministry of Mines and Metallurgy	Iran
7.	Mr Cho, Chun Heating	Assistant Director, Non-ferrous Metals Division, Ministry of Commerce & Industry	Korea
8.	Mr R.H.Ismail	Heavy Industries Corporattion of Malaysia, Berhad Perwaja	Malaysia
9.	Mr W.M.Z. Ismail	-do-	Malaysia
10.	Mr M.A. Qazi	Principal Scientific Officer, Pakistan CSIR, Lahore	Pakistan
11.	Mr F.S. Samson	Assistant Chief, Product Standards, Ministry of Trade and Industry	Philippines
12.	Mr L.C.R.Wijesingha	Sr. Metallurgist Ceylon Steel Corpn.	Sri Lanka
13.	Mr T. Chairat	Director of Office of Basic Industry Dev.	Thailand
14.	Mr Pham Chi Cuong	Metallurgical Engineer, Metallurgical Institute of Engg and Metallurgical Industry	Vietnam

Sl. No.	Name	Status	Country/Place/ Organisation
B.	Countries		
i)	Indonesia		
1.	Mr T. Ariwibowo	President Director	PTK Steel
2.	Mr Djoko Subagio	Associate Production Director	-do-
3.	Mr Chosdu Saiin	Superintendent Process Engineering	-do-
4.	Mr Kusna	Maintenance Supdt (DR)	-do-
ii)	India		
1.	Mrs. N. Buch	Joint Secretary Deptt of Steel	Govt. of India
2.	Mr D.C. Bajpai	Director Deptt of Steel	-do-
3.	Mr P.K. Aggarwal	Industrial Adviser Deptt of Steel	-do-
4.	Mr S. Vangala	Managing Director	SIIL & VNSL
5.	Mr V.L.N. Murthy	Dy. General Mgr (O)	SIIL
6.	Mr K.P. Patnaik	Dy. General Mgr (E&P)	SIIL
7.	Mr P.S. Raju	Chief Public Relations Officer	SIIL
8.	Mr K.S.N. Murthy	Dy Manager (O&M)	SIIL
9.	Mr P. Srinath	Asst Manager (E&P)	SIIL
10.	Mr V. Narahari	Asst Manager (A&PR)	SIIL
11.	Mr S.K. Chabria	Sr. Engineer (E&P)	SIIL
12.	Mr V.M. Daptardar	Sr. Metallurgist (TC)	SIIL
13.	Mr A. Rajasekharan	Sr. Metallurgist (O)	SIIL
14.	Mr M. Ramachandran	Sr. Engineer (O)	SIIL
C.	UNDP		
1.	Mr M.J. Priestley	Resident Representative	New Delhi
2.	Mr P.N. Pathak	Programme Officer	-do-
D.	UNIDO		
1.	Dr B.R. Nijhawan	Sr. Inter-regional Adviser	Vienna
2.	Mr F. Iqbal	SIDFA	Djakarta
3.	Mr A.B. Krasiakov	SIDFA	New Delhi
4.	Miss G. Hynek	Research Assistant	Vienna

Sl. No.	Name	Status	Country/Place/ Organisation
E.	ESCAP		
1.	Mr V.I. Gorchkov	Economic Affairs Officer	Thailand
F.	RCTT		
1.	Mr B.R. Devarajan	Director	Bangalore
2.	Dr C.V.S. Ratnam	Adviser on S&T Policy	-do-
3.	Mr N. Suryaprakash		-do-
G.	Observers		
1.	Dr W. Schlebusch	Lurgi Chemie	West Germany
2.	Mr R. Dayal	Lurgi India	New Delhi
3.	Mr J.E. Hells	Midrex	USA
4.	Mr J.M. Pena	HyL	Mexico
5.	Dr A. Chatterjee	IPITATA	India
6.	Mr Supriyadasgupta	M.N. Dastur & Co	India
7.	Dr T.K. Roy	-do-	India
8.	Mr K.T.V.Desikachar	Vijaynagar Steel Project	India
9.	Mr Nagaraj	-do-	India

LIST OF DOCUMENTS

Country papers

Country	Title	Author
Afghanistan	Country paper	Eng. Nasir Ahmad, General Director of Investment Department
Burma	Country paper	U Myint Thain, General Manager No. 1 Iron Project
China	General situation of the study of Direct Reduction in China	Wei Juan Xian, Central Iron and Steel Research Institute, Beijing
India	Country paper	S. Vengala, Managing Director, Vijayanagar Steel Ltd. and Sponge Iron India Limited
Indonesia	Some notes on the Commissioning of Direct Reduction Plant	Fazwar Bujang, Superintendent, DR Plant, P.T. Krakatau Steel
Iran	Country paper	M.R. Taheri Shahrain, Deputy Ahwaz Steel Complex
Malaysia	The development of sponge iron plant in Malaysia	R.H. Ismail, General Manager, Heavy Industries Corporation of Malaysia Berhad/Perwaja
Pakistan	Possibility of Utilization of Domestic Iron ores for Sponge Iron Prodn.	M.A. Qazi and Izharul Haque Khan, Pakistan Council of Scneitific and Industrial Research
Philippines	Iron and Steel Industry in the Philippines (sponge iron manufacture)	Felix Samson, Assistant Chief Product Standards, Ministry of Trade and Industry
Rep. of Korea	Country paper	Chun Heaing Cho, Assistant Director, NF Metals Div., Ministry of Commerce and Industry
Sri Lanka	Country paper	L.C.R. Wijesinghe, Senior Metallurgist Ceylon Steel Corporation
Thailand	Development of the sponge iron industry in Thailand	Trakarn Chairat, Director of Office of Basic Industry Development
Viet Nam	Country paper	Mr Pham Chi Cuong, Metallurgical Engineer, Institute of Engg. and Metallurgy

ANNEX II (Contd.)

Company/ Organization	Title	Author
UNIDO	UNIDO's technical assistance in the field of metallurgical industries	UNIDO Secretariat
UNIDO	UNDP Project Document for "Regional Development of Sponge Iron Industry through Direct Reduction Technology for Mini Steel Plant Operations'	UNIDO Secretariat
ESCAP	Problems, Trends and Technology Development in Iron and Steel Making Including Sponge Iron Production	V.I. Gorchkov Economic Affairs Officer, ESCAP/UNIDO Div. of Industry, Human Settlements & Technology
RCTT	RCTT Network on sponge iron for ESCAP developing countries	RCTT Secretariat
RCTT	Issues in the promotion of technology development and transfer in the area of sponge iron manufacture and use in developing countries of ESCAP region	RCTT Secretariat
MIDREX	Midrex Direct Reduction Process - State of the Art Technology	J.A. Lepinski and G.G. Carinci Midrex Corporation
LURGI	Various papers and leaflets including SL/RN coal/based direct reduction The State of the Art	presented by D. Schlebusch
TATA Steel	An appraisal of the current status of DR processes with particular reference to their adaptation in developing countries in the ESCAP region	A. Chatterji, Managing Director IPITATA Sponge Iron Plant Ltd. Tata Steel
Indonesia	Direct Reduction plant as part of First Indonesian Integrated Steel Plant (presented at CAFEOI Conference in Jakarta in August 1982)	Fazwar Bujang, Superintendent, Direct Reduction Plant, PTKS
Indonesia	Aspects of high ratio DRI melting practice for the production of weldable high tensile reinforcing bars in the electric arc furnace	Eng. Chosdu Saiin Superintendent, Process Eng. and Quality Control, Primary operation

ANNEX III

SUMMARY OF COUNTRY PAPER

DEMOCRATIC REPUBLIC OF AFGHANISTAN

by Eng. Nasir Ahmad
General Director of Investment Department
Ministry of Mines and Industries

The Democratic Republic of Afghanistan is a land-locked country located in Central Asia, covering 647,5 thousand km^3 of rugged mountain and desert areas.

The climate is semi-arid, with an average annual precipitation of 416 mm per annum ranging from 75 mm to 1,164 mm per annum between the driest to the wettest observation points.

During the 1975 census, the population was estimated at 17 million people, largely rural.

Available reserves of natural resources have yet to be fully gauged. Among those known there are important deposits of oil, coal, iron ore, copper and natural gas.

Industry in the sense of modern industry is in its early stages of development and contributes only 6.5% of GNP.

Available resources

Raw materials of the country may be classified into agricultural and natural resources.

Agricultural production includes mainly food grains, fruits, and vegetables, cotton, and some quantity of beetroot, sugar canes and oil seeds.

Afghanistan possesses a good potential of natural resources. Since the past several years, mapping, surveying and exploration of interesting areas has been carried out for the mineral resources and subsequently substantial reserves of mineral deposits have been opened up and are being worked. The main mineral resources discovered are as follows:

	Estimated reserves	
1. Coal	65,8	million tons
2. Iron ore	176	million tons
3. Copper	5.5	million tons
4. Beryl	15,659	tons
5. Lithium	158,5	thousand tons
6. Fluorite	8,792	thousand tons
7. Talc	531,3	thousand tons
8. Asbestos	162,3	thousand tons
9. Sulphur	200	thousand tons
10. Barite	1,693	thousand tons
11. Lapis Lazuli (only sari-sang)	1,501	tons
12. Aragonite	1,091.5	thousand tons
13. Chromite	185,000	tons
Cr_2O_3 55.1 % :	27,000	tons
Cr_2O_3 44 % :	158,000	tons

14. Some other minerals like kunzite, emeralds, ruby, green tourmaline, etc. are also found

The Democratic Republic of Afghanistan, in order to meet the need of the country is paying special attention to industrialization of the country based on raw materials available within the country. One of those are the mini steel plant based on scrap available in the country, the feasibility study of which is being carried out by UNDP/UNIDO technical assistance.

Constraints on Industrialization

1. Limited financial resources
2. Lack of adequate technical personnel
3. Lack of experience and management and planning in the industrialization process
4. Lack of technical know-how in many cases
5. Afghanistan being a mountanous country with spread deposits, the highways to villages and mountain areas are in poor condition which slows down the progress of industrial development

Recommendations

UNDP/UNIDO and ESCAP are kindly asked to assist in the following

1. To carry out a feasibility study on sponge iron production in Afghanistan
2. To arrange for training of staff in the field of sponge iron production as well as in mini steel plant operations
3. (a) To investigate iron ores, coal and limestone by using the testing facilities at Sponge Iron India Ltd. at Paloncha, Kothagudem

   (b) The purpose is to determine the possibility of suitability and utilization of the natural resources in the DR process
4. To finance the establishment of the mini steel plant.

ANNEX IV

SUMMARY OF COUNTRY PAPER

SOCIALIST REPUBLIC OF THE UNION OF BURMA

by U Myint Thein
General Manager, No 1 Iron Project

Burma started her first sponge iron plant in October 1981. It was the Kinglor-Metor direct reduction method that was chosen using local resources of lignite and hematite ores.

The plant is situated at Anisakan near Maymyo in the northern part of Burma. The iron ore deposits are about 12 miles from the plant site. Coal comes by rail from Lashio, about 125 miles from the plant site. Limestone is mined near Sagaing, about 50 miles from the plant.

The capacity of the sponge iron plant is 20,000 tons per year and there are also facilities for melting sponge in the electric arc furnace of 15/17 tons capacity. At present, sponge iron is used in producing pig iron in the elctric furnace.

Operation parameters and average results obtained during 17 months of operation are given in the paper.

An expansion programme to increase the sponge iron production to 40,000 tons per year and to produce steel by EAF and continuous casting plant with two strands will be added. The expansion project is scheduled for start-up at the end of December 1983.

ANNEX V

SUMMARY OF COUNTRY PAPER

PEOPLE'S REPUBLIC OF CHINA

by Wei Jun Xian
Central Iron and Steel Research Institute
Beijing, China

The Chinese iron and steel industry has been developing rapidly. 1982 production was upto 37 million tons.

The direct reduction process is at a trial stage.

China has rich resources of iron ore and coal and also has oil, natural gas, water and electricity which is being developed. All of these form a raw material base for the iron and steel industry.

Most of the ore is of low grade, the ric ore with an iron content of more than 50% accounts for only 6%, most of the ore with an Fe content of around 30% must be selected and agglomerated. Many ores are of complex nature, i.e. vanadium-titaniferous magnetites; iron ore containing rare earth elements, etc.

Although the country possesses rich coke, it is concentrated in the northern provinces.

In some areas the direct reduction process may be adopted. From the developments of the DR process abroad it could not only solve the problems of development of the iron and steel industry in areas with little coke but it could also utilize the complex ores and treat industrial waste slag which contains iron.

Studies are going on since 1958, on the rotary furnace process, pre-reduction of rotary furnace, electric furnace, shaft furnace, fluidization, etc.

Some results could be obtained. Among these the semi-industrial application of rotary furnace, pre-reduction in rotary furnace-electric furnace has achieved an international level of trial. At present the total volume of teting equipment of rotary furnace is about 1300 m^3 and most of them are small testing furnace.

There are 3 shaft furnaces, 2 of them located in Guangdom province and their production is 5 tpd and 100 tpd respectively. Water-gas reduction is used for both, the coal consumption is 1.5 ton/1 sponge iron and is not economic.

One shaft furnace with 25 tpd production operates in the Sichuan province. The reducing gas is produced from the natural gas in the reformer with a catalyst. The reformer is of regenerative type. Vanadium-titaniferous magnetite was used for testing and a metallization rate of more than 90% was achieved with low contents of S and P. Energy consumption was about 500 m^3 natural gas per ton of sponge iron. The process needs improvement.

A number of other experimental furnaces exist. In order to strengthen and develop the direct reduction method in China, the following points should be considered:

1. A new plant should be built in an area with reliable supplies of material and fuel, successful semi-industrial equipment, convenient transportation and good technical management.

2. For the complex ore, general utilization should be considered, so as not to waste any valuable metals.

3. There are some ores in the interior of the country suitable for making high-quality sponge iron and special steels. Gas DR process may be recommended.

4. In China, only Sichuan province has rich resources of natural gas. Therefore the future of shaft furnace and fluidized methods largely depend on the development of gas-making techniques with coal and its economy.

ANNEX VI

SUMMARY OF COUNTRY PAPER

REPUBLIC OF INDIA

by S. Vangala
Managing Director
Sponge Iron India Ltd and
Vijayanagar Steel Ltd.

India has about 17,000 million tonnes of iron ore reserves of which about 11,000 million tonnes are of Hematite quality and remaining of the Magnetite type. The country also has reserves of non-coking coal estimated at 82,000 million tonnes, whereas the availability of coking coal is limited. Natural gas though available is committed to other priority end uses and as such the country has considered it necessary to develop sponge iron production capacity based on lump iron ore and non-coking coal to provide feed material for the electric arc steel melting furnaces located in different parts of the country having a total licensed capacity of 4.2 million tonnes. As processes of sponge iron production from lump iron ore and non-coking coal are not fully established, Government considered it necessary to set up a Demonstration Sponge Iron Plant of 100 tonnes per day capacity to test at a semi-commercial level different iron ores and coals occurring in India to generate data for planning of commercial sponge iron plants. UNDP/UNIDO whose assistance was sought by the Government of India also endorsed this approach and a Demonstration Plant has been set up at Kothagudem in Andhra Pradesh based on the SL/RN process of Lurgi Chemie. The plant which was constructed in 1980 at a cost of US$ 20 million received UNDP assistance amounting to over US$ 4 million, the remaining foreign exchange cost as well as Rupee cost of the project having been borne by the Government of India.

As an adjunct to the Demonstration Sponge Iron Plant, UNDP assisted in the setting up of a well equipped laboratory capable of undertaking bench scale test work to assess the suitability of different raw materials for direct reduction. The Demonstration Plant went into regular operations in November 1980 and during the last 2½ years it has tested various ores occurring in India. It has also been established that Sponge Iron of high quality can be produced at or above rated capacity; that the product can be safely stored and transported and that it can be satisfactorily melted in Electric Arc Furnaces. With the assistance of UNDP/UNIDO, designs have also been developed for continuous feeding of sponge iron for optimal results. On the basis of the excellent record of this plant, Government of India have also approved doubling of the capacity of the plant. The expansion work which would be based entirely on the engineering expertise available with SIIL, is expected to be completed by 1984.

In addition to the testing of Indian Iron ores, UNIDO have assigned to SIIL recently, projects covering the evaluation of the suitability of Pakistan coals for Direct Reduction in a Rotary Kiln and benefication and reduction studies on iron ores from Hungary. Taking note of the testing facilities available at the Demonstration Sponge Iron Plant and also the capability of the Engineering Division of SIIL, UNIDO have registered SIIL as a consultancy organization in the field of Direct Reduction.

ANNEX VII

SUMMARY OF COUNTRY PAPER

REPUBLIC OF INDONESIA

by
Eng. Fazwar Bujang
Superintendent, DR plant
P.T. Krakatau Steel

Thanks to all the experience we have accumulated during and over the last 4.5 years to day we are able to run the DR plant very smoothly and maintain the production level at the designed rate.

The first DR plant was commissioned in August 1978 but the design performance was reached only two years later after such difficulties/problems like process, equipment failures, improper design and/or a combination of them.

The second DR plant was completed in 1982 and started very successful performance in August 1982. Some factors which contributed to the success of the DR plant II performance test are:

a. Careful steps taken by PTKS management prior to the start-up and performance;
b. Improvement to the plant initiated by the contractor modification and additional equipment requested by the plant owner based on experience drawn from operating the DR plant I over 2 years;

c. Plant owner personnel had more experience and also better advice from the Contractor who supervised and directed the plant operations. More participation and more support for the Contractor from PTKS personnel during commissioning and performance tests of DR plant II could be provided.

d. Better knowledge behaviour of pellets to be reduced during performance.

e. The Contractor wished to fulfil his obligations with good reputation.

Conclusion

The commissioning of 2 DR plants and their related facilities has given PTKS the opportunity to document some of their experiences as follows:

1. A well prepared organization to handle activities as soon as the construction is terminated such as cold test, commissioning, etc. with sufficient qualified personnel is required.

   Assumed that there is still a warranty period after the contractor handed over the plant to the owner, but it is more difficult to claim equipment failures or inferiority during the warranty period rather than refuse to accept the equipment during commissioning period, which may be decided by qualified commissioning personnel.

2. It is not recommended to build twin plants at the same time which only duplicates the possible design mistakes, construction errors, etc. Although a lot of modification was done to DR plant 2 (also to plant I, later on), still there are some important things which could not be modified because the contractor was not obligated to bear the cost and/or could not be done due to time constraint. Such modifications were e.g.

a. The finfan condensors are not a suitable type for a plant like the DR plant since a lot of dust is generated. The location of the fin fan must be selected far from the material handling system and the fin fan must be provided with filters to prevent dust accumulation on the fin tubes.

b. Aside from low efficiency of small steam turbine drives, it is better to have a big stream turbine generator rather than a lot of steam drives for pumps and compressors which requires more maintenance effort, than electric motors.

3. As soon as the performance test is finished it is advisable to stop the plant immediately and start to establish punch list of items to be fixed by the contractor from internal plant/equipment inspection, and weakness of the plant detected during start-up/performance test of the plant.

4. Selection of suitable raw material is very important for the performance test in order to identify plant weaknesses separately from poor raw material.

5. The philisophy of plant performance evaluation must be based on maximum load, e.g. all common facilities to be tested on simultaneous load and if it is not possible at least a simulation operation must be performed.

6. In the case of the DR plant, which looks more like a chemical plant than a metallurgical plant, the monitoring of the mechanical condition of the plant will make an important contribution both to production and to the safety of the plant.

ANNEX VIII

COUNTRY PAPER

ISLAMIC REPUBLIC OF IRAN

by
M.R. Taheri Shahrain, Deputy,
Ahwaz Steel Complex
Ministry of Mines and Metallurgy

1. General condition of steel industry in Iran:

A- The steel making capacity readily completed and started-up are as follows:

Blast Furnaces: 1.5 million tons per year

Scrap Melting: 360 000 " " " "

(Purofer) Direct
Reduction: 330 000 " " " "

B- Projects under construction and near completion:

3 moduls midrex DR Plant total capacity 1200000 tons per year

3 moduls HyL DR Plant total capacity 1,000,000 tons per year

C- Project under bid evaluation:

3 million tons sponge iron per year

2. PLANNING: For the first period of our 4 steps 20 years planning (next 5 years) we have in mind to: a - completing the existing projects.
   b. Bringing them to the designed production capacity
   c. Adjusting sponge iron production and melting capability by adding new melting facilities.

3. PROBLEMS:

a- The licensing companies after having supplied the first engineering and equipment are not willing to keep us aware of new improvements resulting a better process and efficiency.

b- A big amount of fines (Metalic 4 oxide) and slurry will be wasted in the midrex. Purofer and HyL plants of awaz steel complex which are not considered in the initial engineering of the companies involved.

c- While our country in this period of revolution needed a lot of steel for its development programmes, Iraqi Regime attacked to the South-West of our country where about half of our steel industries are located. It took us a large amount of money and time to refacilitate them again after pushing back the agressor troops.

4. RESULTS AND PROPOSALS:

a- While the people of our country are trying to overcome the aforementioned and other problems since these problems will be similar for the countries of the ESCAP Region I would suggest that instead of having every country separate research and investment UNIDO and or RCTT take care of these problems.

b- I suggest that UNIDO/RCTT by gathering enough information about raw materials and products of sponge iron, oxio pellets and steel from the countries of the ESCAP region. Study and recommended required adjustments and try this to be handled.

With regards and best wishes
For the development and
Independence of the countries
Of Region
M.R. TAHERI SHAHRAIN

ANNEX VIII-A

In the name of Allah

1. Considering that the previous activity and investment of UNIDO has been in the area of Coal based direct reduction it is reasonable that the new project will be in the area of gas based direct reduction including finding best methods of using sponge iron.

2. The new project should be under the direction of UNIDO so that the result and information easily been conducted through the countries of ESCAP region.

3. Whilst the contribution of UNIDO/UNDP in the Indian project was about 5 million dollars, in this Regional project the UNDP/UNIDO contribution is only 500 000 US $, it should be much more for the Regional Project as it would assist all the ESCAP countries.

4. In the case which we come to the result that the new project shall include also a semicommercial plant on the gas based direct reduction. I suggest that the process employed thereof should not be the licence of the companies which in their turn cause restriction for technology transfer. I think that the UNIDO experts together with the experts of the countries of the ESCAP region now will be able to establish a good process among the existing processes and the experiences obtained from them.

ANNEX IX

SUMMARY OF COUNTRY PAPER

MALAYSIA

by

R.H. Ismail
Heavy Industries Corporation of
Malaysia Berhad/Perwaja

The Development of Sponge Iron Plant in Malaysia

Introduction

The economy of Malaysia has been traditionally agriculture oriented. In the past the growth of the manufacturing sector was minimal with the economy being heavily dependent on the income from export of rubber, tin, palm oil, timber and of late crude oil and natural gas. In recent years there has been a marked shift in the national planning strategy, with growing emphasis being laid on the creation and development of strong and modern industries.

Steel is synonimcus with industrial progress and the level of steel prod..
in a country is often considered as the yardstick of that country's industrialization. The crude steel consumption in Malaysia is estimated at around 1.85 million tons per year in 1981 and projected to reach 3 million tons per year in 1990, which is equivalent to a per capita steel consumption of about 200 kg. Hence the establishment of direct reduction plants in Trenggan (capacity 600,000 tpy) and Sabah (capacity about 700,000 tpy).

The resources situation in Malaysia

The iron ore resources of Malaysia are very limited thus requiring import of iron oxide feed.

In regard to the energy situation, Malaysia has large reserves of off-shore natural gas but no known deposits of metallurgical grade coal. In addition there are substantial reserves of oil. Therefore, from the energy resources situation creation of new steelmaking capacity in the country should be logically based on the adoption of direct reduction (DR) of iron ore/pellets using natural gas and use of DRI as metallic charge in the electric arc furnace. This route of iron and steelmaking is commonly referred to as DR/EF route.

The first DR/EF plant in Malaysia

In early 1982, a contract was signed for the first DR-EF plant in Malaysia. The project is a joint venture between the Government of Malaysia and Nippon Steel Corporation (NSC) who are also the leader of the Japanese Consortium that will supply and erect the plant on a turn-key basis. The plant is to be located at Kemaman in Trengganu state on the east coast of Peninular Malaysia.

The DR plant will be based on the NSC/DR process and will be the first commercial plant to adopt this recently developed process. The DRI from the shaft furnace will be hot briquetted, about 0.52 million tons of DRI briquettes will be consumed in the plant for production of billets (through electric arc furnaces and continuous casting machines) and the balance will be sold to various Arc Furnace plants in Malaysia.

Construction work on the project commenced in October 1982. The plant is scheduled to go on stream by early 1985.

Conclusion and Technology Transfer

Malaysia is now entering into an era of sponge iron production in joining the rank of other sponge iron producers. It is opportune to state that any valuable assistance from UNIDO in the field of training of operation and maintenance of DR plant in particular, and of overall steel plant would be most appreciated.

Transfer of technology in steelmaking industry (sponge iron in particular) is the main theme of this UNIDO Workshop and has been the main topic to many works on steelmaking industry. What is now needed is a positive and sincere contribution from the experienced countries in the field of DR to the newly established ones, with a view to production efficiency. Industry's common objective is optimum utilization of the available resources, mineral, energy, etc.

ANNEX X

SUMMARY OF COUNTRY PAPER

ISLAMIC REPUBLIC OF PAKISTAN

Possibility of Utilisation of Domestic Iron Ores for Sponge Iron Production

by

M.A. Qazi
Principal Scientific Officer,
Pakistan CSIR, Lahore

The steel production in Pakistan which was about 20,000 tonnes per year in 1947 rose to 224,000 tonnes by 1974 and 550,000 tonnes by 1982. The demand for iron and steel is about double this production. Upto 1981 the steel industry in Pakistan was based on Electric Steelmaking with 50% of the scrap requirements of the rated capacity of 600,000 tonnes per year through imports. The first integrated iron and steel plant based on imported iron ore and coking coal went into production in 1982. On present estimates the demand for iron and steel in Pakistan by 1985 would be about 1.7 million tonnes and additional capacity required, is proposed to be created with electric arc furnaces.

As the availability of good quality scrap is limited, Pakistan is considering establishment of sponge iron production capacity based on local iron ores.

Preliminary studies in this direction have been carried out by the Pakistan Council of Scientific and Industrial Research and on present indications a capacity of 400,000 tonnes per year is expected to be created.

IRON ORE RESERVES

The iron bearing deposits of Pakistan are conservatively estimated at 450 million tonnes, the properties of which are summarized in Tables I and II. As the ores contain large amount of impurities, systematic benefication studies have been taken on hand by the Pakistan Council for Scientific and Industrial Research. The results of the beneficiation tests are summarized in Table III. Pelletisation and reduction tests have also been carried out on the ores and pellets produced in the concentrates, the results of which are furnished in Tables IV and V. The concentrates and pellets were also tested at the Japan Consulting Institute, Tokyo and Armco in USA and both the organizations have recommended the use of concentrate for sponge iron manufacture.

CHOICE OF REDUCTANTS

As the available natural gas reserves are committed for use in Fertilizer and other industries, coal is to be considered as the reductant. The estimated coal reserves of Pakistan are over 500 million tonnes. The coals contain ash between 3-30% and Sulphur of 1-7%.

TECHNOLOGICAL REQUIREMENTS

In the context of the future development of sponge iron production capacity in Pakistan, it is considered necessary that

i) Technical information and data on R&D as well as on the production levels on DR iron is made available to the ESCAP countries.

ii) Short courses and in-plant training facilities are extended to the scientists and technicians of the member countries so desiring.

iii) For a situation, as in the case of Pakistan, R&D facilities on laboratory and pilot plant scale may be strengthened, so as to enable the scientists to carry out preliminary evaluation and testing of domestic raw materials. Also, technical guidance for the production of low sulphur iron ore concentrate may be provided.

iv) Frequent workshops are held to exchange ideas and to disseminate information.

v) A panel of experts is organized to assess and advise the country on the sponge iron manufacture and assist in preparing techno-economic feasibility reports.

TABLE 1 : IRON RESOURCES OF PAKISTAN

DEPOSIT	Reserves Mt	Fe %	SiO_2	Minerals
Sedimentary				
Chichali	165 - 335	32.5	21.2	Lim Sid Gla
Kutch	34.0	33.1	23.2	Cham Sid
Makerwal	52 - 200	33.4	24.5	Lim Sid Cham
Rakhi Munh	14.5	37.5	13.9	Lim Sid
Pezu	12	31.0	-	Sid Lim Hem
Langrial	28	40.2	14.8	Cham Lim Hem
Galdanian	60	20.0	9.9	Hem Claystone
Igneous & Metamorphic				
Dammer Nissar	6.5	59.43	9.9	Mag
Swat	300	14.5	32.1	Mag Ilm
Chilghazi	2.5	45.3	12.0	Mag Hem
Chigendik	5.2	39.2	20.0	Mag
Pachinkoh	25.0"	46.8	15.6	Mag

Lim Cham Chamosite Sid Siderite Ham Hematite
Ilm Ilmentite Mag Magnetite Gla Glauconite

"Probable 100 Mt

TABLE-2 : AVERAGE CHEMICAL ANALYSIS OF SOME PAKISTANI IRON ORES (%)

	Kalabagh	Chitral	Chigendik	Pachinkoh
Fe(t)	32.5	59.43	39.16	46.80
Fe(II)	14.3	-	5.6	14.62
SiO_2	22.4	9.94	20.01	15.6
Al_2O_3	5.8	0.80	3.19	4.41
CaO	3.0	3.36	9.19	5.86
MgO	3.2	0.80	0.83	1.39
Na_2O	0.14	-	-	-
K_2O	2.34	-	-	-
P	0.34	-	0.02	0.10
S	1.58	-	1.07	3.96
LOI	15.91	0.91	7.76	2.72

TABLE-3 : CHEMICAL ANALYSIS OF IRON ORE CONCENTRATES TEST (Wt%)

	Chichali (indurated)	Chitral	Chigendik	Pachinkoh
Fe(t)	54.7	66.72	65.30	68.20
Fe(II)	-	23.38	14.77	26.39
SiO_2	9.5	3.47	3.28	2.10
Al_2O_3	0.5	0.71	0.51	-
CaO	3.6	0.66	0.85	-
MgO	4.41	0.22	0.04	-
Na_2O	0.04	0.09	0.03	-
K_2O	0.09	0.05	0.01	-
P	0.15	0.01	0.07	-
S	0.11	0.01	0.56	0.66

TABLE-4 : REDUCTION TESTS OF CHITRAL, PACHINKOH AND CHIGENDIK ORES

	Chitral A	Chitral B	Chigendik	Pachinkoh
Fe(t)	65.31	66.49	65.58	68.34
FeO	0.38	0.53	1.18	0.15
Static bed reduction				
Direct Reduction%	97.67	98.31	95.05	97.36
Compression strength (Kg/p)	82	110	101	60
Clustering test				
Shrinkage $	21.3	21.1	7.3	17.5
Pressure drop (mm)	4.8	4	3	4
Cluster strength (2 min)	8.8	8.9	80	18.1
Fines%	3.75	2.04	1.2	12.1
Linder test				
Direct reduction%	98.28	98.26	93.24	97.05

TABLE-5 : REDUCTION PROPERTIES OF INDIGENOUS ORE PELLETS

	Chitral A	Chitral B	Pachinkoh	Chigendik
Chemistry				
Iron contents	Little low for DR feed	Acceptable DR Feed	Good for direct reduction feed	Acceptable DR feed
Prosphorous	very low	very low	very low	very low
Sulphur	low	low	very low	very low
Physical properties	good	good	good	excellent
Reduction properties				
Reductibility	good	good	good	excellent
Fine generation	little	little	little	little
Clustering	little	little	little	little

ANNEX XI

SUMMARY OF COUNTRY PAPER

REPUBLIC OF THE PHILIPPINES

by

Mr Felix Samson
Assistant Chief Product Standards
Ministry of Trade and Industry

The Philippines has been in the iron and steel industry for decades, However, in the recent years she has lagged behind her Asian neighbours.

After a series of feasibility studies conducted since early 1960, the Government seriously considered the construction of an integrated iron and steel mill complex. In 1981 the project was deferred and the Minister of Industry stated that instead expansion and modernization of existing facilities would be taken up.

In the meantime the Ministry of Industry investigated the possibility of other routes to produce steel instead of the originally foreseen coke-oven BF route. A DR plant was under consideration which could use 100 % locally available raw materials. The new plan calls for an integrated plant complex with an annual capacity of 1.5 million metric tons. 6 kilns are proposed.

The Workshop can be an eye opener on the pros and cons of the proposed processes and capacities. The Philippines may even request the sponsors (UNDP, UNIDO, RCTT, India and Indonesia) for an actual observation and training programmes in different operating plants for personnel directly involved in the proposed DRI manufacture in order to avoid failures.

ANNEX XII

COUNTRY PAPER

REPUBLIC OF KOREA

by

Mr Chun Heaing Cho
Assistant Director
Non-ferrous Metals Division
Ministry of Commerce and Industry

Since the Korean Government policy emphasized the promotion of heavy industries including machinery, automobiles and shipbuilding, the demand and supply of steel has increased rapidly. Crude steel production in 1982 was about 11 million metric tons, making Korea the second largest steelmaking country in Asia, next to Japan.

Parallel with a rapid increase in steel prodection, iron scrap requirements also increased to 3.7 million metric tons in 1981, and about 50 % of this requirement has been met by imports from abroad. Domestic demand for iron ore and coal used as a raw material in iron and steel industries was imported from abroad and natural gas and oil are not produced in the country. The electricity cost is very high compared to the energy-rich countries.

The Rep. of Korea does not have any working unit producing sponge iron and does not have plans or programmes for development of the sponge iron industry in the near future, as there is neither natural gas nor oil or iron ore. When the price of iron scrap will be increased, the possibility of establishing a sponge iron industry would be considered. Information about properties, price and the status of the sponge iron in the world is welcomed.

Supply and demand of steel

	million tons	
	1981	1987 (estimate)
Demand	12.4	18.4
Export	5.3(43%)	
Domestic	7.1	
Production	10.8	14.1
Import	1.6	4.3

Supply and demand of raw material in 1981

	Demand	Domestic production	Import
Irone ore	11.6	0.4	Australia 40 % India 25 %
Scrap	3.7	1.8	USA 80%

ANNEX XIII

COUNTRY PAPER

DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

by

L.C.R. Wijesinghe, Senior Metallurgist
Ceylon Steel Corporation

With the inauguration and implementation of several large scale development projects, the steel making industry in Sri Lanka has received a great impetus due to an increased demand for steel products, especially the reinforcing steels. The present requirement for reinforcing steels in the country is about 150,000 MT/year.

The largest manufacturer of reinforcing steels in the island is the Ceylon Steel Corporation which has a rolling mill of capacity 100,000 MT/year. The Corporation has also recently commissioned a 25 MT Electric Arc Furnace (EAF) with an associated 4 strand continuous billet casting facility of capacity 60,000 MT/year. The next phase of development is the installation of another 25 MT EAF which would bring the total capacity to 120,000 MT/year. In addition to these facilities the Corporation also has a steel foundry and a Wire Mill.

The feed material for steel making at present is a 100% scrap charge, and at the projected levels of production, the Corporation's stockpile of scrap would be depleted by mid 1984. As with most developing countries scrap is not widely available in Sri Lanka too, and hence it is mandatory that scrap will have to be imported to the country, expending precious foreign exchange. Due to these circumstances the Ceylon Steel Corporation has been looking actively at the possibility of using an alternative feed material to scrap. With the acceptance of the Direct reduction/Electric Arc Furnace (DR/EAF) route for lower capacities, the viability of sponge iron as a feed material has grown. Hence Sri Lanka will be looking closer at the experience of others in the region in the use of sponge iron in steel making.

The Island though not endowed with large mineral deposits have discovered a Magnetite ore body with an estimated 7 million MT of ore extending to a depth of about 50 metres. The metallic iron content of the Magnetite is about 40% and compares well other Magnetite Ores of the world. This Ore is also associated with a copper bearing chalcopyrite, with a metallic copper content of 1%. Preliminary laboratory studies on the behaviour of the local magnetite to direct reduction with a solid reductant such as coconut shell charcoal has been promising.

ANNEX XIV

SUMMARY OF COUNTRY PAPER

KINGDOM OF THAILAND

by

Mr Trakarn Chairat
Director of Office of Basic
Industry Development

The sponge iron industry in Thailand was considered when the commercial quantities of natural gas were discovered in the Gulf of Thailand. The quality of natural gas is qualified to feed various types of industries. Moreover, there are semi integrated steel plants which need scrap as a raw material for electric arc furnace in order to produce non-flat steel. Thailand has to import scrap in the amount of 300,000 tons per year. However, steel scrap has become relatively scarce and expensive.

In the year 1978 the Ministry of Industry received the technical assistance from the Austrian Government in the form of a pre-feasibility study for the establishment of a sponge iron plant based on natural gas. It is recommended in the report which was submitted to the Ministry of Industry in May 1978 that a 600,000 tpy sponge iron plant be established. This plant will need natural gas in the amount of 22 million cubic feet per day and need to import iron ore in the amount of one million ton per year. The total investment is about US$ 100 million. The sponge iron produced can substitute the imported steel scrap and feed the local semi integrated steel plants. From the other amount of sponge iron, billets could be produced in order to distribute to the re-rolling mills. It was anticipated that the sponge iron plant could operate by 1983.

The Ministry of Industry perceived that this project was essential to the economic development of the country and therefore encouraged the local investors to form a company named the Siam Ferro Industry Co. in 1979. As the Government concurred with the project it considers to participate as a minor shareholder of about 11 per cent. Besides, the Government will support the project by providing the necessary infrastructure.

In 1979, the detailed feasibility study for the establishment of a sponge iron plant was conducted. After that, the project was proposed to the Board of Investment (BOI) for special privileges in January 1980. The project was pending for the final decision of BOI on site location. Later on, the Cabinet decided that the sponge iron plant should be established at the eastern coast of Thailand.

However, due to the site which is decided by the cabinet and the gas price tendency to go up as well as the depression of the steel industry, the Siam Ferro Industry Company reviewed the study report again in 1981. It was decided that the sponge iron industry project should be kept in abeyance. This is owing to the depressed situation of the steel industry at that time. Moreover, the estimated cost of investment raised by about 30% and the rather high natural gas price had to be taken into account.

The Ministry of Industry has considered that the natural gas in the Gulf of Thailand is costly, its price was determined at US$ 3.50 per thousand cubic feet. This is higher than the optimum natural gas price which could be used for the production of sponge iron at a competitive price with steel scrap. Therefore, the Ministry of Industry is interested now in the solid reductant such as lignite for producing sponge iron. This can be considered as an alternative process route.

In 1982, LURGI Chemie and Huttentechnik GmbH of the Federal Republic of Germany conducted a proposal for the establishment of a SL/RN direct reduction plant based on Thai lignite as solid reductant with a capacity of 400,000 tpy. The Ministry of Industry has realized that the detailed study on the availability and quality of lignite in main sources of Thailand. This study should go into detail, including laboratory testing.

In this respect, the Ministry of Industry considers to approach the Federal Republic of Germany for the financial assistance in the frame of technical cooperation funds for carrying out the feasibility study on the implemenation of a lignite-based direct reduction plant in order to produce sponge iron as the substitute for imported ferrous scrap. The said study will be an alternative process route which the Ministry of Industry shall compare with other process routes. The most economically viable and promising route for Thailand sponge iron project shall be selected. This should be the most important step towards the development of a sponge iron industry in Thailand.

ANNEX XV

COUNTRY PAPER

SOCIALIST REPUBLIC OF VIETNAM

by

Pham Chi Cuong
Metallurgical Engineer
Metallurgical Institute of Engineering
and Metallurgical Industry
Hanoi

Industry of iron and steel production of the SR of Vietnam is quite new. The country has just passed through a long period of war. Almost all of the steel plants and metallurgical institutes were heavily damaged during the war.

In 1975, after the reunification of the whole country, we have restored these steel plants and the institute for metallurgy was also improving its activities.

In fact, the study of sponge iron production in Vietnam has been started at the beginning of 1970. The metallurgical institute was assigned the responsibility of this task.

Background

In the industry of iron and steel production, the country faces two difficulties:

- shortage of coking coal for blast furnace
- shortage of steel scrap for steel making in electric arc furnaces

In order to overcome these difficulties they had to consider the production process of sponge iron according to the natural resources availability in the country. At first, they have chosen the production method of sponge iron in rotary kiln, using coal of anthrazite, mostly exploited in Vietnam.

Technical characteristics of rotary kiln (small scale production)

Based on the technical documents of sponge iron production in laboratory and in order to assure the study quite similar with the production in plant with industrial equipment.

The Metallurgical Institute has built the rotary kiln for sponge iron production. The equipment was totally manufactured locally, including design. The rotary kiln started operation in November 1978.

The product from the rotary kiln was used in the steelmaking arc furnace of 10 ton capacity in the south of Vietnam.

From the results of sponge iron production in the rotary kiln (small scale) Vietnam has proposed a new design for the rotary kiln with an output of about 60,000 tons per year using domestic raw materials and anthracite and to supply the sponge iron to the steelmaking arc furnace.

To improve the technology of sponge iron as well as the steelmaking in the electric arc furnace, to overcome difficulties of shortage of coking coals and scrap, Vietnam would like to receive technical assistance and equipment from foreign countries in the field of sponge iron production.

We hope that the international organizations will offer the opportunity for specialists to be trained abroad and gain much more experience and practice in the production of sponge iron through study tours and training programmes.

ANNEX XVI

UNIDO's Technical Assistance in the field of Metallurgical Industries

1. The metallurgical industry, as a basic industry in laying the grounds for further industrialization, occupies an important place within the technical assistance programme of UNIDO. It assists the following branches of industries of extractive and physical metallurgy:

- Light non-ferrous metals (processing of bauxite to alumina and aluminium; titanium-oxide production based on ilmenite smelting and related operations; production of other light non-ferrous metals)
- Heavy non-ferrous metals (processing of copper, zinc, nickel, lead and tungsten bearing ores and other heavy non-ferrous and rare metal ores)
- Iron and steel industry, including choice of technologies, (such as BF vs. DR route) use of locally available reductants (coking coal, charcoal, natural gas, etc.)
- Foundry industry (both ferrous and non-ferrous) comprising alternative foundry technologies and use of local raw materials and auxiliary materials like sands; establishment of pilot and demonstration foundries in least developed countries.
- Metal transformation technologies (application of specific metallurgical processes such as rolling, forging, extruding, heat treatment and surface treatment; welding).
- Transfer of metallurgical know-how and technology (establishment and/or strengthening of Centres for Metallurgical Research and development, development of local expertise for servicing and application in the metal industries)

2. Within the above branches the Section's technical assistance activities primarily cover the following functions:

- Planning, establishment and operation of new metallurgical plants, including national planning of major metallurgical industry sectors (master plans); techno-economic and marketing studies;
- Processing of metallurgical minerals covering evaluation, concentration and benefication of ores and non-ore minerals including assessment of data on volumes and quality of reserves, sampling and laboratory and pilot test work to identify optimum use of indigenous raw materials for local processing into added value products;

- Provision of expertise for efficient operation of existing plants and selection and application of appropriate technologies and equipment, also including:
  - technological consulting;
  - technical consulting on management, on production, maintenance, materials supply, quality control, and cost accounting of metallurgical plants;
  - design, programming and modernization of existing metallurgical plants;
  - advisory services on standardization of metal products;
  - establishment of managed maintenance systems in metallurgical plants;
- Establishment of centres, laboratories or of testing/evaluation units for metallurgical technology development, thereby increasing research and development capabilities with a view to decrease dependency on or facilitate adaptation of foreign know-how;
- Establishment of pilot and demonstration metallurgical and foundry/forge plants and foundry/forge technology centres;
- Programming, organizing and implementation of specific training programmes;

3. The technical assistance programme is complemented by the organization of symposia, seminars, workshops and expert group meetings on metallurgical subjects as well as the preparation of special studies and documents and their dissemination to developing countries.

4. Special emphasis is accorded to the provision of technical assistance to least developed countries and a number of projects, particularly projects in the foundry industry sector aimed at improving the output and quality of urgently needed cast spare parts, tools and implements, are under implementation in least developed countries.

5. With the objective of promoting industrialization and increasing the share of developing countries in world industrial production, the Metallurgical Industries Section assists in the acceleration of the tempo of exploitation and processing of local ore resources to yield added value products for home use and export.

6. This objective is achieved through the following means and instruments:

(a) Direct technical assistance (field projects)

Such assistance is being provided at the request of developing countries' Governments and can take the following forms:

i. Provision of expertise: an international expert or a team of experts is provided to solve short-term problems or to render long-term assistance up to and including full management of plant operations. The duration of such assignments may vary from two weeks up to two years and more.

ii. Provision of consulting firms hired by UNIDO on sub-contract to undertake, for a requesting developing country, tasks such as the preparation of pre-feasibility and feasibility studies, techno-economic and regional studies, design of laboratory and pilot plants, investigations of ores and other raw materials, or to assist with a complex team of experts to solve complex operational and management problems.

iii. Provision of equipment: Although not financing investment, certain items of equipment needed for research and development work, such as instruments and laboratory equipment can be provided.

iv. Organization of practical training programmes:

- Group training programmes: A number of group training programmes are organized by the UNIDO Industrial Training Section on a regular basis, like the foundry in-plant training organized by the Marmara Technological Institute in Turkey; this programme is particularly recommended for supervisory staff. Another programme is the training on modern foundry technology, undertaken in cooperation with the Foundry Research Institute, Cracov, Poland, for a duration of two months, starting in April every year. Twice a year, an in-plant training programme is organized at Zaporo-Steel, Zaporozhye, USSR, in the iron and steel industry field. The spring programme has a duration of 5 months and starts in January; the autumn programme has a duration of 3 months and starts in September every year.

- Individual fellowship training: Individual training of developing countries' fellowship candidates in companies, institutes, organizations abroad can be arranged, for a period which normally should not exceed 6 months, and is tailored to the needs and requirements of the candidate to be trained.

7. During the past ten years the Metallurgical Industries Section has implemented some 300 technical assistance projects with a total value of about US$ 48 million. In many cases a few components are involved in one project. A typical case is a combination of expert and fellowship components. In case of large scale projects, such as the establishment of metallurgical research and development centres, a combination of all four components can usually be found in one single project.

(b) Supporting activities

i. Symposia, Seminars, Workshops, Expert Group Meetings

Such gatherings are organized with a view to enhance the understanding of new technologies and to discuss problems and opportunities for developing metallurgical industries. They provide a forum for an exchange of opinions between participants from both developed and developing countries. Since its inception in 1967, UNIDO has organized 26 such meetings on various aspects of metallurgical industry development in developing countries. The numb of participants for each meeting ranged from 20 to 200.

ii. Special studies and Documents

About 50 special studies and documents have been prepared by various sections of UNIDO in the last decade in the metallurgical sector. The list of documentation 1967 - 1981 can be obtained from the Metallurgical Industries Section, UNIDO, P.O. Box 300, A-1400 Vienna, free of charge.

iii. Consultation Meetings

The system of consultations, a unique and new activity of UNIDO, has been launched during 1979 in accordance with the recommendations of the Lima Declaration and Plan of Action. In the metallurgical field, the iron and steel sector is one of the few sectors which was selected as of prime importance to the system. So far, three consultation meetings on the iron and steel industry were held and a number of working groups were organized (iron ore, training, coking coal). The system provides useful fora for dialogue and consent with participation from both developed and developing countries to discuss the problems and opportunities of developing countries' steel industry.

iv. Collection and dissemination of information

UNIDO's Industrial Information Section, through its Inquriy Services, assisted by the Metallurgical Industries Section and UNIDO's Technology Group is anxious to satisfy all incoming inquiries from individuals/companies/organizations from developing countries related to industrial development and technology. The Technology Group of UNIDO has launched the operation of INTIB (Industrial and Technological Information Bank) which includes the iron and steel sector as one of the prime features of the Bank. The Bank will also publish Technologial Profiles, such as the one on Iron and Steel Industry (symbol No. ID/218, New York, 1978). Publication of UNIDO Guides to Information Sources, e.g. on foundry industry (symbol No. ID/19 , New York, 1977) and iron and steel industry (ID/191, New York, 1977) is one of the useful services provided by the Information Section to developing countries.

8. Mention should also be made here of the UNIDO Newsletter, a leaflet that reports monthly on main events, Industrial Opportunities (information on resources sought by entrepreneurs in developing countries and resources available from industrial firms/organizations), Experts wanted, Publications. Interested subscribers may obtain the Newsletter free of charge, by writing to UNIDO Newsletter, P.O. Box 300, A-1400 Vienna, Austria.

ANNEX XVII

RCTT NETWORK ON SPONGE IRON FOR ESCAP DEVELOPING COUNTRIES

I. AIMS & OBJECTIVES:

1. To promote exchange of experience among developing countries of the region in the development and transfer of technology in the area of sponge iron.

2. To promote exchange of information among developing countries of the region in the area of sponge iron technology development and transfer.

3. To promote visits to R&D institutions, factories and other establishments engaged in activities concerning technology development and transfer in the area of sponge iron.

4. To promote organization of periodical seminars, workshops and field visits to stimulate activities in developing countries of ESCAP region concerning the development and transfer of technology in the area of sponge iron.

5. To make available on request to developing countries of the region facilities that may be available in countries of the region for testing raw materials, making laboratory tests, and conducting pilot plant and demonstration studies in the area of sponge iron.

6. To assist in the publication of a news letter for furthering activities in developing countries of the ESCAP region in the area of sponge iron.

7. To provide training facilities on request.

II. ACTIVITIES

1. Advisory services on technology development and transfer.
2. Periodical seminars, workshops and field visits.
3. Organization of information exchange programmes.
4. Organization of training programmes.
5. Publication of a sponge iron news letter.
6. Organization of special studies in the area of sponge iron.
7. To strengthen institutions for assisting regional activities in the area of sponge iron technology development and transfer.
8. Promotion of TCDC.

III. METHODOLOGY

1. Participants in net-work will nominate a contact person for providing support for promoting net-work. This name will be communicated to RCTT by the end of June 1983.

2. RCTT will provide assistance to promote activities of the network. In this effort RCTT will take assistance from UNDP/UNIDO, ESCAP and other UN organizations and institutions outside the UN system.

3. A nodal institution will be nominated by RCTT to promote the activities of the network.

4. RCTT in association with the nodal institution and assistance from the members of network will take necessary action to achieve the objective of the network.

IV. INSTITUTION IN THE NETWORK

Afghanistan	-	
Burma	-	No. 1 Iron Project
People's Republic of China	-	Central Iron & Steel Research Institute, Beijing
India	-	Sponge Iron India Ltd.
Indonesia	-	PT Krakatau Steel
Iran	-	Ahwaz Steel Complex
Malaysia	-	Perwaja Trengganu Sdn. Bhd.
Pakistan	-	PCSIR
Philippines	-	
ROK	-	
Sri Lanka	-	Ceylon Steel Corporation
Thailand	-	Office of Basic Industry Development
Vietnam	-	Metallurgical Institute of Engineering of Ministry of Metallurgy.

ANNEX XVIII

REGIONAL CENTRE FOR TECHNOLOGY TRANSFER
BANGALORE

UNDP/UNIDO/RCTT/Government of India/Government of Indonesia

Study Tour and Workshop to promote technology development and transfer in the area of sponge iron manufacture and use in developing countries of ESCAP Region

Cilegon, Indonesia
and
Paloncha & Hyderabad, India

29 March - 8 April 1983

Issues in the promotion of technology development and transfer in the area of sponge iron manufacture and use in developing countries of ESCAP region*

*Prepared by RCTT Secretariat

INTRODUCTION

In developing countries of ESCAP region, production of iron and steel by direct reduction processes has been receiving increasing attention during the last few years. This is due to the fact that except for a few countries like India and China, most developing countries of this region do not have coking coal which is an essential raw material for producing iron and steel by the traditional blast furnace route. However, during the last few decades, there has been a sustained effort on the part of the developing countries of the region to industrialise their countries and to increase living standards of their people. It is well known that for industrialisation, iron and steel are required. Therefore, there have been efforts by these countries to make use of their natural resources like iron ores, non-coking coals and natural gas for the production of iron and steel and for this purpose, direct reduction was the way out. Another reason why direct reduction processes are becoming popular is the high cost of integrated conventional steel plants with blast furnaces and the non-availability of large financial resources. Added to this, many developing countries do not have large domestic markets to absorb huge quantities of iron and steel that need to be produced in a large integrated steel plant. Another development which gave fillip to the establishment of direct reduction units is improvements in technologies for the production of sponge iron using either natural gas or coal. Therefore, it is no wonder that the establishment of sponge iron units all over the world is increasing apace. Table 1 lists sponge iron units in production, under construction and in the planning stage in countries of ESCAP region. Such units in the rest of the world are listed in Table 2. In 1981, about 8 million tonnes of DRO was produced in the world.

DEVELOPMENTS IN THE ESCAP REGION

As is evident from Table 1, significant developments have taken place in the ESCAP region regarding the establishment of sponge iron units. A unit for the production of 30,000 tonnes per annum of sponge iron by using SL/RN process utilising solid reductant was established at Paloncha, Andhra Pradesh, India. This plant went into regular production in Nov. 1980. UNDP and UNIDO provided financial and technical assistance to the Government of India for the establishemnt of this unit. This unit has been functioning satisfactorily until now.

After the successful operation of the Paloncha sponge iron unit in India, several other units are now coming up in that country. One unit is now under construction in Keonjhar, Orissa, India, utilizing coal and oil as reductants. This has a capacity of 100,000 tonnes of sponge iron per annum. Another unit which is in the public sector has already come into production in Orissa. This plant located in Palaspanga, Orissa has a capacity of 150,000 tonnes per annum. The unit was inaugurated by the President of India on 18 March 1983. Other units in India are planned in Bihar, Madhya Pradesh, Andhra Pradesh and Karnataka States.

A large direct reduction unit utilizing natural gas was established in Cilegon, Indonesia by P.T. Krakatau Steel, a Government of Indonesia Corporation. This plant, having an ultimate capacity of two million tonnes of sponge iron per annum has been functioning very satisfactorily from 1980. A hot strip mill in this unit was opened by the President of Indonesia on 26 February 1983. A sponge iron unit is now under erection in Labuan island, Malaysia. This unit with a capacity of 650,000 tonnes per annum is expected to come into production in 1984. In Burma, a sponge iron plant using coal and with a capacity of 20,000 tonnes per annum is already working. Another unit with a similar capacity is expected to go into operation during 1983.

INITIATIVES IN THE UN SYSTEM

In view of the growing importance of direct reduction processes in the ESCAP region, UNIDO, ESCAP and RCTT have been implementing an active programme of providing assistance to developing countries of the region in the planning, establishment and operation of direct reduction units. Attention has been drawn already to the fact that UNDP and UNIDO assisted the Government of India in the establishment of direct reduction unit in Paloncha, India. With assistance from UNDP and the Government of Netherlands, UNIDO, ESCAP and RCTT organized during Nov. 1979, a workshop on problems of technology transfer for promotion of sponge iron industry in the countries of the ESCAP region, in Bangkok, Thailand. As a result of this workshop, a working group consisting of several countries of the region was formed to exchange information on developments in the area of sponge iron. UNIDO organized in Jamshedpur, India, during 7-11 December 1981 a workshop on regional cooperative research among metallurgical research and development centres in Asia and the Pacific. During this workshop, direct reduction processes were also discussed. In view of important developments that have since taken place in the region, UNDP, UNIDO and RCTT have organised this Study Tour and Workshop in Indonesia and India to stimulate exchange of experience and information on latest technological advances in direct reduction processes and use of sponge iron and evolve suitable programmes for development of this industry in this region.

The objectives of the Study Tour and Workshop are the following:

1) To assess latest developments in technology for making sponge iron using solid and gaseous reductants.

2) To study the working of sponge iron plants of
   a) Sponge Iron (India) Limited at Paloncha, Andhra Pradesh, India, using solid reductant, and
   b) P.T. Krakatau Steel at Cilegon, Indonesia using gaseous reductant.

3) To determine the potential for, and interest of countries in the development of sponge iron industry.

4) To exchange experience among developing countries of ESCAP region in the planning, establishment and operation of sponge iron units.

5) To consider a request for UNDP assistance in the development of sponge iron industry through direct reduction technology for mini steel plant operations, in those countries which express interest and have potential for such an industry.

6) To consider other regional activities in this field including the establishment of a network of institutions engaged in the area of sponge iron.

During the course of this Study Tour, participants had the opportunity of visiting Krakatau Steel Plant at Cilegon, Indonesia, It is one of the largest plants of its kind in the world. The participants also had the opportunity to discuss problems the authorities in Indonesia had in the planning, establishment and operation of the unit. The participants had the benefit of visiting the sponge iron unit of Sponge Iron (India) Limited in Paloncha, Andhra Pradesh, India and discuss problems involved in its planning, establishment and operation, which uses a relatively poor quality noncoking coal with high ash content. In spite of difficulties inherent in using such a reductant this plant has been functioning very satisfactorily.

In the light of the above developments, the Workshop will have opportunities to discuss issues relating to exchange of knowledge and promotion of technology development and transfer in the area of direct reduction processes and use of sponge iron in the developing countries of the ESCAP region.

ISSUES FOR CONSIDERATION

Latest developments in sponge iron technology

The countries of this region will be interested to know what have been the latest developments in the direct reduction processes using both solid reductants and gaseous reductants. There have been continuous improvements in these processes. For example, the vendors of these processes have been claiming improvements in their processes which make it possible to operate these plants more satisfactorily and efficiently. The country papers and the papers by others would give an idea of these latest developments. Discussion of these papers will enhance the awareness of countries of this region of the latest developments in technologies of direct reduction processes and production of sponge iron. Another aspect that could be discussed under this is with regard to the utilization of sponge iron. The combination of direct reduction and electric furnace for making steel is now well developed. The latest developments are highlighted in the papers before the Workshop. These papers could be discussed in order to understand fully all the latest developments in technology.

Potential for development of sponge iron industry in ESCAP region

Earlier in this paper, a short review has been made with regard to the development of this industry in developing countries of the ESCAP region. There is considerable interest in the establishment of such units in other developing countries of the region as well as establishment of more units in countries where such units are already working. For example, Pakistan, Sri Lanka, Bangladesh and Thailand are interested in establishing these units. More units are being planned in India. The plant in Cilegon is establishing units for making full use of facilities already established. Recently, a hot strip mill has started functioning in this unit. The Workshop, therefore, may like to discuss the potential for this industry in developing countries of this region in the light of developments that have already taken place all over the world, the establishment of this industry in some countries of this region and the availability of raw materials and other resources in these countries. Table 3 gives an idea of mineral resources available in countries of ESCAP region for establishing direct reduction units. Recent exploratory work reveals that there are possibilities of finding larger reserves of ores, oil and natural gas in some of these countries.

As already mentioned, some direct reduction units have been functioning in developing countries of this region. The discussion of their experience in the planning, establishment and operation of these units will be of immense benefit to the countries of this region especially those planning to establish new units and those already having these units in their coutnries. Some country papers already describe this experience. The Workshop may like to discuss this experience and suggest pointers for the benefit of those who plan to establish new units. Another aspect which could be discussed will be the kind of   that existing units could extend to those who are planning to establish new units. For example, it may be possible for existing units to test and evaluate raw materials available in other countries. SIIL is already in the process of doing this work. They have taken up testing of raw materials from Pakistan and some countries outside region. Sri Lanka is interested in getting their materials tested in this unit. Another aspect is training of personnel from countries of the region in planning, establishment and operation of these units. This training will be of immense benefit to those planning the establishment of such units and even those who already have such units. Another important matter is with regard to exchange of information on a continuing basis. The units already existing may be in a position to provide this information service to those who are interested in establishing new units. The Workshop may like to discuss all these aspects for sharing experience among developing countries of the region.

UNDP REGIONAL PROJECT

In order to assist countries of this region in promoting the establishment of direct reduction units, a project has been prepared by UNIDO for obtaining support of UNDP. A separate document describing this project has been circulated at this Workshop. The purpose of the project is to maximise utilization of existing facilities for assisting countries of the region in the planning, establishment and operation of sponge iron units. This includes the testing of raw materials and training of personnel. The Workshop may like to discuss this report in detail and make recommendations for consideration by UNDP.

NETWORK OF INSTITUTIONS

At the earlier Workshop on Sponge Iron held in November 1979 in Bangkok, a 12 member working group was constituted. In the light of developments that have since taken place, consideration may be given to the establishment of a network of institutions and chalk out a programme of activity for this network. The programme could consist, among others, exchange of experience and information, advisory services, training, group visits, seminars and workshops. The Workshop may like to nominate a lead institution such that it could act as a nodal point for promoting the network activity.

CONCLUSION

The participants of this Workshop had had the opportunity to see two working sponge iron units, one utilising solid reductant and another gaseous reductant. They had the benefit of disucssions with those in charge of these units. The country papers and papers by others presented at the Workshop have given the latest position not only with regard to developments in technology but also with regard to plans and programmes of developing countries in this region in the establishment of direct reduction units. The deliberations of this Workshop will, therefore, be of immense benefit to all the countries of this region who are interested in the establishment of these units.

Table 1

Direct Reduction Installations in Operation and under Construction in the ESCAP Region

Country	Plant Name/ Location	Process Used	Capacity in 000 tpy	Major Fuel	Status
Australia	Western Titanium	SL/RN I	14	Coal	In Operation
Burma	N, A., (2 plants)	Kinglor Metor	20	Coal	1-In Operation 1-Under Construction
India	SIIL Paloncha	SL/RN	30	Coal	In Operation
	Palaspanga Orissa	ACCAR	150	Gas/Coal	Started operatio in March 1983.
	IPI TATA Sponge Iron Ltd. Keonjhar, Orissa	TDR	100	Coal	Under Construction
Indonesia	P.T. Krakatau Steels Cilegon	HYL	2000	Gas	In Operation
Iran	NISC	HYL	1000	Gas	Not Started
	NISC	Midrex	1200	Gas	Not Started
Japan	Nippon Steel Hirohata	NSC	150	Kerosene	Shut Down
	Hitachi Metals	Wiberg	10	...	In Operation
	Kawaski Steel Misushima	Kawaski	240	...	In Operation as required
	Kawaski Steel Chiba	Kawaski	250	...	-do-
	Sumitomo Metals	Sumitomo	240	...	In Operation
	Nippon Kokan	SL/RN	400	Coal	In Operation as required
Malaysia	Sabah I&S Labuan Island	Midrex	600	Gas	Under Construction
	HICOM Trengganu	NSC	600		Letter of Intent Issued
New Zealand	New Zealand Steel	SL/RN I	160	Coal	In Operation
		SL/RN III	900	Coal	Under Construction

Table 2

Sponge Iron units in production, under construction and in the planning stage in countries outside ESCAP region

Major Fuel: Gas

Process	Plant	Start	In Operation*	Shut Down*	Contracted Under Construction*	
Armco	Armco Steel,USA	1972		330		
FIOR	Matanzas,Venezuela	1976	400			
HIB	Minorca,Venezuela	1973		650		
HyL I	Monterrey I,Mexico	1957	95			
	Tamsa, Mexico	1967	235			
	Puebla I,Mexico	1969	315			
	Monterrey III,Mexico	1974		475		
	USIBA, Brazil	1974	300			
	Puebla II,Mexico	1977	700			
	SIDOR I,Venezuela	1977	420			
	Khor Alzubair,Iraq	1978/81	485			
	SIDOR II,Venezuela	1981	700			
	SIDOR II,Venezuela	1982	1400			
HyL III	Monterrey II,Mexico	1980	270			
	Monterrey 3M,Mexico	1982			500	
	Sidersur, Argentina	?			500	Lol**
	Monterrey 4M,Mexico	1984			750	
	Sicartsa Stage II, Mexico	?			2000	
	Premexa, Mexico	1984			1000	
MIDREX	Oregon Steel,USA	1969		300		
	Georgetown,USA	1971	400			
	HSW,West Germany	1971	400***			
	Sidbec I,Canada	1973	400			
	Dalmine,Argentina	1976	400			
	Sidbec II,Canada	1977	650			
	SIDOR I,Venezuela	1977	400			
	Acindar,Argentina	1978	420			
	Qatar Steel,Qatar	1978	400			
	SIDOR II,Venezuela	1979	1275			
	ISCOTT I,Trinidad	1980	420			
	NFW, West Germany	1981	800			
	BSC, Hunterston, Great Britain	?		800 (not started)		
	Warri, Nigeria	1982			1020	
	OEMK, USSR	1983			1670	
	ISCOTT II,Trinidad	1982			420	
	HADEED,Saudi Arabia	1982			800	
	Misurata, Libya	1984			1100	
Purofer	Thyssen,W.Germany	1970		150		
	COSIGUA, Brazil	1977		350		
Wiberg	Sandvik, Sweden	1952		25		
	Uddeholms AB,Sweden	1954		30		
	SKF, Sweden	1969		25(conversion to Plasmared)		

Major Fuel: Coal

Process	Plant	Start	In Operation*	Shut Down*	Contracted Under Construction *
ACCAR	Allis Chalmers,USA	1973	35***		
	Sudbury, Canada	1976		240	
DRC	AZCON,Rockwood,USA	1978	60		
	Scaw Metals,South Africa	1983			80
Hoganas	Hoganas Corp.,USA	1954	70		
	SSAB, Sweden	1954	30		
	Hoganas, Sweden	1963	130		
Kinglor Meter	Kinglor Metor,Buttrio, Italy	1973		11	
	Arvedi,Cremona,Italy	1976		40	
Krupp/Codir	Dunswart, South Africa	1973	120		
Rotary Kiln	Tohoku-Satetsu	1957		24	
SL/RN	Acos Finos Piratini, Brasil	1973	60		
	Hecla, USA	1975		68	
	Stelco, Canada	1975	360***		
	Siderperu, Peru	1980	120		
	ISCOR,South Africa	1984			720
Prereduction					
Lurgi-Highveld	Highveld,South Africa				
	Module 1-4	1968	1000		
	Module 5	1974	250		
	Module 6	1976	250		
	Module 7+8	1978	500		
	Module 9	1980	250		
	Module 10	1981	250		
	Module 11,12,13	1982			750

*1000 tpy **Letter of Intent ***in operation as required

Table 3

Natural Resources Available in ESCAP Countries for Sponge Iron Manufacture

Country	Iron Ore (million tons)	Coal (million tons)	Natural Gas (billion m³)
Afghanistan	2,100	85	-
Bangladesh	-	1,491	235
Burma	100	265	3
India	21,500	94,734	70
Indonesia	592	639	285
Iran	820	367	10,760
Malaysia	97	-	323
Pakistan	400	1,491	459
Philippines	920	91	1
Sri Lanka	32	-	-
Thailand	45	235	
Vietnam	141	1,000	-

UNIDO - Draft World Wide Study of the Iron and Steel Industry 1975-2000

ANNEX XIX

UNITED NATIONS DEVELOPMENT PROGRAMME

Regional Project of the Governments of

Democratic Republic of Afghanistan, People's Republic of Bangladesh, Socialist Republic of the Union of Burna, People's Republic of China, Republic of India, Republic of Indonesia, Islamic Republic of Iran, Republic of Korea, Malaysia, Islamic Republic of Pakistan, Republic of the Philippines, Democratic Socialist Republic of Sri Lanka, Kingdom of Thailand and Socialist Republic of Viet Nam

Title: Regional Development of Sponge Iron Industry through Direct Reduction Technology for Mini Steel Plant Operations

Project Number: DP/RAS/81/063 Duration: 3 years

Sector: Industry Sub-sector: Iron and Steel Industry

Primary function: Direct support Secondary function: Industry

Government Implementing agency: Ministries of Industries in participating ESCAP countries

Executing Agency: United Nations Industrial Development Organization (UNIDO)

Estimated starting date: 1 September 1983

Government inputs: UNDP inputs US$ 500,000

Signed: ______________________ Date: ______________

On behalf of the Governments

______________________ Date: ______________

On behalf of UNIDO, the Exeucting Agency

______________________ Date: ______________

On behalf of the United Nations
Development Programme

PART I - LEGAL CONTEXT

This project document shall be the instrument referred to as such in Article I, paragraph 2 of the Agreement between the Governments of:

and the United Nations Development Programme, signed by the parties on

respectively.

The Governments' Implementing Agencies shall, for the purpose of the Standard Basic Agreement, refer to the Government's Co-operative Agencies described in that Agreement.

PART II - OBJECTIVES

A. DEVELOPMENT OBJECTIVES

Within the principal context of industrial development of the ESCAP countries, based on the exploitation of those countries' natural resources and raw materials, the major development objectives are to survey, investigate and technologically assess the possibilities of promoting sponge iron production for development/expansion of the steel industry, with a view of economically utilizing raw material resources and applying the most appropriate sponge production technology (gas or coal as a reductant) as well as estimating the domestic market for sponge iron and consider possible exports, including intra-regional trade.

B. IMMEDIATE OBJECTIVES

The project will facilitate co-operation among the participating countries in the promotion/establishment of national and/or regional plants for the production of sponge iron, through the most suitable route, depending on individual conditions. In particular, the immediate objectives will cover the following:

(a) to study the application of well-proven direct reduction technological processes in developing countries, based on available resources, such as
   i. iron ores (high grade lumps/oxide pellets) and ilmentic ores for sponge production;

ii. natural gas including naphta resources for direct reduction;
iii. solid reductants (non-coking coals, charcoal)

(b) to select the optimum direct reduction technology best suited for sponge production in different countries of the ESCAP region, through the establishment of:

i. sponge plants on a national basis;
ii. sponge plants on a regional basis.

(c) to recommend the appropriate steps to be taken in establishing such plants on a bilateral and multilateral basis, including the mechanism of exchange of raw materials and sponge products amongst developing coungries in the Asia region to meet the national and regional steel market needs.

(d) to assess the capital investment needs to set up facilities envisaged under (a) and (b) above and make techno-economic appraisals thereof including evaluation of production costs based on alternative technological routes.

(e) to prepare a master plan for the growth of the iron and steel industry based on sponge iron production on a national basis for various developing countries in the region, with particular reference to (a) and (c) above, and in doing so, to undertake wherever necessary:

i. laboratory/pilot demonstration scale investigations on sponge production based on high grade iron ores/pellets, ilmenitic ores and solid (non-coking coals) reductants at a Demonstration Plant including the UNDP/UNIDO established Pilot and Demonstration Plant for the production of sponge iron at Kothagudem, Andhra Pradesh, India (DP/IND/71/611);
ii. formulate the production flow-sheets for respective sponge plants in different countries; and
iii. assess the overall techno-economic analyses of sponge production and its use for the steel industry in the developing countries of the ESCAP region.

C. SPECIAL CONSIDERATIONS

The effective implementation of this project will, to a great extent, depend on the technical co-operation among the participating developing countries. Sponge iron production in countries of the Asia and the Far East region would represent an important step in their drive to promote their steel industries on techno-economically acceptable scales, taking into account and utilizing the technical and demonstration scale facilities arleady established through UNDP/UNIDO technical assistance at the Demonstration Plant for the production of sponge iron at Kothagudem, Andhra Pradesh (India) and other possible centres and operational plants such as the direct reduction facilities at the Krakatau Steel Plant in Indonesia.

D. BACKGROUND INFORMATION AND JUSTIFICATION

During the last decade several technical advisory missions and meetings have been carried out under the auspices of UNDP and UNIDO to focus attention on problems and potential of developing viable iron and steel industries in the developing countries of the world. However, in spite of all these efforts, on national and regional basis, the integration achieved is still far from ideal, largely because of different socio-political conditions, but also owing to numerous technical and financial problems faced by the concerned countries. However, in recent years promising technological changes have taken place in the iron and steel industries and it is now possible to establish and operate viable plants on a much smaller scale, based on sponge iron production and its melting in electric arc furnaces to produce commercial grades of steels. It is now essential to explore ways and means of increasing regional steel production by means of application of modern steelmaking technology and, in particular, the direct reduction process to produce sponge iron for mini steel plant operations.

The subject for development and promotion of sponge iron production was amply discussed at the UNDP sponsored and UNIDO/RCTT organized Study Tour and Workshop to Promote Technology Development and Transfer in the Area of Sponge Iron Manufacture and Use in Developing Countries of the ESCAP region, held from 29 March to 8 April 1983 at Hyderabad, India, and incorporating visits to the Krakatau Steel Plant, Cilegon, Indonesia (Direct reduction plant using gaseous reductant) and Pilot and Demonstration Plant for the Production of Sponge Iron at Kothagudem, India (using solid reductant).

The participating countries (

urged the need for UNDP assistance in the development of sponge iron industry through the promotion of the direct reduction route to produce sponge iron suitable for mini steel plant operations. It was appreciated by the participants that the Workshop and Study Tour provided a good opportunity for them to assess latest sponge iron production developments, to study the working of sponge iron plants and to exchange experience on plant operations and planning of sponge iron plants. Support was considered desirable in strengthening their sponge technology capabilities and in the assessment of demand for sponge iron and techno-economic feasibility of setting up production units and in the selection of appropriate technology to suit conditions and resources prevailing in the various countries of the region. Such support could possibly be provided in a UNDP/UNIDO sponsored project which would consider both the national and regional aspects of sponge iron production and co-operation among the countries of the region.

It has been recognized that steel scrap in recent years has been such an uncertain and unpredictable commodity, both with respect to availability and price, that electric arc steel melting capacity has to find alternative feed material for sustained growth. The scrap position for some of the developing countries for the years 1985 and 2000 are given in the table below. It shows that there will be an overall scrap deficit of about 4 million tons by 1985 and 10 million tons by the year 2000.

Table 1

Scrap position and sponge iron requirements by 1985 and by 2000

(in 1000 tons)

	1985		2000	
	Scrap position	Equivalent sponge iron requirement	Scrap position	Equivalent sponge iron requirement
Afghanistan	(-) 23	25	(-) 32	35
Bangladesh	(-) 75	83	(-)364	400
Bhutan	(+) 0.35	-	(+) 1	-
Brunei	(+) 0.53	-	(+) 2	-
Burma	(+) 11	-	(-)295	324
India	(-)694	760	(-)1180	1300
Indonesia	(-)630	690	(-)715	786
Iran	(-)2,538	2,790	(-)6265	6900
Kampuchea	(-) 22	24	(-) 35	38
Laos	(+) 4	-	(+) 11	-
Malaysia	(-)212	233	(-)978	1075
Nepal	(-) 20	22	(-) 32	35
Pakistan	(-) 10	11	(-)329	362
Philippines	(+) 77	-	(-) 53	58
Singapore	(+) 48	-	(-)200	220
Sri Lanka	(-) 37	41	(-)149	164
Thailand	(+) 16	-	(+)151	-
Vietnam	(+)173	-	(+)502	-
TOTAL	(-)3931	4,679	(-)9960	11697

The countries which will face a severe scrap deficit by 1985 to warrant establishment of sponge iron capacities would be Bangladesh, India, Iran, Indonesia and Malaysia. By the year 2000 the list would further swell by the addition of Burma and Pakistan. Other countries like Afghanistan, Kampuchea, Nepal, Philippines, Singapore and Sri Lanka will also require sponge iron which may, however, be met on export basis from sponge producing countries of the region.

Assuming that the projected scrap shortage would have to be met by sponge iron, the corresponding demand for sponge iron is projected at 4.7 million tons and 11.7 million tons by 1985 and the year 2000 respectively.

Iron ore situation

Estimates of the availability of iron ore in countries like Afghanistan, India, Indonesia, Iran, People's Democratic Republic of Lao, Pakistan and the Philippines have been outlined in various documents.

India, Iran, Malaysia and Thailand are the only iron-ore exporting countries in the Asian region and had a total production around 40 million tons in 1979. The iron ore reserves of Burma, Nepal, Sri Lanka and Viet Nam are rather low. India possesses about 20 billion tons of potential iron ore reserves, while Pakistan has about 400 million tons, Afghanistan about 2 million tons and the Philippines about 900 million tons. Total Reserves of these countries is about 22 billion tons.

Whilst Sri Lanka has very meagre iron ore reserves, it possesses titaniferous beach sands which can be effectively processed through direct reduction technology to yield highly metallized sponge which will contain the titania contents of the original beach sand. This sponge can be further treated to yield a slag high in its TiO_2 content and the metallic iron content is processed on to steelmaking. Similar deposits exist in other countries such as South Africa and New Zealand and those countries are already processing these vanadiferous and titaniferous deposits respectively on an industrial scale to produce sponge iron and steel.

Hajigak iron ore deposits of Afghanistan, Pange Pet of Burma, Bailadila, Barajamda, Bellary-Hospet, Goa, Kudremukh and Bababudan deposits in India, Sebuku and Larona deposits of Indonesia, Arak and Bafque areas in Iran, Kieng Khouang deposits of Lao, Bakit Ibam deposit of Malaysia, Pulcnoke of Nepal, Mazara Laugrial and Chi Chali deposit of Pakistan, Lammin and Larap and Manicamni deposits of Philippines, Amphoe Chian Karn and Amphoe Muang deposits of Thailand are the important iron ore deposits in the ESCAP region. A preliminary examination of the type of ore and chemical analysis as can be seen from Table 3 suggests that many of these deposits could be explored either directly or after beneficiation for further processing by the DR route. The iron content in the various deposits shows a fairly wide range and in certain cases Al_2O_3 is also on the higher side. However, steps have to be taken for iron ore beneficiation/pelletizing for establishing the suitability of various grades of ores for sponge iron production.

Detailed information on iron ore reserves in ESCAP countries, major deposits and chemical analyses of iron ores are provided in the following tables 2 and 3.

Table 2

Iron ore reserves in ESCAP countries

(in million tons)

Country	Measured and indicated	Measured, indicated and inferred	Potential reserve
Afghanistan	-	-	2,110
Bangladesh	-	-	-
Bhutan	-	-	-
Brunei	-	-	-
Burma	6	30	100
India	5,580	8,646	21,500
Indonesia	30	57	592
Iran	30	160	820
Kampuchea	-	-	-
Laos	-	-	1,008
Malaysia	83	89	97
Nepal	-	14	30
Pakistan	-	400	400
Philippines	77	907	920
Singapore	-	-	-
Sri Lanka	-	10	32
Thailand	-	26	45
Viet Nam	-	63	141

Table 3

Major deposits and chemical analysis of iron ores

No.	Country	Reserves (in million tons)					Type	Constitutents (%)				
		Measured	Measured and indicated	Measured indicated & inferred	Potential ore	Total resources		Fe	SiO_2	Al_2O_3	P	S
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	AFGHANISTAN											
	Hajigarh Pass	-	-	-	1,000	1,000	-	30-50	-	-	-	-
2.	BURMA											
	i. Pant Pet	-	1	20	69	89	Goethite Hematite Magnetite	45-65	1.6-16.0	-	0.04-0.33	-
	ii.Tungoo	-	-	-	97	97	-do-	25-43	13.0-29.0	15.0-25.0	0.10-0.45	0.30-0.90
3.	INDIA											
	i. Bihar-Orissa	2,578	3,420	3,050	-	3,050	Hematite	55-59	1.0-6.5	0.9-6.4	0.03-0.38	0.01-0.05
	ii.Bailadila	990	1,550	1,625	-	1,625	Hematite	59-66	0.9-3.4	-	0.05-0.16	0 03-0.44
	iii.Bellary	425	837	868	-	868	Hematite	55-68	0.6-14.0	0.2-5.3	0.02-0.08	-
	iv.Goa	100	218	396	-	396	Hematite	55-65	Upto 6.0	Upto 6.0	0.02-0.06	-
4.	INDONESIA											
	i. Sebuku	-	-	-	87	87	Goethite	48	2.2	-	0.01	0.12
	ii.Seidua	-	-	-	39	39	Goethite	48-50	4.5-5.0	-	0.03-0.04	0.11-0.12
	iii.Larena	-	-	-	370	370	Goethite	48-55	2.5-5.0	9.0-13.0	-	-
	iv.Erzberg	-	30	30	-	30	Magnetite	50	-	-	-	-

(1)	(2)	(3)	(4)	(5)	(6)
5.	IRAN				
A.	Arak Aron				
i.	Kajar Ab.	-	-	-	20
ii.	Ahmad Rowghant	-	-	-	10
iii.	Shamsabad	-	-	-	48
B.	Bafqu Area				
i.	Chador Malu	14	30	69	-
6.	LAO				
	Xieng Khouang	-	-	-	1,000
7.	MALAYSIA				
	Bukit Ibam	11	14	14	-
8.	PAKISTAN				
i.	Hazara	-	-	60	-
ii.	Langrial	-	-	8	16
iii.	Chichali	-	-	450	-
9.	PHILIPPINES				
i.	Larap	43	43	43	-
ii.	Manicani	-	-	-	20
iii.	Lammin	-	-	-	14
iv.	Goto	-	-	-	12
v.	Dinagat	-	-	104	1,444
vi.	Surigao	-	-	475	139
10.	THAILAND				
i.	Amphoe Chiengkarn	-	-	-	16
ii.	Amphoe Muang	-	-	-	11
iii.	Khao Thap Khuwai	-	-	8	-

(7)	(8)	(9)	(10)	(11)	(12)	(13)
20	Hematite	35	-	-	-	-
10	Hematite	40	-	-	-	-
48	Hematite Goethite	44	14.0	-	-	0.45
69	Magnetite Hematite	50-60	-	1.9	-	-
1,000	-	60	-	-	-	-
14	Hematite Goethite	62	8.1	-	0.05-0.06	0.05
60	Hematite	16-40	9.0	-	0.30	-
24	Hematite	30-45	13.0	9.0	-	-
450	Chamesite Goethite Siderite	31-34	22.0-24.0	5.0-9.0	0.39-0.69	0.07-0.22
43	Magnetite Hematite	37-40	10.0	2.5	0.15	0.50-4.00
20	Goethite	48-49	8.0-10.0	1.8-2.0	0.03	0.20
14	Magnetite Hematite	51-71	Upto 11.0	1.2	0.03-0.14	0.30
12	Goethite Hematite	50	-	-	-	-
1,548	Goethite	48	-	-	-	-
614	Goethite	47	-	-	-	-
16	Magnetite Hematite	59-68	Upto 16.0	-	0.02-0.09	-
11	Magnetite Hematite	45-65	Upto 7.5	-	0.12-0.13	-
8	Hematite	44-67	2.2-17.0	-	0.04-0.18	0.01-0.03

Natural gas and coal resources

Many of the South and South-East Asian countries have either natural gas or coal, or both. An estimate of the availability of natural gas in Iran, Pakistan, Burnei, Malaysia, Indonesia and Bangladesh and of non-coking coal - an alternate reductant - in India, Bangladesh, Pakistan, Viet Nam, Indonesia, Iran, Burma and Thailand is given below. The countries which do not have either of these reductants are Afghanistan, Bhutan, Kampuchea, Laos, Nepal, Singapore and Sri Lanka. Sri Lanka may use inter alia Indian Singareni non-coking coal for direct reduction trials and investigation.

Table 4

Natural gas and non-coking coal resources

No.	Country	Natural gas x 109 Nm^3	non-coking coal million tons
1.	Afghanistan	-	85
2.	Bangladesh	235	1,491
3.	Bhutan	-	-
4.	Brunei	456	-
5.	Burma	3	265
6.	India	70	59,968
7.	Indonesia	283	639
8.	Iran	10,760	367
9.	Kampuchea	-	-
10.	Laos	-	-
11.	Malaysia	323	-
12.	Nepal	-	-
13.	Pakistan	459	1,491
14.	Philippines	1	91
15.	Singapore	-	-
16.	Sri Lanka	-	-
17.	Thailand	-	235
18.	Viet Nam	-	1,000

Considering the availability of these raw materials as well as the power potential of certain developing countries and sponge iron demand, Bangladesh, Burma, India, Indonesia, Iran, Malaysia and Pakistan could be potential producers of sponge iron in the region of South and South-East Asia. These countries fulfil exceedingly well the conditions required for the creation of sponge iron facilities. The current status and projections of sponge plants are given in Table 5.

Table 5

Logistics for sponge iron capacity planning

No.	Country	Potential reserve: Iron ore (1) Quantity Mt	Potential reserve: Iron ore Fe %	Potential reserve: Non-coking coal Mt	Potential reserve: Natural gas 10^9 m^3	Potential reserve: Oil Mt	Power situation: Installed capacity in 1974 MW	Power situation: Potential hydro-power GW	Projected EAF capacity 1985	Projected EAF capacity 2000	Scrap Balance 1985	Scrap Balance 2000	Sponge iron requirement 1985	Sponge iron requirement 2000	Sponge iron capacity planned 1985	Sponge iron capacity planned 2000	Scrap/sponge demand and justification for installation of sponge iron capacity or otherwise
									(in '000 tonnes)								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1.	Afghanistan	2,110	30-50	85	NA	-	284 (236)	6,000	40	80	-23	-32	25	35	-	-	Limited demand; Reductant limited. Good hydro-power potential. No planning of sponge iron capacity. EAF to operate with imported scrap/sponge.
2.	Bangladesh	NA	-	1,491	235	-	661 (80)	1,300	50	650	-75	-364	83	400	1x400G	1x400G	Requirement less in '85 increasing in 2000. Enough natural gas reserves. Hydropower potential exists. Sponge iron capacity of 400,000 t planned in '85 itself will suffice upto 2000.
3.	Bhutan	-	-	-	-	-	NA	-	-	-	+ 0.35	+1	-	-	-	-	No sponge iron capacity called for due to limited market and absence of raw materials.
4.	Brunei	-	-	-	456	294	81 (-)	-	-	-	+ 0.53	+2	-	-	-	-	Demand very small; resource : natural gas and oil. No sponge iron capacity planned.
5.	Burma	100	45-65	265	3	6	263 (101)	75,000	50	550	+11	-295	-	324	-	1x400S	Limited market; reductant : coal; very large hydro-power potential; sponge iron plant using coal as reductant envisaged.
6.	India	21,800	55-65	58,858	70	118	20,196 (7,523)	70,000	4,900	9,500	-694	-1,100	760	1,300	1x300S 1x400G	1x300S 2x400G 1x400G	Moderate demand. Ore and coal available in plenty. Very good hydropower potential. Sponge iron plant contemplated both solid & gaseous route.
7.	Indonesia	602	50	639	283	1,558	1,044 (404)	30,000	1,380	2,380	-630	-715	690	786	2x400G	2x400G	Demand not very large; ore available; gas potential good; hydro-potential good. Sponge iron plant envisaged through gaseous route.
8.	Iran	820	90-68	307	10,760	9,308	4,200 (NA)	10,200	5,000	12,000	-2,538	-6,266	2,790	6,900	8x400G	8x400G 8x600G	Huge market; ore available; natural gas richest reserves; good hydropower potential. Good number of gaseous DR plants contemplated.
9.	Kampuchea	-	-	-	-	-	NA	-	40	80	-22	-66	24	38	-	-	Limited demand. Absence of raw materials. No sponge iron plants envisaged. Scrap/sponge for the EAF to be imported.
10.	Lao	1,800	63	-	-	-	60(2) (44)	NA	-	-	44	41	-	-	-	-	Small demand. Ore exists; No sponge iron capacity thought of.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
11.	Malaysia	97	42-62	-	323	-	1,092 (298)	1,300	550	2,050	-212
12.	Nepal	30	59	-	-	-	59 (42)	NA	60	120	-20
13.	Pakistan	408	30-40	1,491	459	4	1,920 (2) (586)	20,000	400	1,400	-10
14.	Philippines	920	30-60	91	1	-	3,090 (2)	7,500	500	1,500	+77
15.	Singapore	-	-	-	-	-	1,109 (-)	-	400	900	+48
16.	Sri Lanka	32	50-60	-	-	-	201 (195)	1,200	100	300	-37
17.	Thailand	45	45-65	236	-	NA	2,431 (910)	6,200	500	1,000	+46
18.	Vietnam	141	NA	1,000	NA	NA	NA	53,600	40	40	+173
						Total			14,110	33,550	

Note: (1) Analysis based on major deposits.

(2) For public consumption.

Figures in brackets indicate hydropotential

(13)	(14)	(15)	(16)	(17)	(18)
-978	233	1,075	1x400G	1x400G 1x600G	Limited demand by '85 increases by 2000. Ore exists; gas abundant. Gas based DR plants have been thought of.
-32	22	35	-	-	Limited demand; Not favourably disposed with respect to raw materials. No sponge iron capacity planned. Scrap/sponge requirement to be met through imports.
-329	11	362	-	1x400G	Limited demand. Abundant natural gas reserves. Very good power potential. DR plant gaseous based envisaged.
-53	-	58	-	-	Limited sponge iron requirement. Ore available. Some power potential exists. The requirement can be easily met through imports.
-200	-	220	-	-	Limited demand. No natural resources. Scrap to be imported.
-149	41	164	-	-	Small demand. Limited raw materials. No sponge iron plant envisaged. Scrap/sponge to be imported.
+451	-	-	-	-	Ore and non-coking coal - small quantity. No sponge iron facility envisaged.
+502	-	-	-	-	Lack of demand. Non-coking coal available. No sponge iron capacity envisaged.
	4,679	11,697	5,500	12,500	

Considering the deep interest of a number of developing countries in establishing steel capacity based on sponge iron, the urgency of technical assistance in strengthening their technological capabilities in the sponge technological fields is imperative. These countries need technical assistance in the assessment of current demand and future projections for sponge iron and of techno-economic feasibility of setting up production units, in the selection of appropirate technology to suit their conditions and resources endowment, in the development of technological expertise.

The following areas need concerted attention and assessment:

. Surveys of the existing and projected (over the next 10 years or so) demand for sponge iron.

2. Surveys of the availability and characteristics of the raw materials for sponge production; in case the raw materials have to be imported, the economics of import and characteristics of the raw materials from the sources contemplated are to be taken into account.

3. Assessment of techno-economic feasibility of projects for the production of sponge iron.

4. Surveys of the available technologies and optimum selection of the most appropriate technologies and process routes suited to the conditions of the ESCAP region countries for sponge production.

5. Assessment of capital and production costs for sponge production for developing countries based on sound techno-economic rationale.

The foregoing data provide the background and justification for this inter-country project for developing countries in Asia and the Pacific. The recently held Study Tour and Workshop on Sponge Iron Production (29 March - 8 April 1983 in Indonesia and India) has come up with the strong desire and recommendation to undertake the necessary surveys including laboratory/pilot scale investigations of metallurgical raw materials for the direct reduction method processing for the interested countries of the region so that a Master Plan for the development of sponge iron capacities can be established which would provide a useful document for planning and decision makers as well as technologists in developing countries of the Asia and the Pacific region. The meeting approved the project concept and recommended an early implementation of the project.

E. PROJECT OUTPUTS

The project will result in the preparation of a comprehensive study, a Master Plan for establishment of sponge iron production facilities in the ESCAP region countries which will be a useful policy document for decision-makers and planners of developing countries in the region. For preparation of the Master Plan the consultants will assess the current situation and markets for sponge iron and will take into account all available studies. As necessary, laboratory, pilot and demonstration scale tests with local raw material and ores will be carried out for individual countries of the region, possibly at the UNDP/UNIDO established Pilot and Demonstration Plant for the Production of Sponge Iron at Andhra Pradesh, India or at any other plants/centres that dispose of the required know-how and technological process routes. The individual tests and investigations will result in specialized country reports which will also be made available to the participating countries in the region. The Master Plan will give due consideration to regional co-operation as regards raw materials availability and supply as well as trading of the sponge iron to be produced to feed the mini steel plants of the region.

F. PROJECT ACTIVITIES

A team of individual top level experts specialized in sponge iron production through the direct reduction route or a consulting firm will be selected through international bidding and will undertake the following:

(a) Visit the countries in the region that have endorsed the project document and thus manifested their interest in the proposed regional project. The respective Governments will identify national offices/institutions/centres/plants which will be responsible for co-ordination of activities at the national level. They would closely co-operate with the UNDP/UNIDO experts/consulting firm and provide all necessary data, such as previous reports and surveys related to raw materials availability, processing, financial studies, market studies, etc.

(b) Based on collected material and available background information at the disposal of the international experts/consulting firms they will study and appraise the iron ores, non-coking coals, natural gas and fluxes required; this will include recommendations on the required beneficiation/agglomeration techniques to upgrade iron ores should these be of low grades warranting their upgrading/concentration to high grade lumpy ore and/or pellets. Likewise the non-coking coals will be analysed for use as possible reductant to produce sponge iron. The availability of natural gas and the application of the direct reduction route using the latter reductant will also be considered where available. A techno-economic appraisal will be made of these studies/processing technologies in the report to be prepared.

(c) The above activities will entail the undertaking of investigation work which may be based on the following scale of oprations, according to the individual requirements of the participating countries and their raw material resources:

i. Laboratory bench scale test work for direct reduction to produce sponge iron; the scale of operation will be limited to the processing of 100 - 300 kg/day of raw materials in laboratory kiln operation. The results will be analysed in order to investigate sponge production on a laboratory pilot plant scale operation - with 40 - 120 kg/day of produced sponge iron.

ii. Laboratory pilot scale operations will be conducted on processing about 10 - 12 tons of raw materials per day to produce 5 - 6 tons of sponge iron per day. The results will be technically analysed and if these yield promise the investigations will be conducted on to a demonstration and pilot plant scale.

iii. Demonstration scale trials will be conducted on a minimum of 10 days continuous rotary kiln trial operation which will yield about 100 tons of highly metallized sponge per day - these trials will require about 160 tons of iron ore, about 130 tons of coal per day and about 30 - 40 tons of limestone to sustain a single day (24 hours) continuous operation and the requisite raw materials will be needed in a quantity and allow for a continuous/non-stop investigation trial of 10 days on a demonstration scale or on a more extended scale of operation lasting 3 - 4 weeks of non-stop operations.

Individual sub-contracts will be issued for undertaking the required tests. The results of test work and trials based on i., ii. and iii. above will be compiled, analysed and techno-economically adjudged through the preparation of a detailed project/feasibility report which will technically analyse all the pros and cons and include a techno-economic appraisal of sponge production from demonstration scale on to possible industrial/commercial scale operations.

Apart from the above work to be undertaken and/or co-ordinated by the international experts/consulting firm in the indicated sequence, the latter will also undertake the detailed study to prepare a comprehensive project/ feasibility report covering inter alia the following areas:

(a) Area I (A) Reduction Process

Study of reduction process of iron ores/pellets

- technology of reduction process including direct reduction
- Assessment of capital investment needed to set up the necessary facilities for sponge iron production

(b) Area II (B) Study of possibilities in setting up a Sponge Iron Plant

- Study of the background materials available in UNIDO and in the Regional Economic Commission
- Field visits to member countries and collection of necessary data as well as discussion of major problems and opportunities with representatives of national ministries of industries and other officials

(c) Completion of the final report/master plan for sponge production in developing countries of the ESCAP region

The above will be based on:

i. Practical investigations on laboratory, pilot/demonstration scale for sponge iron production

ii. Techno-economic analyses and evaluation of the results obtained vide i. above

iii. Assessment of capital and infra-structure costs and the production and operational costs of sponge production in the countries of the region.

The international consultants will be required to prepare an interim and a draft final report which will be discussed in the presence of UNDP, UNIDO and ESCAP countries before completion of the final report for dissemination to participating developing countries in the region.

G. PROJECT INPUTS

1. Participating Governments

(a) Each participaitng Government will appoint a National Co-ordinator responsible for managing the project at the national level which includes close collaboration with the team of experts/consulting firm selected under the UNDP/UNIDO project. Appropriate personnel will also be designated to assist in such co-operation. The Government/Project authorities will provide to the consultants/contractors any previous reports, studies and surveys pertaining to the establishment of sponge iron production and/or steelmaking in the country, as specified in Annex A to this Project Document (Items 5 and 6).

(b) The Government/project authorities will undertake to select, prepare and arrange for transport of representative samples of raw materials for necessary testing, as specified in item 1 of the Annex to this Project Document. They have the right to send their representatives at their own cost to observe the tests (see item 2 of Annex 1)

(c) The Government/project authorities will provide due local facilities to the UNIDO consultants/contractor, such as the office space, secretarial assistance and local transport (see item 4 of Annex 1).

2. UNDP/UNIDO INPUTS

(a) International staff

i. Assignment of international technical consultants (team of experts or consulting firm) to undertake the preparation of a master plan for development of sponge iron production facilities in ESCAP region countries. The team of experts will comprise:

ii. Selection, through international bidding, of laboratories, R+D centres and/or pilot and demonstration plants for undertaking the following, as need may be:

- laboratory bench scale operations, including detailed report to analyse the results
- laboratory pilot plant scale operations including the preparation of a detailed report analysing the results obtained and conclusions drawn

- demonstration scale operations based on 100 tons/day of sponge production over a 10 day non-stop operation, including the preparation of a detailed project/feasibility report, analysing the results obtained and a detailed techno-economic appraisal of industrial scale operations. In certain cases the demonstration scale trials may have to be extended on to 3 - 4 weeks continuous operations.

The costs for the above three types of testing/investigation work are estimated as follows:

laboratory bench scale operations: US$ 10,000 - 12,000
laboratory pilot plant scale operations: US$ 25,000 - 50,000
demonstration scale operations (10 days, 100 tons/day of sponge production): US$ 80,000 to 130,000. If the demonstration trials are extended on to 3 - 4 weeks continuous operations, the costs will exceed US$ 200,000 and will need to be negotiated.

In addition to the bearing of costs for selection, preparation and transportation of materials to be tested, it is expected that participating Governments will provide cost-sharing of the test work to be undertaken, particularly on the demonstration scale operation level. Such arrangements will be individually negotiated.

The UNDP inputs to support the project should therefore be viewed as a stimulus to get the participants more deeply involved in the deliberate and voluntary exchange or sharing of their technical resources, skills and capabilities.

(b) Training

Participating countries will be entitled to send at their cost representatives to the Centre where the tests/investigations/demonstration trials will take place. They will be regarded as observers for the period to be mutually agreed upon in each individual case (see item 2 of Annex 1).

(c) UN mission costs

This item includes costs of UNDP/Executing Agency participation in meetings related to the discussion of iterim and draft final reports and tripartite project review meetings.

H. WORK PLAN

A detailed Work Plan for the implementation of the Project will be finalized by the Secretariat in consultation with the Team Leader of the selected consulting firm. This Work Plan will be annexed to the Project Document and considered as part of that document. Tentatively, the Work Plan may be outlined as follows:

	Activity	Location	Date, Duration 1/
1.	Project Document, as approved by Workshop participants in Hyderabad in April 1983 will be sent to potential participating ESCAP countries for endorsement	Vienna	May 1983
2.	Governments of participating countries signs project document and designates national co-operating institution and appoints representative	All participating governments	August 1983
3.	UNIDO invites bids from international consulting firms	Vienna	September 1983
4.	Assignment of international technical consulting firm to prepare the study/master plan for sponge production in countries of the region	Vienna in co-operation with countries	October 1983
5.	Collection of data by consulting firm and identification of countries whose raw materials are to be tested (interim report)	Individual ESCAP countries	November 83 - April 84
6.	UNIDO invites bids from laboratories/ R+D centres/pilot and demonstration plants for carrying out necessary test work	Vienna in consultation with countries and contractor	April 1984
7.	Negotiations with individual countries regarding cost-sharing of laboratory/pilot/demonstration tests	Individual countries	May - June 1984
8.	Assignment of laboratory(ies), centre(s), pilot and demonstration plants for undertaking required test work	Vienna, in consultation with countries	July 1984

1/ The identical timings will be revised and updated depending upon the timing of the approval of the project.

9.	Selection of representative samples of raw materials to be tested, their preparation and transportation to the testing site	Individual participating countries	August - October 1984
10.	Undertaking of required test work at selected centre(s), with participation of representatives from participating countries, as to be agreed upon	Contractor's testing facilities	October 84 - March 85
11.	Preparation of test reports discussion with contractor of master plan and individual countries	yet to be established	April 1985
12.	Preparation of draft final report by contractor. Discussion in presence of UNDP, UNIDO and ESCAP/ RCTT representatives	Vienna India	August 1985
13.	Completion of final/report master plan for sponge iron production in the region	Contractor's residence	November 1985
14.	Dissemination of report to participating countries in the Asia and Pacific region	Vienna	December 1985

I. PREPARATION OF THE FRAMEWORK FOR EFFECTIVE PARTICIPATION OF NATIONAL AND INTERNATIONAL STAFF IN THE PROJECT

The activities required to yield the indicated outputs and achieve the project's immediate objectives will be carried out and co-ordinated by the national staff and international consultant's personnel with UNIDO playing the catalytic role. This frameowrk will be reviewed from time to time and, if necessary, be formulated and attached to this Project Document as an Ennex.

J. DEVELOPMENT SUPPORT COMMUNICATION

The technical/progress reports to be prepared through this regional project are subject to distribution, as appropriate, for the effective maintenance of development support communication throughout the project's life/duration.

K. INSTITUTIONAL FRAMEWORK

UNIDO wil , as the Executing UN agency, be respcnsib: e for various project activit es to oe undertaken/implemented on a regional bas: s and the interests of the egional developing countries will be kept uppermost to provide the requisi :e institutional framework for this regional project. The national instite :ions/centres/plants designated by the participating countries to co-o erate in the project will provide the necessary inputs as required and as s ecifically listed in Annex I to this Project Document. They will closely c)-operate with the UNIDO sub-contractors, selected through international bidding.

L. PRIOR OBLIGATIONS AND PREREQUISITES

Nc prior oblgiations and prerequisites are envisaged other than the regional countries providing full support in the implementation of this project to UNIDO, to the internatior 1 technical consultants and the laborat)ries/centres/pilot and demonstration plants involved in the implementation of the project.

M. FUTURE UNDP ASSISTANCE

The provision of future UNDP assistance will need to be identified and, if so required, formulated during the course of and at the end of this regional project.

PART III - SCHEDULES OF MONITORING, EVALUATION AND REPORTS

A. Tripartite review meetings

The project will be subject to periodic review in accordance with the policies and procedures established by UNDP for monitoring project and programme implementation.

Two tripartite review meetings will be held each year. Because of the complexity of the project, provisions will be made to assure participation of all organizations involved which are partly co-responsible for the successful implementation of the project.

B. Evaluation

The project will be subject to evaluation, in accordance with the policies and procedures established for this purpose by UNDP. The organization, terms of reference and timing of the evaluation will be decided by consultation between UNDP and UNIDO.

C. Progress and Terminal Reports

Progress and terminal reports will be prepared by the international technical consultants and testing laboratories/centres/plants in accordance with UNDP policies and procedures and as agreed upon with the individual Governments of the participating countries in the region.

AGREEMENT TO BE ENTERED INTO BY THE GOVERNMENTS/PROJECT AUTHORITIES CONCERNED WITH UNIDO

1. The Government concerned will undertake to:

(a) Select and prepare requisite quantities (tonnages) of the raw materials (iron ores, coal, fluxes) to be specified by UNIDO which will be classifed "representative samples";

(b) In preparing the "representative samples" of the raw materials the Government/Project authorities will ensure the representative nature of the samples through the well known method of "quartering and coning", normally followed.

(c) These samples of the raw materials vide (a) and (b) above will be transported in required tonnages to be specified by UNIDO, depending upon the scale and nature of the tests/investigations/demonstration trials, free of all transport charges to the Centre where these tests/investigations/demonstration trials will take place; such transport charges will cover the inland road/rail transport and ocean freight as the case may be.

2. The Government/Project authorities can send at their cost their representatives to the Centre where the tests/investigations/demonstration trials will take place, as observers for a certain period to be mutually agreed upon in each case.

3. The Government/Project authorities will be entitled to receive all the interim, draft final and final reports to be prepared by the contractors/consultants who will be contracted by UNIDO. These reports will have restricted circulation to be specifically determined by the Government concerned in each case.

4. The Government/Project authorities will provide due local facilities such as office space, secretarial assistance and local transportation for the contractors/consultants personnel that are normally provided by them at the former's cost, unless otherwise stipulated in the contract signed by the consultants/contractors with UNIDO.

5. The Governments/Project authorities will provide to the consultants/ contractor any previous reports, studies and surveys pertaining to the following:

(a) Raw materials studies/characteristics, mineralogical/chemical/ metallurgical data;

(b) Any prior studies conducted by the Government/Project authorities on raw materials processing, beneficiation, agglomeration, etc. and/or on sponge production and/or steelmaking;

(c) Any financial studies/data available with the Government/Project authorities concerned, inter alia:

i) Extraction of raw materials and their processing/ beneficiation/agglomeration, etc.;
ii) Labour and man power costs/wages, etc.;
iii) Any capital investment data available on the above subjects.

6. The Government/Project authorities will provide any market studies, if available, made by them on iron and steel products and which do have a bearing on the sponge/steel production in a general way;

7. The Government/Project authorities will be free to propose/make any change to this Agreement to be mutually agreed upon by them with UNIDO.

UNIDO PROJECT BUDGET/REVISION

3. COUNTRY	4. PROJECT NUMBER AND AMEND.	5. SPECIFIC ACTIVITY
RAS	DP/RAS/81/063	31.8.C

10. PROJECT TITLE
Regional Development of Sponge Iron Industry through DR technology for mini steel plant operations

15. INTERNATIONAL EXPERTS (functional titles required except for line 11-50)	16. TOTAL m/m	16. TOTAL $	17. m/m	17. $	18. m/m	18. $	19. m/m	19. $	20. m/m	20. $
11-01										
02										
03										
04										
05										
06										
07										
08										
09										
10										
11										
12										
13										
14										
15										
16										
11-50 Short term consultants										
11-99 Sub-total - International experts a/										

1. REMARKS

a/ If more than 16 experts are required check here ☐ and attach continuation sheet 1A.

PROJECT BUDGET/REVISION

4. PROJECT NUMBER DP/RAS/81/063		16. TOTAL m/m	16. TOTAL $	17. 1983 m/m	17. 1983 $	18. 1984 m/m	18. 1984 $	19. 1985 m/m	19. 1985 $	20. m/m	20. $
	OPAS EXPERTS (functional titles required)										
12-01											
12-02											
12-03											
12-99	Sub-total - OPAS experts b/										
	ADMINISTRATIVE SUPPORT PERSONNEL										
13-00	Clerks, secretaries, drivers										
13-50	Freelance Interpreters (non-UNDP PROJ)										
13-99	Sub-total - Admin support personnel										
	UN VOLUNTEERS (Functional titles required)										
14-01											
14-02											
14-03											
14-04											
14-99	Sub-total - UN Volunteers b/										
15-00	Project travel										
16-00	Other personnel costs (including UNIDO staff mission costs)		16,000		2,500		6,500		7,000		
	NATIONAL EXPERTS (functional titles required)										
17-01											
17-02											
17-03											
17-04											
17-05											
17-99	Sub-total - National experts b/										
19-99	TOTAL - PERSONNEL COMPONENT		16,000		2,500		6,500		7,000		

b/ If additional individual budget lines are required, check here ☐ and attach continuation sheet 1A. These sub-totals must include budget-lines listed on page 1A.

PROJECT BUDGET/REVISION

4. PROJECT NUMBER DP/RAS/81/063	16. m/m	TOTAL $	17. m/m	1983 $	18. m/m	1984 $	19. m/m	1985 $	20. m/m	$
SUBCONTRACTS 21-00 Subcontracts		475,000		75,000		100,000		300,000		
TRAINING 31-00 Individual fellowships										
32-00 Study tours; UNDP group training										
33-00 In-service training										
34-00 Non-UNDP group training										
35-00 Non-UNDP meetings										
39-99 TOTAL - TRAINING COMPONENT										
EQUIPMENT 41-00 Expendable equipment										
42-00 Non-expendable equipment										
43-00 Premises										
49-99 TOTAL - EQUIPMENT COMPONENT										
MISCELLANEOUS 51-00 Sundries		9,000		2,000		3,500		3,500		
55-00 Hospitality (non-UNDP projects)										
56-00 Support costs (CC and DC Proj. only)										
59-99 TOTAL MISCELLANEOUS COMPONENT										
SURPLUS/DEFICIT 81-00 Surplus/Deficit ADM/FS use only)										
99-99 PROJECT TOTAL		500,000		79,500		110,000		310,000		
c/ COST SHARING (UNDP/IPF projects only)										
c/ NET UNDP CONTRIBUTION										

c/ For information only - not for PAD input

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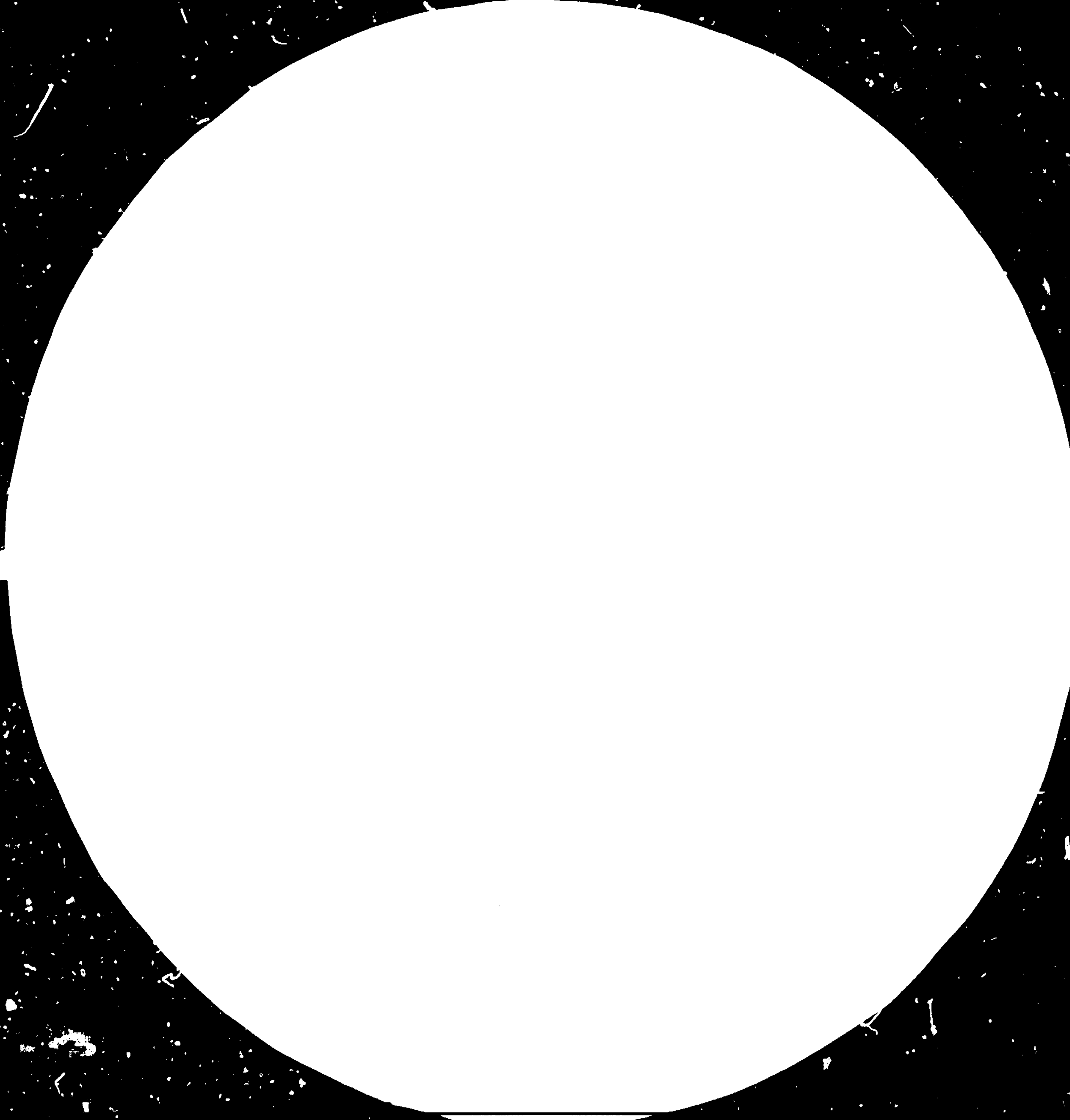

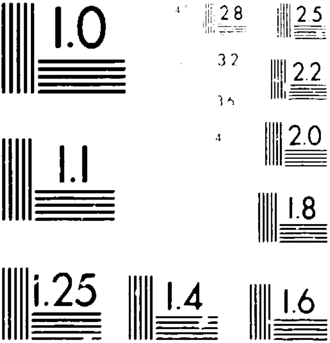
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Study Tour and Workshop to Promote Technology Development and Transfer in the Area of Sponge Iron Manufacturing in Developing Countries of the ESCAP Region

Indonesia and India

29 March - 8 April 1983

C O U N T R Y   P A P E R S

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AFGHANISTAN

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General Outlook

1. The Democratic Republic of Afghanistan is a landlocked country located in Central Asia, covering 647.5 thousand sq. km. of rugged mountain and desert areas. The Hindukush mountain extension of Himalayas cuts the country roughly along an East-West line. Even the foothills and most of the plain have an altitude between 500-2,000 mts. Afghanistan's climate is semi-arid, with an average annual precipitation of 416 mm. per annum ranging between 75 and 1,169 mm per annum between the driest to the wettest observation posts. Most of the precipitation falls during the early months of the year, and much of it in the form of snow. The melting of snow gradually releases water until well into the summer. Therefore the available water resources are distributed over the entire year.

2. During the 1975 census, the population was estimated at 17 million people, largely rural. Agriculture and animal husbandry are the main sources of income. Great amount of gross national product orginiated in the agricultural sector, and agricultural exports accounted for a considerable percentage of the total export earnings.

3. The National population has been increasing at an estimated rate of 2.3% per annum over the past ten years, while the urban population is increasing at the rate of 3.2%. Fourteen per cent of the national population is urban.

4. Since permanent irrigation system is lacking, much of the productivity of the agricultural land depends on climatic conditions. Of the 8 million hectares of arable land (12% of the total surface), 5.8 million hectares (66%) is irrigable. However, only 2.5 to 2.6 million hectares (32%) is irrigated annually while about

1.4 million hectares (17%) of this land only receives a sufficient amount of water. Possibilities for expansion depend on both extension and improvement of irrigation system and on the application of more intensive and more technologically appropriate farming methods.

Livestock holding is extensive and consists of sheep and camels for the largest part, although the number of cattle is also considerable. The products are meat and milk for domestic consumption, wood, karakul skins and well-known astrakhan fur for exports.

5. Available reserves of natural resources are yet to be assessed fully. Among those known, deposits of oil, coal, iron ore, copper and natural gas are important.

6. Industry, in the modern sense, is in its early stages of development, contributing only 6% of the gross national product (GNP). Production at present mainly consists of food processing, fruit processing, cotton-ginning and oil extraction, textiles, fertilizers, cement and sugar. Of the traditional handicrafts, the carpet industry is internationally known. The potential of this industry remains to be tapped.

7. To make up for the time lost in the past and to strengthen the foundations of a prosperous Democratic Republic of Afghanistan and to foster its economic growth the Government intends to follow vigorous development policy.

II. A Brief History of the Country's Industrialization Experience

As the existing industries are inadequate to meet the internal needs and requirements. Afghanistan is taking preliminary steps towards industrialization.

In the country's development plans that are being formulated special attention is being paid towards the development of different sectors of the industries based on the available raw materials and resources. During the past few years, the main industrial activities of the country were confined to the following.

No.	Industry/Plant
1.	Textiles
2.	Wool
3.	Ginning
4.	Vegetable oil
5.	Sugar
6.	Cement
7.	Fertilizers
8.	Jangalak factory
9.	Some small-scale government and private industries like textiles, shoe-making, socks, plastics, carving and carpentry.
10.	Handicraft industries, especially carpets, which are known world-wide.

To meet the urgent and pressing needs of the people, the development of the following industries has been taken up for the past couple of years. It is hoped that they will commence production soon.

No.	Industry	Capacity
1.	Textile	52.5 million meter/year
2.	Cement	1,000 tons/day

The feasibility studies of some new promising projects have been completed recently and some of them are still continuing. These projects, included in the development Plan of the country are:

No.	Industry
1.	Textile manufacture
2.	Dyeing
3.	Ginning
4.	Curing of hides and skins

No.	Industry
5.	Vegetable oil extraction
6.	Glass making
7.	Improvements and development of fruit processirg and preservation industry
8.	Cement production
9.	Sugar production
10.	Copper complex
11.	Caustic soda manufacture

If the feasibility studies of some other interesting projects like the following already undertaken indicate them to be viable, they will also be established:

- starch production
- manufacture of asbestos cement products
- salt refining and iodization
- mini-steel plant (based on scrap)
- demonstrative foundry

III. Basic Objective of the Country's Industrialization Programme

Afghanistan is a developing country facing financial and infrastructural problems like other developing countries. The geographical location of the country is another constraint in the development; not only is the country land-locked but also much of the area is under mountainous terrain leaving little area for agriculture.

For the betterment of the lot of people, progress, creation of employment opportunities and for raising the standard of living of the people, to reduce imports and [illegible] strain on the country's foreign earnings, it is necessary to pay special attention to the development of different sectors [illegible] industries based on local raw materials.

With unconditional help from friendly countries, Afghanistan envisages to invest in future on various industrial projects.

IV. Main Sectors of Industrial Development

Sl.No.	Sector	Development of local market	Development of foreign market
1.	Textile industry	x	x
2.	Dyeing industry	-	-
3.	Ginning industry	x	x
4.	Curing of hides and skins	-	-
5.	Vegetable oil	x	-
6.	Glass industry	x	-
7.	Cement industry	x	-
8.	Sugar industry	x	-
9.	Wool industry	x	-

V. Available Resources and Constraints on Industrialization

Raw materials available in the country can be classified into two categories: agricultural and natural resources.

1. Agricultural production includes mainly food grains, fruits and vegatables, cotton and some quantity of beetroot, sugar cane and oil seeds. Most of these products are not sufficient to meet the country's needs and are imported.

2. Natural resources: Afghanistan is abundant in natural resources. For the past several years, mapping, surveying and exploration of potential areas has been carried out for mineral resources. Substantial reserves of mineral deposits have been found and are now under production. The feasibility studies of some other mineral deposits have been taken up. The main mineral resources discovered so far are:

	Estimated Reserves
1. Coal	65.8 million tons
2. Iron Ore	176 million tons

		Estimated Reserves
3.	Copper	5.5 million tons
4.	Beryl	15,659 tons
5.	Lithium	158.5 thousand tons
6.	Flourite	8,792 thousand tons
7.	Talc	531.3 thousand tons
8.	Asbestos	162.3 thousand tons
9.	Sulphur	200.0 thousand tons
10.	Barite	1693.0 thousand tons
11.	Lapis Lazuli (Only sari-sang)	1501.0 tons
12.	Aragonite	1091.5 thousand tons
13.	Chromite	185,000 tons
		Cr_2O_3 55.1% : 27,000 T
		Cr_2O_3 44% :158,000 T

14. Some other minerals like Kunzite, Emeralds, Ruby, Green Tourmaline, etc. are also found.

Many of the above minerals have not been exploited because of limited financial resources, absence of proper market surveys in the past and poor management and bureaucracy of the past regimes.

The mineral resources which are under exploitation are as follows:

Item	Production Capacity per Year	Local Consumption	Export
Rock salts	75,000 tons	x	-
Barite	15,000 tons	x	x
Gypsum	25,000 tons	x	-
Talc	10,000 tons	x	x
Lapis Lazuli	5,000 kg	x	x
Coal	172,000 tons	x	-

Emeralds and rubies, the precious stones available in the country are planned to be exploited in thu near future.

As its financial resources are limited, Afghanistan is keen to obtain easy term credits and help from some countries.

Technology has been a recent introduction to Afghanistan. Although universities and technical institutions exist in the country to impart short-term as well as long-term training funds for scholarships and fellowships are lacking. To man the industries evisaged under our first 5-year plan, many people need to be trained in trades. Although a good number of young engineers are graduating from universities in the country and from some of the projects, and skilled workers are being trained, there is a great need for advanced training foi engineers and on-the-job training of skilled workers. We need the help and co-operation of friendly countries in this regard.

Constraints on Industrialization

1. Limited financial resources
2. Lack of adequate technical personnel, especially high level technical personnel
3. Lack of expertize to plan and manage industries
4. Lack of manufacturing industries within the country forcing the import of all required machinery from abroad
5. Delay in procurement of spare parts for old and existing machines and equipment
6. Import of foreign goods at the expense of indigenously manufactured goods
7. Lack of technical know-how in many cases
8. Being a mountainous country, the road connections to villages and mountainour areas are in poor condition which slows down the progress of industrial development.

VI. Customs and Tariff

1. Import Tariffs: For this purpose, a schedule of the goods and materials imported is prepared, and the import tariff on them is fixed on the basis of the demand for the product and its quality i.e. duty is low in the case of articles of mass consumption.

2. Taxes and Industrial Promotion

As private industrial sector also plays an important role in the development of industries, we may mention here two types of industries:

a. Small-scale industrial enterprises: Industries whose total machinery and equipment cost does not exceed Afs. 4 million are included in this category.

b. Medium-scale industrial enterprises: These are enterprises whose total machinery/equipment cost exceeds Afs. 4 million.

Experience has shown that sound management plays a significant and positive role in the development of private enterprises.

Medium-scale industries, after the end of tax holiday, as stated above, are subject to payment of taxes on account of project registration in the courts, 1% for bond printing, 6% on durable machinery and equipment, 2% on profits and 1% miscellaneous taxes.

Small-scale industries are also liable to payment of taxes on production, income, durable machinery and equipment (6%)and 1% misc. taxes, after the tax holiday.

Medium-scale industries score over the small-scale industries in one case. As per Article 5 paragraph (c) of the investment law they need not pay taxes on raw material imports in the first phase; the latter do not enjoy this privilege.

In accordance with the investment law enacted in 1353 (1974) the small-scale industries get loans at six per cent interest from the Industrial Development Bank, which is the lowest charged in the country. On the other hand, medium-scale industries obtain loans at ten per cent interest. Privileges and exemptions allowed in the case of such industries have been specified in the Investment Promotion Law in 1353/1974.

Marketing

Afghanistan is keen to develop and establish projects. It is willing to import and export raw materials on finished products required and produced by it. It needs the co-operation of other countries in its efforts to industrialize Afghanistan.

BURMA

U Myint Thain
General Manager,
No. 1 Iron Project

Introduction

1. The Socialist Republic of the Union of Burma inaugurated her first sponge iron plant in October 1981. Since the country's independence in 1948, it was planned to establish iron and steel industry using indigenous raw materials. Accordingly in 1956 a preliminary geological survey and exploration of iron and coal deposits were carried out. ... 1958-59 and again in 1961-62 a detailed geological exploration and a prefeasibility study for establishing iron and steel industry were carried out jointly by the Burma Geological Survey Department and Krupp Co. with the co-operation of the Federal Republic of Germany.

2. Two major deposits of iron ore and one deposit of coal were considered feasible and commercial scale testing to produce 200,000 tons of steel per annum were carried out with successful results. However, because of the poor quality of the coal (sub-bituminous with non-coking properties) and the requirements of large capital and infrastructure such as,facilities for transportation of coal, iron ore and power, the plan was shelved.

3. The Burmese technicians came to know of the "Kinglor Metor" Direct Reduction Process of Danieli Co., Italy in 1975. Laboratory and pilot plant scale testing with local raw materials were carried out in 1976 and 1978. The Kinglor Metor Process offered two main advantages which are particularly suitable to Burma's conditions i.e.

(a) it was found that low ranking coal (in this case Lignite) and medium grade iron ore (Heametite and Limonite) were found useable to produce a good quality sponge iron.

(b) a small scale economical unit (20,000 t/y) could be built.

4. Therefore, a decision in favour of Kinglor Metor Process was taken and No. 3 Mining Corporation, Ministry of Mines and Danieli Co. signed a contract in 1979 to establish a sponge iron plant known as No. 1 Iron Project. A site in the vicinity of an iron ore deposit was chosen and the foundation stone was laid in February 1980. After 20 months, the plant was successfully put into operation in October 1981.

No. 1 Iron Project

5. It is situated at Anisakan (96° 24.5' 21° 59') near Maymyo in the northern part of the country. The iron ore deposit is about 12 miles from the plant site and is connected by an all-weather road. The ore is mined by oper-cast benching method. Bulldozer with ripper and wheel loaders are used. No heavy drilling and blasting are necessary; only small amount of secondary blasting are necessary; only small amount of secondary blasting for heametite boulders is required. The ore is primarily screened at mine site to separate fines under 5 mm size. The screened ore is then transported by 12-ton trucks to the plant site. Coal comes by rail from Lashio about 125 miles from the plant site. Limestone is also used to control sulphur content in the sponge. It is mined near Sagaing about 50 miles from the plant and transported by trucks. Iron ore, coal and limestone are crushed, screened and washed in the sizing plant at the plant site. Diesel oil is used as fuel for heating the direct reduction furnace. The capacity of the plant is 20,000 ton/year. Sponge iron is at present smelted in 15/17-ton electric arc furnace to produce pig iron. Petroleum coke and ferro-alloys are added to get the required quality of pig iron.

Process Description

6. "Kinglor Metor Process" or KM-Process" is the process developed by Danieli & C., S.p.A. Italy for the direct reduction of iron oxides wherein the iron oxide is mixed with a solid carbonaceous

reducing agent and is passed continuously downwards through vertical shafts. The shafts are externally heated by burning gaseous or liquid fuels. The temperature within the shafts is maintained at a level which promotes the reduction of the iron oxide to a high degree of metallization and avoids the melting, softening, or sticking of the burden. The reduced material is cooled in the lower part of the shafts by indirect water cooling.

7. The reduction of ores from 5 to 25 mm dia. takes place in the presence of a solid fuel. The screened iron ore is mixed with lime to neutralize the effects of any sulphur contained in the coal. This mixture is introduced in the top part of the furnace called the "preheating zone". The preheated charge descends subsequently into the reduction zone of the furnace. After reduction, the sponge iron, the ashes and the unused reductant are then removed to undergo a magnetic separation.

8. The materials iron oxide, reductant and limestone first pass the preheaters where they are dried and heated prior to entering the reduction zones in which oxygen is gradually removed from the iron oxide to yield metallic iron. It is generally accepted that reduction of iron oxide by carbon of the reductant occurs through gaseous intermediates CO and CO_2 in accordance with the following mechanism:

$$FeO + CO \rightleftharpoons Fe + CO_2$$

$$CO_2 + C \rightleftharpoons 2\,CO$$

For the sake of simplicity here only the reduction of FeO is considered and not of superior oxides.

9. The initial formation of CO is an important step in the overall reaction; it can be formed either by the reaction action of carbon with oxygen gas released by the dissociation of iron oxides:

$$C + \tfrac{1}{2}\,O_2 \rightleftharpoons CO$$

or by "true" direct reduction occurring at the points of contact between the carbon and oxide particles:

$$C + FeO \rightleftharpoons CO + Fe$$

When the materials pass through the shaft,they encounter the gas stream which basically consists of CO and CO_2, and the reactions take place. The composition of this gas stream is continuously analysed at the pilot plant in four points along the shaft. This composition gives a clear idea of the reactivity of the coal - in fact, the higher the CO content the greater is the reactivity of the coal processed. The described sequence of reactions is subject to operation with solid reductant in excess which is completely recovered except for insignificant losses. This excess has at the same time a loosening effect on the charge thus counteracting the agglomeration of individual ore particles.

10. Sulphur is generally introduced in the process by the reductant and passes at first from the reductant to the sponge iron. After the desulphurizing agent limestone is added and after it has been calcined, they become active.

Following is the mechanism of the desulphurizing process:

$$FeS + CO \rightleftharpoons COS + Fe$$

$$COS + CaO \rightleftharpoons CO_2 + CaS$$

CO acts as a sulphur carrier.

Implementation and Operation of Project

11. No serious problems were encountered during the implementation of the project. Since the plant is situated in a mountainous region (1000m above sea level) and since there are some limitations of weight and size allowable on the roads and bridges, some improvisations and temporary arrangements had to be made during transportation of machinery from Rangoon port to the plant site. It was one of the projects completed in a record time.

12. After operating it for nearly 17 months the following average results were obtained:

(a) Quality raw material fed to the plant

1. Iron Ore

Fe tot.	58.50 %
Cangue max.	3.6 %
Sulphur max.	0.014%
Moisture	1.4 %
Combined water	8.7 %
Calcination losses	1.5 %

2. Coal

Moisture max.	10.00 %
Volatile matter	46.50 %
Fixed carbon min.	43.18 %
Sulphur max.	1.26 %
Ash max.	10.32 %

3. Limestone

$CaCO_3$	97 %
SiO_2	1 %
MgO	1.5 %
Al_2O_3	0.3 %
Fe_2O_3	0.2 %

(b) Consumption per ton of sponge

1. Iron ore	1550	kg
2. Coal	680	kg
3. Limestone	93	kg
4. Fuel	50	gal.
5. Power	100	KWH.

(c) Quality of sponge iron produced

Fe tot.	87.21 %
Fe Metal	80.00 %
Degree of metallization	91.70 %
Carbon	0.81 %
Sulphur	0.08 %

13. It was found that quality, size and moisture content of the limestone are important in the control of sulphur in sponge. At present a new roll crusher and screen are under construction to produce more suitable limestone, and it is expected that sulphur content in the sponge iron will then be lower.

Expansion Plan

14. After the completion of No. 1 Iron Project it was decided by the Government to increase the capacity of sponge iron production and also to produce steel billets. Therefore, a new contract was signed between the No. 3 Mining Corporation and Danieli Co. for expansion of the project at the end of 1981. The capacity of the sponge iron furnace will be doubled, a new module will be added and the total production capacity will increase to 40,000 ton of sponge/year. A new 15/17 ton electric arc furnace and a two-strand continuous casting machine for steel billets will be added. Other services such as oxygen plant, compressed air plant.fume collectors and water treatment plant are also included. The expansion project will become operational in December 1983.

Conclusion

15. Sponge iron making in Burma is very recent and first of its kind. There lies a tremendous opportunity for future expansion of the industry. Other processes of producing iron and steel from indigenous raw material are also under consideration. Training of more personnel will be required. Technical experience gained in the implementation of similar projects in other developing countries should be frequently exchanged to promote the development and transfer of technology in iron and steel making.

CHINA

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Chinese iron and steel industry has been developing rapidly since liberation. Last year we produced about 37 tons of steel, all of which was made by traditional methods.

The direct reduction process is in the initial stages.

China has a rich source of iron ore and coal, as also oil, natural gas, water and electricity which are being developed. All of them are vital for developing iron and steel industry. However, these resources have the following features:

1. Lean ore

The rich ore, with iron content greater than 50% that can be charged directly into the furnace, is about 6% of the total estimated reserve. The other iron ore, with iron content of 30%, has to be selected and agglomerated before charging. Some ores like clint on hematite, available in Hunan province, are difficult to select and are not suitable for blast furnace.

2. Complex ore

Some iron ores contain a large quantity of minerals such as vanadium-titaniferous magnetite as in the Panzhihua province, rare-earth elements and Niobium as in the Baotou province, coppen, lead, zinc and arsenic as in the middle-southern area. When such ores are used a large amount of valuable metals are wasted and the quality of iron and steel, when made in blast furnace, is affected.

3. Uneven dispersion of energy

Although we have rich coke available in the country it is concentrated in the northern provinces and there is hardly any in Guangdong, Guangxi and Fujian provinces. The coke available in the south-west area is inferior and contains large quantities of sulphur. However, water and electricity in this area are abundant accounting for 70% of the whole country. Limited quantities of natural gas is also found in Sichuan province.

The availability of mineral resources and their distribution make the direct reduction technique adoptable at least in some areas.

The development of direct reduction process helps the development of the iron and steel industry in areas where coke is sparse. It also helps in utilizing a variety of iron ores and treated-industrial wastes containing iron for the manufacture of iron and steel.

Since 1958, in the light of our resource position, we have made some studies on direct reduction process of rotary furnace, pre-reduction of rotary furnace, electric furnace, shaft furnace, fluidization and so on and obtained some results. Among these results, the semi-industrial rotary furnace, pre-reduction of rotary furnace-electric furnace has achieved international level of the trial. Table 1 gives a comparison of specifications of some experimental furnaces.

The testing equipment contains small rotary furnaces and the present is about $1300M^3$.

There are three shaft furnaces in China, two of them located in Guangdong province where the production rate is 5 ton/day and 100 ton/day respectively. Water-gas reduction is employed in both the plants. The coal consumption is 1.5 ton/t of sponge iron which is found uneconomical.

There is a shaft furnace in Chengdu city of Sichuan province with a capacity of 25 ton/day. The reducing gas is produced from the natural gas in the regenerative type reformer with catalyst. Vanadium-titaniferous magnetite is used for testing in Panzhihua province. The metallizing ratio of product is greater than 90% and the sulphur and phosphorus content is very low. The energy consumption is higher in the initial experiment, approximately at 500 M^3 natural gas/t of sponge iron. The equipment and process needs to be improved.

In Shandong province, there is a fluidizing testing equipment of tonnage capacity. The reducing gas is supplied by a fertilizer plant. The ore used for testing here also is V-Ti magnetite, the consumption of hydrogen being 600M^3/t of Fe circulating gas, about 8300 M^3/t Fe and light oil, 0.115 t/t Fe.

In general, though in China there are a large number of experimental furnaces using direct reduction process, only a few of them could go into operation in the long run. The reason for this is that the process equipment is not matching and long term prospects were not considered when building up the testing equipment. Many pilot plants are far away from the raw material and fuel sites and the transportation cost makes them uneconomic.

In order to strengthen and develop the direct reduction process in China, the following points should be considered:

1. The new plants should be built in areas with assured and reliable supplies of raw material and fuel and convenient transportation. They also require an industrial climate and good professional and technical management.

2. The complex ore should be utilized to make not only iron, but also other metals from other constituents of the ore.

The comprehensive utilization of the ore requires perfection and improvement of the process, equipment, material and techniques. This needs to be studied in depth.

3. In some interior provinces of the country there are some iron ores which can easily be magnetic ore-dressed, the ore grade being about TFe=71%. They are ideal for making high quality sponge iron and special steels. By using the direct reduction process the pollution by fuel ash content and other

impurities can be prevented of high purity iron concentrates.

In China, only Sichuan province has an abundance of natural gas. Therefore, the future of shaft furnace and fluidizing methods largely depends on the development of gas-making techniques with coal and its economy.

A lot more effort is required in this area to achieve satisfactory results.

I am sure that we would learn a lot through this conference and it will be very helpful in the development of our direct reduction process.

Table I - Comparison of technical specifications of some furnaces

Sl. No.	Factory Items	German Krupp Pilot Plant	China Capital Iron and Steel Co. Pilot Plant	China Zhejiang Yunhe Steel Plant	China Fuzhou Iron Plant
1.	Rotary kiln				
	l (M)	14	10	8.06	14
	D (M)	1.2	0.87	0.72	1.5
2.	Material size	lump ore	pellet	pellet	pellet
	(mm)	5-30	7-13	5-14	6-15
	TFe (%)	65-68	64.6	65.6	64.7
	S (%)	0.01-0.02	0.03	0.29	0.7
3.	Reducing agent				
	size (mm)	0-3	0-10	0-3	0-18
	type	Crushing coke	anthracite	75% anthracite 25% Bituminous	anthracite
4.	Desulphurizer size (mm)	1-3	0.5-4	1-2.5	0.5-6
	type	limestone dolomite	dolomite	dolomite	limestone
5.	Filling ratio (%)		13	20	-
6.	Utilization coefficient (t/m^3 day)	0.71	0.8	0.7	-
7.	Product TFe (%)	>90	84.91	84	84.5
	C (%)	0.1-0.5	0.1	0.1	0.1
	S (%)	0.03-0.06	0.05	0.01	0.1-0.5
8.	Metallizing ratio (%)	95-9[illegible]	94.5	95	95
9.	Sponge iron $<$ 5mm (%)	5.0	5.0	4	5-7
10.	Hot consumption 10^6 Kcal/t sponge iron	6.5	6.5	6-7	-

INDIA

S. Vangala
Managing Director,
Vijayanagar Steel Ltd. and
Sponge Iron India Ltd.

1. Introduction

1.1 Over a period of more than two decades, starting from 1950, there has been a remarkable growth in the iron and steel industry the world over to sustain and accelerate the global industrial development effort. The large demand for steel for construction, automobile, consumer and engineering industries spurred steel-makers in their efforts in creating additional steel capacity at phenomenal growth rates. As a result the world crude steel production rose from 192 million tonnes in 1950 to nearly 651 million tonnes in 1975.

1.2 Even though the Indian Steel Industry had not recorded such an impressive growth yet, significant additions to the capacity were made with investments by Government of India in setting up integrated steel plants in different locations of the country. As a consequence, during this period, the crude steel production in India grew from a meagre 1.64 million tonnes to 8.9 million tonnes.

1.3 India has currently an installed capacity of 15.62 million tonnes of which 11.40 million tonnes is in integrated steel plants in which iron ore is smelted using coke in blast furnaces to produce liquid metal which is refined in open hearth or basic oxygen furnaces for steelmaking. The remaining capacity is available in arc furnaces which recycle ferrous scrap and produce steel billets or ingots which provide feed material for a number of small rolling mills. Tables I and II indicate the installed capacity of integrated steel plants and region-wise break up of electric arc furnace capacity in the country respectively.

1.4 For India, a country with population of 700 million, to achieve an increase of 1 kg. in the per capita consumption of finished steel, a capacity of 1 million tonnes of crude steel would have to be created which indicates the extent of effort needed for the development of steel industry. Taking note of the important role of the steel industry in the economic growth of the country, the government of India have drawn up coordinated plan ior its development. A new shore-based integrated steel plant of 3 million tonnes capacity is being constructed at Visakhapatnam and proposals are afood for setting up two more integrated steel plants in the public sector. Besides, plans have been drawn up for modernization and expansion of existing plants. The above proposals aim to create additional installed capacities of 10 to 12 million tonnes, thus increasing the total installed capacity to around 30 million tonnes by the turn of the century.

TABLE - 1

INSTALLED CAPACITY OF INTEGRATED STEEL PLANTS

Name of the Plant	Installed capacity (in Million Tonnes)
Bhilai	2.5
Bokaro	2.5
Durgapur	1.6
Rourkela	1.8
IISCO	1.0
TISCO	2.0
Total	11.4

Source: Minerals & Metals Review - Annual, 1982 P.131

TABLE - II

LICENSED CAPACITY OF MINISTEEL PLANTS

Region	No. of Ministeel Plants Licensed	Licensed Capacity (MI)
Eastern	46	983,700
Northern	54	1,230,000
Western	65	1,348,000
Southern	29	663,300
	194	4,225,000

Source: Steel Furnace monthly - February, 1980 p.56

2. Raw Materials

2.1 Iron Ore

2.1.1 Fortunately for India, the country is endowed with rich and large deposits of iron ore which are evenly distributed throughout the country. The iron ores in the country are broadly divided into enriched high grade Hametite ores available in Peninsular and Central India and low grade Magnetitie iron ores spread evenly over all parts of the country. The estimated reserves of high grade hametite ore are about 11000 million tonnes whereas in respect of magnetite ore estimated reserves are about 6000 million tonnes.

2.1.2 As against the above reserves, currently, about 40 million tonnes of ore is raised of which only 15 million tonnes is consumed by the steel industry the rest being exported. For the estimated 30 million tonnes of steel capacity to be attained by the end of the current century, the iron ore requirements would be about 40 million tonnes and taking into account the development plans of the mining sector, no difficulty is envisaged in meeting this order of requirement.

2.2 Coal

2.2.1 In respect of coal, the country's reserves of prime metallurgical coking coal from which coke is produced are about 5000 million tonnes. Further, available coking coal is of high ash content contributing to lower productivity of blast furnaces. In recent years, the country has started importing coking coals for blending with domestic coals to improve the quality. However, for the anticipated increase of steel output as stated above, there would be greater dependance on import of coking coals to at least meet the steel-making requirements based on conventional BG/SMS/BOF routes. On the contrary, large reserves of non-coking coal estimated at 82,000 million tonnes are available in the country. Fairly sizeable deposits of lignite are also available in some parts of the country. Table-III below gives the various grades of coal reserves in the country.

TABLE - III

COAL RESERVES IN INDIA

(in million tonnes)

Description	Proved	Indicated	Inferred	Total	Percentage
Prime coking coal	3653.2	1237.3	359.4	5249.9	6%
Medium coking coal	3848.9	4275.2	1252.5	9376.6	11%
Semi or weekly coking coal	1545.5	2452.7	714.8	4722.0	6%
Non-coking coal	12290.3	22863.9	28196.8	63351.0	77%
Total	21337.9	30829.1	30523.5	82699.5	100%

Source: Symposium on Direct Reduction Processes in Iron & Steel making held at Rourkela during 11th to 14th November 1982.

2.3 Limestone

2.3.1 Limestone, the third major raw material used as a fluxing agent is extensively available throughout the country, both for iron and steelmaking. As per the latest reports, measured quantity of limestone in deposits is 4397 million tonnes whereas the inferred quantity is 44906 million tonnes. Table-IV gives the details of various grades of limestone available.

TABLE - IV

LIMESTONE RESERVES IN INDIA

(in million tonnes)

Grade	Measured	Indicated	Inferred
Lime kanker	-	-	3.20
Flux and Blendable	4.0	23.80	16.00
BF & Cement	-	-	1694.03
All grades	4396.96	814.46	44901.01 to 44965.76

Source: Indian Minerals year book - 1976

2.4 Natural Gas

2.4.1 The available reserves of natural gas have so far been commicted to other priority industrial needs and it seems unlikely that large quantities would be available for iron and steelmaking.

2.4.2 The question of considering use of natural gas as a basic fuel in iron and steel industry would also depend on the economics, particularly in view of the likely long leads from the recent off shore gas finds.

2.5 Electricity

2.5.1 The total power generation in the country is equally distributed between hydro-electric and thermal sources. More emphasis is being laid on increasing thermal power generation so that reliable and adequate power without interruptions is assured to meet the industrial needs of the country.

2.5.2 With recent investments made in the power sector, increases have already been recorded in availability of power.

2.5.3 As per estimates the total power availability is expected to be 108,000 MW by the end of the century.

2.5.4 In view of the above promising and satisfactory power situation, it is anticipated that lack of electric energy will in no way be an impediment for fuller utilisation of installed electric steel capacity in the country. The electric arc furnace industry is also expected to record a growth and by the end of the century, the anticipated production of steel in electric arc furnaces is expected to be 6.6 million tonnes as against the present installed capacity of 4.2 million tonnes.

3. Development of Alternate Route for Steelmaking

3.1 So far the major contributor to the steel capacity has been the blast furnace open hearth or BOF combination. However, the steadily increasing capital investment of plants based on such a process route, had necessitated the development and setting up of larger unit sizes of equipment capable of operating at higher production rates thereby saving on operating costs. The order of increase in investments has been five to six times in the last decade and is anticipated to be even more in respect of plants coming up in the future. Besides the high investment in the plant sizable investments are required for the development of infrastructure facilities like transport, power and utilities.

3.2 To counter the spiralling equipment costs and the massive investments needed for blast furnace-based plants, the capacity of individual blast furnaces was steadily increased from 2000 tonnes to about 10,000 tonnes of hot metal per day. The development of large blast furnaces was matched by an equally significant development in the steelmaking technique, the slow open hearth furnace giving way to the basic oxygen furnace which also went through an equally spectacular development of steadily increased unit sizes.

So significant has been this growth that by the 80s, the global open hearth steelmaking capacity came to a low of 9.7% as against 68.9% from the basic oxygen furnace. Other solutions like continuous casting of liquid steel in place of conventional ingot casting and primary rolling, enabled the steel industry to improve yields and cut the operating costs to the minimum. However, the large sized equipment and the need for higher productivity meant investments for improved feed preparation, in-line computerisation of operations to eliminate human error and stringent specification of raw materials, particularly the metallurgical coal.

3.3 In the face of the above and the rapid depletion of world reserves of coking coal both quantitatively and qualitatively, steelmaking technologies which did not depend on coking coal naturally merited attention. Further, subsequent international developments necessitated dispersal of steel industry due to the emergence of newer markets and the need to locate steel production facilities closer to the centres of consumption. In this quest, the electric arc furnace gained a new and important role totally different from the one it had played as a producer of molten steel in the foundry industry. It also came to be recognised as a tool which not only recycles ferrous scrap back into the economy, but also as a facility to convert prime materials like sponge iron into steel. Thus direct reduction whose potential had fascinated ferrous metallurgists almost from the time Henry Bessemer invented his steelmaking process, came to be looked upon as a suitable process which could directly convert iron oxide of the ore into metallic iron and thereby provide iron units to the electric melting furnace in partial substitution of the ferrous scrap feed.

3.4 In their endeavour to reduce the operating costs and with the rising prices of petroleum products, the blast furnace switched to sinter as a preferred burden in place of pellets

The pellet capacity thus delinked from the blast furnace, together with easy availability of cheap natural gas, provided the stimulus for the development of sponge iron capacity based on natural gas and pellets. The capacity grew from 0.57 million tonnes to 20.5 million tonnes over a period of 20 years (1960-80). Complementary developments took place in the electric arc furnaces like increased unit size of furnace, powered by high power and ultra high power transformers to melt the charge faster, continuous delivery of sponge iron into the arc furnaces, ladle metallurgy, which converted the arc furnace to a melting tool, with the entire refining work done outside, thereby greatly altering the furnace productivity and permitting the production of the entire range of ordinary and special quality steels.

4. Developments in India

4.1 The above technological developments which took place elsewhere in the world did not have much impact on the country's steel industry which has a different set of problems to contend with viz.

- The coking coal reserves continue to get depleted both in quantity as well as in quality.
- The quality of domestic coking coal did not permit consideration of large unit sizes of blast furnaces.
- Import of coking coal, though taking place in a limited scale, is not considered as a long term solution.
- Even though electric furnace steelmaking was considered as a means of supplementing the capacity of the blast furnace-based plants and therefore, encouraged, its growth was limited due to inadequate availability of power and scrap.
- Direct reduction based on pellets and natural gas could not be considered due to non-availability of pellets and other uses committed for natural gas.

4.2 In view of the above, it was felt necessary to evolve a solution which would suit local raw materials and conditions. In this context, production of sponge iron by directly reducing lumpy ores with non-coking coals in a rotary kiln appeared to be the most appropriate for an alternative steelmaking route not based on coking coal. The investments being made in power generation were also a factor in coming to the conclusion as sponge iron produced could be converted to steel in electric arc furnaces. Further, the sponge iron electric are furnace route has the following additional advantages:

- Lower investment in comparison to the blast furnace-basic oxygen furnace route.
- Permits smaller incremental growth of steelmaking capacity.
- Enables dispersal of steel industry so that small capacities can be created close to raw material sources to cater to regional demands.
- Plants have a shorter gestation period.
- Makes available feed material of consistent quality to the arc furnaces and insulates them from the vagaries of scrap market.

4.3 However, when this decision was taken in the late 70s sponge iron production on this route was still not an established process as the plants set up elsewhere in the world were beset with problems of low metallisation and under utilisation of capacity. The plants could also not be worked on 100% coal and the properties of iron ore particularly its degradation under the operating conditions, were major obstacles in the satisfactory operation of such plants.

4.4 Even though a considerable amount of laboratory scale work had already been done in India by that time followed by extensive pilot plant testing at the National Metallurgical Laboratory and Tata Iron and Steel Company, it was considered expedient to set up a semi-commercial demonstration plant based on the rotary kiln process for production of sponge iron so that raw materials available could be extensively tested at this level of operations before the process could be commercially exploited. The following factors influenced the Government of India in coming to this decision.

- As the process is greatly affected by the characteristics of raw materials, any combination of ore and coal would have to be tested first at the bench scale and appropriate process regime developed at semi-commercial level as scale-up from the bench scale tests is not reliable.
- While preliminary design parameters could be developed from laboratory scale tests, for firming up engineering designs, a semi-commerical level of operation is essential.
- The setting up of a semi-commerical plant would prove the necessary interphase for developing design and engineering capabilities within the country for commerical plants.
- Detailed test work with process adjustments are essential before reliable commercial scale operations can be achieved.

5. UNDP/UNIDO Assisted Demonstration Sponge Iron Plant

5.1 Accordingly Government of India approached UNDP for assistance in adapting to Indian conditions the technology for production of sponge iron from non-coking coal. The various considerations as well as the constraints of the rotary kiln processes as mentioned earlier were taken due note of by UNIDO, who deputed a mission comprising of Dr. Nijhawan and Mr Miller an expert in the field to study the proposal. UNDP endorsed the recommendations of the team, that in the first instance a Demonstration Sponge Iron Plant of 100 tonne per day capacity be set up to establish the techno-economic feasibility of producing sponge iron from lump ore and non-coking coal. The immediate objectives for such a plant were set out as follows:

5.1.1 To demonstrate the technical and economic feasibility on a semi-commercial scale of producing sponge iron by a direct reduction process using iron ore and non-coking coal available in Andhra Pradesh in India.

5.1.2 Thereby to supplement local supplies of iron and steel scrap and make possible an increase in local steel production.

5.1.3 To carry out semi-commercial scale tests to determine the feasibility of producing sponge iron from materials drawn from other locations in India.

5.1.4 To develop sponge iron production technology appropriate to the raw materials available at various regions in India.

5.2 The Government of India accepted the recommendations of UNDP/UNIDO and decided upon setting up such a plant near Kothagudam in the Singareni coal field region of Andhra Pradesh which produces about 101 million tonnes of non-coking coal per year. It was decided that the plant would be set up by Sponge Iron India Ltd. (SIIL) a joint enterprise of the Government of India and the Government of Andhra Pradesh. The Government of India decided to implement the project on cost sharing principle whereby they would provide the balance foreign exchange cost after accounting for the UNDP contribution and also provide for the rupee of the project. The various technology options available were considered and it was decided to adopt the SL/RN process of Lurgi Chemie (Lurgi) as this process envisages use of 100% non-coking coal. A contract was awarded by UNIDO in November 1977 to Lurgi for the supply of critical equipment, engineering and personnel services needed for the plant.

5.3 Before taking up the engineering design, extensive tests were carried out on the raw material at the National Metallurgical Laboratory, Jamshedpur and also at the plant laboratory at Kothagudem. This was followed by bulk tests conducted at the Lurgi Test Centre at Frankfurt Main, FRG. The results were carefully evaluated before deciding upon the parameters for the design and operation of the plant. M/s M.N. Dastur & Co. were appointed as the Indian Engineering Consultants.

6. Project Implementation

6.1 Prior to commencement of construction activities at site, it became necessary to ensure availability of infrastructure facilities as the site is located in a remote area where proper communication facilities were not available at that time. While construction, water and power could be arranged without much difficulty, continuous supply of consumables needed for construction activities proved a major constraint which was overcome by having adequate stocks although it meant operating at high inventory levels. Another major handicap was the lack of unloading facilities, as equipment needed for a project of this nature are usually heavy and overdimensioned. Necessary rigs and tackles had to be designed and fabricated in advance.

6.2 The basic engineering for the reduction plant was supplied by Lurgi Chemie based on which detailed engineering work was carried out by M.N. Dastur & Co. and the Engineers of SIIL. In such a situation normally a considerable amount of co-ordination and proper interpretation of basic engineering and inter-phase of indigenous equipment is necessary. Foreseeing the likely problems in the above critical areas of work, a compact and well-knit project organisation with civil, mechanical, electrical, metallurgical and instrumentation engineering disciplines was established so that problems if any could be set right and the implementation of the project proceeded smoothly. Also a detailed schedule of implementation was drawn up commencing from despatch of equipment by the manufacturer, their transportation, unloading, storage and installation in the proper sequence so that no delays took place. Frequent reviews were carried out with the contractors so that bottlenecks encountered such as non-availability of fronts for working, non-receipt of equipment and lack of consumable stores were removed. Also during the implementation, it became necessary to carry out several deviations in specifications, sequence of erection, etc. all of which are considered normal for a project of this type and these were carried out through effective coordination among the various agencies.

6.3 Major civil construction at the site started in June 1978 and plant erection was completed by March 1980. The trial runs of the plant commenced immediately thereafter when it emerged that certain modifications were required in the equipment supplied by Lurgi. This was attended to and the plant commenced regular manufacture from 1.11.1980.

7. Review of Plant Operations

7.1 The plant has been in operation for over two years. During this period some 55,000 tonnes of sponge iron was produced representing 90 percent capacity utilisation which is well above the rated capacity for the initial two years of operations. During this period it has been established that sponge iron with high degree of metallisation can be produced using 100% non-coking coal. The plant was also operated with different iron ore, coal combinations and the results have been extremely satisfactory indicating the adaptability of the process to a variety of raw materials. Besides test work on Indian raw materials, the plant is also undertaking test work for other countries.

7.2 In addition to establishing the suitability of the process for various Indian ores and coals, the plant is engaged in finding ways and means of utilising a number of waste products which arise in the operations of the plant. Considerable amount of work has been done in this direction, the most notable being the utilisation of waste sludge from the gas cleaning plant for the production of construction ceramics, a programme which is being implemented with the assistance of UNIDO.

7.3 In the course of operations of the plant it became necessary to effect a number of modifications to the equipment whereby it has been possible to make the process 100% coal based, increase the campaign life, develop indigenous substitutes for refractories, lubricants, replacement parts and so on. Process adjustments are carried out from time to time like control of temperature profile, air quantities, feed rates, retention times, etc. to suit the raw materials and to ensure satisfactory operations.

7.4 The sponge iron produced at the demonstration plant is non-pyrophoric, can be safely stored and handled and transported by road and rail. The product is extremely stable and requires only minimal protection to avoid reoxidation. Even in cases where the product had come in contact with water, the loss in metallisation has been insignificant and was restricted to the superficial layers only. There is absolutely no fire hazard.

8. Melting Trials with SIIL Sponge Iron

8.1 When the plant began making sponge iron, the product was introduced into the market according to a carefully planned programme. First experimental melting trials were conducted in a 3-tonne furnace in the steel foundry of Singareni Collieries Company Limited with varying proportions of sponge iron in the charge from 5-30%. This was followed by trials in a 5-tonne furnace nearby and high quality billet size ingots for rolling into bars and rods were produced. In this furnace proportions of sponge iron upto 85% of the charge were also tried. To evaluate the results on bigger furnaces having continuous casting facility and also to see the effect on production of special quality steels, melting trials were conducted at Tamilnadu Steels, Arakkonam, Zenith Steels, Bombay, Poddar Steels, Hyderabad and A.P. Steels, next door. In these furnaces proportions upto 25% of the charge were tried. A summary of these results is shown in Annexure - 1.

8.2 A.P. Steels, where between 1000/1200 tonnes of sponge iron is consumed on a regular basis every month, had the advantage of close monitoring of operations by SIIL and computer analyses reveal that there has been an increase of 10% in productivity with batch charging of sponge iron. Even though there have been marginal increases in the consumption of electrical energy (about 30KWH per tonne) and limestone (15 to 20 Kg per tonne) with a drop in yield by about 1 to 2%, the increase in productivity arising from the lesser number of batch charges and increased density of charge, low sulphur and phosphorous levels resulting in better quality, have more than off-set the disadvantages mentioned.

9. Batch Charging Technique

9.1 All the furnaces had used the intermittent or the batch charging technique. In the batch charging technique, a mixture of scrap and sponge iron is carefully loaded into a bucket. Charge preparation consists in taking required proportions of sponge iron and distributing the material within scrap in the charging bucket in sandwiched layers of heavy melting scrap, sponge iron and commercial scrap. The sandwiched layer helps in uniform distribution and minimises/avoids sticking problem in the furnace to a great extent. The material thus prepared is fed to the furnace in two to three charges. Normally it would be possible to complete the entire charging of sponge iron and scrap in 2 to 3 charges.

10. Continuous Charging

10.1 The continuous charging arrangement ensures that sponge iron is dropped into the pool of liquid metal and melts rapidly. Otherwise, sponge iron being of the same density as slag, tends either to float on the metal when it is likely to be carried away in the slag or stick to the walls of the furnace. To derive, the best advantages from the use of sponge iron, it is fed from an overhead bin on top of the furnace through a hole in the furnace roof into the bath. In this method, the furnace is first filled with steel scrap and after the electrode bores a hole through the charge and a pool of liquid metal is formed, feeding of sponge iron is commenced. Melting and refining take place simultaneously the slag being flushed continuously. This contributes to a reduced tap-to-tap time. The experiment carried out by SIIL has shown that up to an hour's saving in time could be obtained in every heat. As the sponge iron is of known chemistry, it is possible to keep tramp elements low, which is an added advantage to continuous casters.

11. Design of Continuous Charging System

11.1 With the assistance of UNDP/UNIDO an inexpensive and simple continuous feeding system has been developed by SIIL which is within the reach of most of the ministeel plants in the country. The system consists of suitable bins located overhead near the furnace for holding sponge iron, limestone and carburising material such as coke breeze or anthracite coal which are fed into the furnace in a controlled manner by operating precalibrated gates located below the bins. The material is fed into the furnace through the opening in the roof which is located in such a manner that sponge iron drops in the middle of the bath.

11.2 Two such installations one at the 25-tonne arc furnace of Tamilnadu Steels near Madras and the other at the 17-tonne furnace of A.P. Steels were designed, fabricated, installed and commissioned by SIIL. Initial trial operations at both the furnaces have shown very encouraging results with sponge feed going up to 50% of the total charge. The trials also revealed that there is a reduction in heat time and improvement in the yields.

12. Facilities available at Demonstration Sponge Iron Plant for rendering Technical Assistance in the Establishment of Coal-Based Sponge Iron Plants

12.1 As an adjunct to the reduction plant, UNIDO assisted in the setting up of a well equipped laboratory for testing of raw materials to establish their suitability for sponge iron production, for process control and for testing the quality of the product. Taking note of the facilities available in the laboratory and at the Demonstration Plant, UNIDO have recognised SIIL as a consultancy organisation in the field of direct reduction. SIIL has also established an Engineering and Projects Division for handling the entire range of services involved in the setting up of coal-based direct reduction plants.

12.2 Testing and Analysis of Raw Materials

While testing of feed materials for the blast furnace is now well known and understood, for the newer direct reduction processes, the picture is far from clear. The process conditions existing in different reduction processes have made it necessary to develop different test methods to evaluate the metallurgical properties of the raw materials. Testing procedures used for evaluating physico-chemical properties of blast furnace burden can be generally used for evaluation of raw materials for direct reduction. In addition to these tests, it is necessary to determine the rate of reduction, disintegration and sticking behaviour of iron ore pellets/lumps for direct reduction processes which use rotary kilns with gas or solid reductants. Experience has shown that the reduction rate and sticking behaviour are important in evaluating pellets, while disintegration plays a major role for lump ores. In case of solid reductants ash softening characteristics, reactivity and sulphur content form important criteria.

12.3 Bench Scale Testing

12.3.1 Bench scale testing forms the first essential step in determining the suitability of any ore, coal and limestone combinations for producing sponge iron suitable for electric arc furnace steelmaking. Bench scale tests are generally undertaken on small amounts of samples. This stage of experiments would also generate data for preliminary planning and for preparation of feasibility report.

12.4 Testing of Iron Ores

12.4.1 The following characteristics of iron ore are important in determining their suitability for direct reduction. Chemical composition (Total Fe, gangue and phosphorous) Physical Behaviour (Resistance to abrasion, impact, handling, etc.).

12.4.2 Behaviour under reducing conditions (Decrepitation and reducibility under static as well as dynamic conditions)

12.5 Chemical Composition

12.5.1 The iron content of the iron oxide feed stock should be as high as possible and the gangue (SiO_2 + Al_2O_3) content should be as low as possible (preferably 4 per cent max.). Higher gangue leads to increased slag volume, higher power consumption and lower productivity in subsequent melting of sponge iron in electric arc furnace.

12.5.2 It is also desirable that the phosphorous content of the oxide feed should be low (preferably below 0.05 per cent) as phosphorous does not get removed during the reduction process.

12.6 Physical Behaviour

12.6.1 Physical characteristics of ore such as cold strength, resistance to abrasion, impact, handling, etc. are studied with the help of shatter and tumbler tests. These tests indicate the behaviour of ores during physical handling and abrasion in kiln operations, all of which result in the generation of fines. The other physical tests such as screen analysis, bulk density and angle of repose provide basic data on physical properties which are required to be taken into consideration while designing the conveying and storage systems for raw materials and product.

12.7 Behaviour under Reducing Conditions

12.7.1 Iron ore/pellets for use in sponge iron production should have good reducibility and favourable decrepitation behaviour. Experience has shown that sticking and swelling behaviour during reduction are important in evaluating pellets while disintegration plays a major role in selecting lump ore. The behaviour of ore/pellets under reducing conditions can be evaluated under static as well as dynamic testing conditions. Although most of the existing plants use heat-hardened pellets as iron feed, the use of lump ore is assuming greater importance because it is more easily available and is cheaper.

12.7.2 SIIL is equipped with static as well as dynamic test apparatus. The reducibility and decrepitation behaviour of iron ore under static conditions are carried out in an apparatus fabricated as per ISC/ISI specifications. Dynamic reducibility and decrepitation tests are carried out in Salvis tube and short rotary kiln where reduction conditions in rotary kiln are stimulated (refer figures 3 & 4).

12.8 Testing of Coals

12.8.1 The following characteristics are of importance in selecting coal for rotary kiln-based direct reduction processes.

a. Reactivity
b. Ash content
c. Volatile matter
d. Softening of coal ash
e. Sulphur content

12.9 Reactivity of Coal

12.9.1 Reactivity of coal refers to the amount and the rate of carbon monoxide generation through the well known "Boudouard Reaction". Reactivity of the coal is the main factor that affects the kinetics of the process;

hence it has a bearing on the selection of operating temperature and kiln through-put. SIIL Test Centre is equipped with coal reactivity apparatus which measures reactivity of coal by the weight loss method.

12.10. Ash content

12.10.1 Ash content of the coal should be low as high ash coal occupies more bed volume resulting in reduction in kiln capacity and hence decrease in productivity.

12.11. Volatile matters

12.11.1 The volatile matter of the coal should be sufficiently high as volatiles form the source of heat. Moreover, high volatile coals are generally more reactive, which is desired for generation of CO for reduction purposes. In rotary kiln operations high volatile coals facilitate in operating the process at lower bed temperatures which reduces the risk of formation of accretions.

12.12. Softening of coal ash

12.12.1 The ash softening temperature of coal ash is an important process control parameter for determining the operating temperature to be maintained in the kiln. In the rotary kiln processes high volatile non-coking coal with relatively high fusion temperature is desirable. Generally the temperature in the kiln is to be maintained 100-150°C below the ash softening temperature of coal.

12.12.2 The determination of ash fusion temperature is carried out in a Leitz heating microscope.

12.12.3 For undertaking the above test work and for interpretation of test results SIIL is equipped with extensive laboratory and testing facilities backed by trained metallurgists and technicians in the field. The list of facilities available in the laboratory with the type of test work

..... that can be carried out is enclosed at Annexure - 2.

13. Engineering and Consultancy Services

13.1 Besides test work on raw materials as mentioned above Sponge Iron India Ltd. possesses the capability to provide engineering and consultancy assistance in the setting up of coal-based sponge iron plants. The scope of such service would cover mainly the following areas:

13.1.1 Identification of a project from the point of view of availability of raw materials, use of sponge iron, location, etc.

13.1.2 Preparation of feasibility report/project report based on test work to be performed on the raw materials as mentioned above.

13.1.3 Evaluation and selection of the most appropriate process.

13.1.4 Detailed engineering of reduction plant and auxiliary facilities such as raw material receipts, preparation, handling, storage, utility services, waste material disposal, storage and handling of finished products.

13.1.5 Preparation of tender specifications, scrutiny and recommendations.

13.1.6 Inspection services

13.1.7 Erection supervision

13.1.8 Commissioning assistance.

13.1.9 Imparting training to operating personnel.

13.1.10 Optimisation and post-commissioning assistance.

13.2 The company has been rendering some of the above services for different clients including design, supply, installation and commissioning of continuous feeding systems of sponge iron for electric arc furnaces. It has acquired recognition from UNIDO as a consultancy agency in the field.

SIIL have already provided assistance to R&D/SAIL, Ranchi in commissioning their pilot sponge iron plant and is presently providing similar assistance to a number of agencies, a few of which are mentioned below:

i)	Government of Hungary through UNIDO	- Testing of raw materials and preparation of feasibility report.
ii)	Government of Pakistan through UNIDO	- Testing of raw materials and preparation of feasibility report. Melting of sponge iron in electric arc furnaces.
iii)	Vijayanagar Steel Ltd	- Bulk scale testing and association in engineering.
iv)	Haryana State Industrial Development Corporation	- Preliminary investigation work on raw materials to assess suitability for direct reduction.
v)	Tamilnadu Steels Ltd. and A.P. Steels Ltd.	- Complete design, engineering, manufacture, erection and commissioning of continuous feeding system of sponge iron.
vi)	Kudremukh Iron Ore Company Ltd.	- Reducibility tests on iron ore pellets.
vii)	Government of Tamilnadu	- Evaluation of raw materials for direct reduction.
viii)	Expansion unit of SIIL	- Complete design, engineering implementation of the expansion for doubling the capacity. The work is in progress and the plant is expected to be ready for commissioning by early 1985.

14. Future Plans

14.1 As a result of the above efforts, besides establishing the use of sponge iron as feed material for steelmaking, foundations have been laid by SIIL for further development of this technology in the country. Encouraged by the success achieved so far in optimising the process, SIIL have taken on hand doubling the capacity of the Kothagudem plant. Whereas in the first stage most of the equipment of the Reduction Plant was imported, in the expansion indigenous contribution would be maximised thereby developing the engineering capability for the setting up for future plants.

15. Commercial Sponge Iron Plants in the Country

15.1 A commercial sponge iron plant of 150-thousand tonne per year capacity has been constructed based on the Allis Chalmers Controlled Atmosphere Reduction Process (ACCAR) of Allis Chalmers Corporation, in the State of Orissa and is reported to have gone into regular operations very recently. The plant is to utilise mainly non-coking coal with a small percentage of fuel oil for production of sponge iron. A plant based on TDR Process developed by Tata Iron & Steel Company with an installed capacity of 90,000 tonnes per year is under construction also in the State of Orissa. This is a 100% coal-based process developed in India. The Bihar State Industrial Development Corporation (BSIDC), Modi Industries and Lurgi Chemie are jointly putting up a 150,000 tonne capacity plant near Jamshedpur in the State of Bihar. SIIL are to provide services like test work, training of personnel, commissioning assistance besides being associated in the engineering of the Plant. Additionally, a plant of 150,000 tonne per year capacity is to be set up in the State of Karnataka based on 100% non-coking coal. Utilising the natural gas deposits of the west coast, a capacity of approximately half a million tonnes of sponge iron is under planning.

15.2 On the strength of the operations of the Kothagudem plant, Government is also examining the setting up of an integrated plant near Hospet in the State of Karnataka to produce direct reduced iron for further processing into steel in electric arc furnaces. Government is also encouraging setting up on sponge iron plants by electric arc furnaces to serve their captive needs. With the above schemes a licensed capacity of 1.3 million tonnes is expected to be available in the country by the end of the decade.

TABLE-V

LICENSED CAPACITY OF SPONGE IRON IN INDIA

Sl. No.	Name of Unit	Location	Licensed Capacity t/yr	Installed Capacity t/yr
1.	M/s Sponge Iron India Limited	Kothagudem, Andhra Pradesh	60,000	30,000
2.	M/s Orissa Sponge Iron Limited	Palasponge Orissa	300,000	-
3.	M/s Industrial Promotion & Investment Corpn. Ltd.	Barbil, Orissa	90,000	-
4.	M/s Bihar State Industrial Development Corpn. Ltd.	Ranchi Bihar	120,000	-
5.	M/s Steel Authority of India Limited	Ranchi Bihar	3,000	3,000
6.	M/s Gujarat Industrial Investment Corpn. Ltd.	Hazira, Gujarat	400,000	-
7.	M/s State Industrial & Investment Corpn. of Maharastra Ltd.	Alibagh, Bombay	400,000	-
		Total	1,373,000	33,000

Source: 20th National Metallurgists Day, 36th Annual Technical Meeting and Symposium on Direct Reduction Process in Iron & Steel-making Rourkela 11th to 14th November 1982.

ANNEXURE [illegible]

SUMMARY OF RESULTS OF MELTING PERFORMANCE

Description	A.P.Steels Ltd.	Poddar Steels	Zenith Steels	Tamilnadu Steels	Padmavathy Steel Melters
i) Proportion of sponge iron used.	10 to 20%	10 to 30%	10 to 25%	10 to 25%	50 to 65%
ii) Type of charging	Batch charging	Batch charging & shoveling of material	Batch charging	Batch charging	Shoveling of material simulating continuous charging conditions
iii) Melting behaviour	Good with tendency for sticking	Very good	Good	Good with tendency for sticking	Excellent
iv) Liquid metal yield (%)	89.0 (1% to 2% less than with 100% scrap)	87.0% (1% less than with 100% scrap)	89 (1% to 2% less than with 100% scrap)	86.0 (2% less than with 100% scrap)	87.0 (1% less than with 100% scrap)
v) Power consumption	Marginal increase of 30KWH when 20% proportion used.	Marginal increase of 10 to 30 KWH	30 KWH increase	Same as 100% scrap with marginal increase in a few heats.	20 KWH increase when higher proportions are used.
vi) Electrode consumption	Almost same with marginal increase	Same as with 100% scrap	Same as with 100% scrap	Same as with 100% scrap	Same as with 100% scrap

Contd...

Description	A.P.Steels Ltd.	Poddar Steels
vii) Slag volume	10% increase	10 to 15% increase
viii) Lime consumption	- do -	- do -
ix) Refractories	Same with bank cutting in a few heats	Same with bank cutting in a few heats
x) Heat time	15 to 20 mts. saving	20 to 25 mts. saving
xi) Product quality	Sulphur and phosphorous in steel lowered below 0.035 level.	Sulphur and phosphorous below 0.04 level and ingot quality better.

Zenith Steels	Tamilnadu Steels	Padmavathy Steel Melters
15% increase	15% increase	15 to 50% increase
- do -	- do -	- do -
Same with bank cutting in a few heats	Same with bank cutting in a few heats	Same with bank cutting in a few heats
No change	No change	30 to 40 mts. saving
(1) Same as with 100% scrap. Possible to produce quality steels En 31, En 44, En 45A (2) Tramp element levels were low.	(1) Sulphur and phosphorous levels lowered and sulphur control easier. (2) Carbon opens low and needs adjustment	Sulphur level below 0.03 in some heats and ingot quality excellent with 10% improvement in productivity.

ANNEXURE - 2

FACILITIES AVAILABLE IN SIIL TEST CENTRE

Sl. No.	Name of the equipment		Purpose
1.	Leitz heating microscope	:	Softening and melting characteristics of coal ashes.
2.	Olympus metallurgical microscope	:	Metallographic studies of sponge iron and steel samples, petrographic studies of iron ores.
3.	Bomb calorimeter	:	Calorific value determination for solid and liquid fuels.
4.	Gas chromatograph	:	Analysis of gases
5.	Differential thermo analyser	:	DTA studies on iron ores and study of phase transformation in substances associated with exothermic reactions.
6.	Vacuum emission spectrometer	:	Rapid analysis of steel samples and monitoring melting of sponge iron.
7.	X-ray fluorescence spectrometer	:	Analysis of sponge iron, iron ore and limestone and other susbstances.
8.	Magnetic balance	:	Rapid metallic iron estimation for process control in sponge iron plant.
9.	Coal reactivity apparatus	:	To determine the reactivity of coal char.
10.	Static reducibility apparatus	:	Reducibility studies on iron ore under static conditions, thermal degradation studies on iron ores.
11.	Laboratory rotary kiln	:	Bench scale testing facility to study the reduction and decrepitation behaviour of iron ores & of reductant coal & desulphurizer and prediction of material behaviour in commercial size rotary kilns.
12.	Short rotary kiln	:	Bench-scale testing facility to simulate the conditions of rotary kiln and study the behaviour of iron ore, reductant coal and desulphurizer.

INDONESIA

Mr Fazwar Bujang,
Superintendent, DR Plant
P.T. Krakatau Steel

I. Introduction

As part of phase I expansion program, PT Krakatau Steel has commissioned two direct reduction plants with a capacity of one million tons per year each. These plants are based on the HYL I process and in addition to the basic reformers, reactors, boilers, and material handling, the overall facilities also include :

- Iron ore pellet handling facilities from the harbour to the plant
- The out-going conveyor for sponge iron for export purpose
- Three product storage buildings, one huge storage for export purpose, another two for raw material supply to the billet plant and the slab plant which will be commissioned early 1983.
- Boiler feed water treatment plant to supply treated water for four boilers of each direct reduction plant.

Although the contract to build the DR plant was signed in June 1974 internal problems prevented completion of the first part of the DR plant and related facilities until 4 years later.

The iron ore handling equipment and boiler water treatment plant were commissioned in mid-1978, followed by the first DR plant which reached design performance two years later in August 1980.

The second direct reduction plant completed performance test very successfully on August 17, 1982.

II. Difficulties and problems encountered during the commissioning of the first DR plant

In general the difficulties and problems encountered during commissioning of the DR plant can be classified as follows :

1. Process, design and equipment problems.
2. External problems such as shortage of natural gas supply and occasional poor quality of natural gas.
3. Lack of experienced and knowledgeable technical personnel.

II. 1. In the early days of commissioning of the first direct reduction plant, difficulties and problems later encountered were not anticipated either by the contractor or by the plant management. It was even difficult for both the parties to decide whether these were due to the process adopted or equipment failure or improper design or even a combination of all these. The plant was shut down two weeks after initial production, and the capacity reached was far below design level.

The problems faced were :

- Poor product quality .
- Large quantities of hot product and free dust, burning of conveyor belt and explosion in separation tower.
- Low production resulting in high consumption of natural gas, water, electricity, etc per unit of production.
- Frequent need to use kelly tools
- Unstable condition of the plant caused by equipment failures, especially in rotary equipment which resulted in excessive use of spare parts.

The plant was restarted on a continuous production basis after 1½ years and the design capacity was reached six months later.

The long delay in restarting the plant was also due to the shortage of natural gas and its poor quality for several months.

Some important solutions to the problems provided by the contractors on the first plant were

a. Replacing most of vibrating feeder in the conveyor system (especially) sponge iron handling) by chute and hydraulic gate system.

b. Introducing precooling (it was later proved that this was not the solution to the cooling problem).

c. Installing an additional recycle compressor for each module to increase the amount of cooling gas.

d. Installing infrared sensors to divert any hot material.

e. Improving the support of reformer i.d. fan

f. Modification of the condensate collectors in the fin fan condensors to avoid leaks on the fin tubes.

g. Installing recycle conveyors in each product storage building and also providing the building with thermocouples to read the temperature of the sponge iron pile in every compartment.

h. Improving the piping support, flexibility of the pipe movement to avoid misalignment of most rotary equipment which are turbine-drive·

i. Installing dust scrubber

j. Improving kelly tools.

It appears from PTKS experience that it is very important to select the right type/quality of pellet in the DR Plant.

Good results from laboratory and pilot tests are not enough to prove that the pellet is suitable for individual plant and or certain process. The best way is to make a full commercial test in the plant itself or a similar plant.

Selecting the right pellet is more important during the initial commissioning of the plant.

If it is already known that the pellet is suitable for the plant it is much easier to identify the equipment failure or design problem.

II.2. External Problems

The shortage of natural gas supply was realized after the contractor mentioned that the plant was nearly ready to be restarted.

While modifications were being made to the plant, another government project, the urea plant of PT. PUPUK KUJANG, was commissioned. The natural gas supply to the ammonia plant of latter (about 55.000 NM^3/hour) also comes from the same pipe line supplying the DR Plant.

Another problem encountered was the fact that some natural gas supplies contained mercury, which is harmful to the catalyst of the DR plant reformer. A vessel containing sulphur impregnated carbon was installed to absorb the mercury before allowing on the reforming catalyst.

II.3. Lack of experienced personnel

The commissioning of the plant seems to be the most critical stage after the completion of the plant.

At this stage, although it is the contractor's obligation to bring the plant up to design level, the role of the plant owner is also very important to assure successful operation of the plant after, as well as during the performance test.

The PTKS personnel participated in the following operations starting from the beginning of the cold test until the performance test :

1. Make cold test inspection of the equipment such as visual inspection, check functioning of the equipment, test the equipment without load, and make check list from such activities.
2. Witness some special testing and activities such as hydrostatic pressure test to the vessel, flushing of lines, dryout of refractories, setting relief valves, etc.
3. Collect all certificates of the equipment from manufacturer and check them.
4. Verify all the drawings and manuals and compare with the actual situation in the plant.
5. Participate in running the plant and maintain it under the supervision and direction of the contractor from commissioning until the plant is accepted.

6. Collect all the production and process data, monitor the condition of equipment, analyze data and comment and/or make a check list of items to be corrected by the contractor.

During the commissioning of the DR Plant I, PTKS personnel were not able to cover the following activities in a correct manner :

- Before the cold test was conducted all manuals and drawings (at least provisional) were not received by the plant owner in time.

  Cold testing procedures are performed by the contractor but the plant owner should be involved in suggesting additional items to be tested or procedures to be followed.

- Sometimes the cold test requires some special instrument tools and simulation system to check functioning of the equipment which the plant owner fails to arrange for.

- Many PTKS personnel did not have sufficient experience to cover all areas of the DR plant and its common facilities in the cold test.

  Most of the people who got training participated as requested by the contractor to help cover all activities.

  They were trained to run equipment without load, run the convection reformer to produce steam for flushing lines, loading the catalyst and checking the pressure drop, etc.

  The people worked on shifts until the plant was accepted.

  There was no specialist engineer to work as process or mechanical engineer to analyze the data collected during the commissioning and performance test.

  The contractor has the option to select the personnel whom they believed were able to supervise and direct PTKS personnel to run and maintain the plant well.

  Though most of the PTKS personnel handling important jobs had a counterpart provided by the contractor, it did not help the contractor to bring the plant to the designed guarantee because most of the people did not have enough knowledge and experience with process behaviour and plant equipment. As PTKS personnel who led and supervised the start up and commissioning operations did not have sufficient experience, it resulted in excessive use of spare parts and consumables.

III. Successful commissioning of DR Plant No. II

The rated capacity of each module is 1515 tone Fe/day and the consumption of natural gas was a maximum of 4,85 G cal/ton Fe at 90% of metallization.

III.1. Result

In 10 days, 38,000 MT ton of sponge iron equivalent to 34,000 ton Fe, was produced which is 112% of rated capacity.

The average metallization was 89.83% while the gas consumption was 4.08 G cal/ton DR I or 521.5 NCM/ton Fe which is 5% better than expected. The material diverted by the sensor station amounted to a total of 0.54% which is less than a tenth of the tolerable amount.

III.2. Reasons for the success of DR Plant II performance Test

The following factors contributed to the success of DR plant II performance test :

a. Precautions taken by PTKS management prior to the start up and performance test.

b. Improvements to the plant initiated by the contractor, modification and additional equipment requested by the plant owner based on DR Plant I experience of over 2 years.

c. Plant owner personnel had more experience and also better advice from the contractor who supervised and directed the plant operation.

   Better participation and support for the contractor from PTKS personnel during the commissioning and performance test of DR Plant II.

d. Better knowledge of behaviour of pellet to be reduced during performance test.

e. The contractor wished to complete his obligation with a good reputation.

a. Precautions taken by PTKS management

Bitter experience from plant I made PTKS top management take very careful and sometime too conservative steps. Modifications similar to Plant I and additional modifications to improve the plant reliability were made. The plant was ready for test at the end of April 1982; however, as the data collected from process observation and monitoring of certain equipment showed suspected weakness, the PTKS management refused to give approval to start the performance test until all suspected problems were solved.

b. Additional equipment and modifications requested by plant owner

Production in plant I was stopped as soon as the performance test was over and a check list of items to be rectified made along with a list of the problems encountered during the two years of operation. They are :

- Install a sponge iron screen to remove fines in order to reduce load on dust scrubber.
- Improve the control system of the gas preheater and replace the unsuitable spring hanger of gas preheater tubes.
- Install the vibration indicator and alarm for air and recycle compressor.
- Improve reactor refractory linings.
- Eliminate hot well pump's cavitation.
- Improve lubrication to the gear box of the turbine.
- Replace the chemical and drainage pump with a suitable type.
- Enlarge capacity of the blow down stack.
- Other minor items such as replacement of safety valves, etc.

c. Experienced personnel from the plant owner and contractor

Plant personnel had more experience and also better advice from the contractor who supervised and directed the plant operation and maintenance. Also better participation and more support for the contractor came from the PTKS personnel during the commissioning and performance test of DR Plant II. The following points are noteworthy :

- Started to record the history of each individual item of equipment since the old test (e.g. when the parts were changed, how long the equipment was run in one month,etc)
- Caution the contractor if the equipment failed repeatedly
- Analyze the data collected during the commissioning and start up.
- Assign special personnel to observe certain critical equipment very closely.

  Record levels of vibration of all rotary equipment daily, prepare a chart, analyze the trend, and also compare with standard specifications given by manufacturer.

- Since most of the rotary equipment always had a stand by unit, the contractor was asked to run off the equipment as dictated by rotating schedule.

  The ratio between PTKS personnel and the experts brought by the contractor to supervise and direct plant operation and maintenance was 5:1 which allowed more responsibility to plant personnel. Also capable experts were brought by the contractor during the commissioning of DR Plant II.

  The curriculum vitae of the experts were checked by PTKS before the contractor was allowed to bring them there.

  Also the plant owner kept the option of sending the expert home if he was found to be unsuitable.

d. Knowledge of pellet behaviour to be reduced during the performance test

As mentioned previously it is very important to know the behaviour of the pellet to be reduced if a successful performance test is expected. The contractor took three days to analyze pellet behaviour and quality and to select the best operating conditions before an official letter was submitted to PTKS stating that they were ready to begin the performance test.

e. <u>The contractor wishes to end their obligation with good reputation</u>

The attitude of the contractor and their effort to solve the problems found over 4 years time, seems to be one of the reason for successful DR Plant II performance test.

- DR Plant II was 90% completed by the time the DR Plant I was ready for performance test which failed to meet the guaranteed figure.
- As unqualified people maintained the plant, most of the spare parts were exhausted soon. Hence, many parts from plant II were taken to run plant I to conduct the performance test. As the DR Plant II itself had to be completed, it was very difficult to find out which parts had been taken out and needed replacement.
- The maintenance had to be done by the contractor for atleast two years prior to the commissioning of Plant II.

IV. Conclusion

The commissioning of two direct reduction plants and their related facilities has given PTKS the opportunity to document some of their experiences as follows :

1. A well prepared organization with sufficiently qualified personnel is required to handle activities such as cold test, commissioning as soon as the construction is completed. Even if some warranty period is still left after the contractor hands over the plant to the owner, it is very difficult to claim replacements for failures or sub-standard quality equipment. They can be refused during the commissioning period if sufficiently qualified commissioning personnel are available.

2. It is not recommended to build twin plants at the same time which only duplicates the possible design mistakes, construction errors, etc. Although a lot of modifications were made to DR

Plant II(also to Plant I, later on), some important things are still left unattended as the contractor is not obliged to bear the cost and/or were not done due to time constraint. Such modifications are for example :

a. The finfan condensors are not a suitable type for a plant like the DR Plant since a lot of dust is generated/. The fin fan must be located far away from the material handling system and provided with filters to prevent dust accumulation on the fin tubes.

b. Apart from the low efficiency of small steam turbine drives, it is better to have a big steam turbine generator rather than a large number of steam drives for pumps and compressors which require more maintenance effort than electric motors.

3. As soon as the performance test is finished it is advisable to stop the plant immediately, and start to establish a check list of items to be fixed by the contractor from internal plant/ equipment inspection, and weaknesses of the plant detected during commissioning performance test of the plant.

4. Selection of suitable raw material is very important for the performance test in order to identify plant weaknesses separately from poor raw material.

5. The philosophy of plant performance evaluation must be based on maximum load, eg. all common facilities to be tested on simultaneous load, if not possible at least a simulation operation must be performed.

6. In the case of the DR Plant, which looks more like a chemical than a metallurgical plant, the monitoring of the mechanical condition of the plant will make an important contribution both to production and to the safety of the plant.

TYPICAL PT. KRAKATAU STEEL SPONGE IRON SPECIFICATION

Chemical	Typical
Metallization	90.02%
Total Fe	91.50%
SiO_2	1.59%
Al_2O_3	0.57%
MnO	0.066%
P	0.017%
CaO	0.212%
MgO	0.424%
S	0.053%
TiO_2	0.397%
V_2O_5	0.28%
Na_2O	0.146%
K_2O	0.057%
Cu	0.013%
C	1.55%
Fe as Oxide	9.13%
Fe as Metal	82.37%

Physical

Particle size.

Over 18 mm	18 %	Max
Under 5 mm	5 %	Max
Apprarent Density	2.6	T/M^3
Bulk Density	1.6	T/M^3
Crushing Stangth	50	Kg.Min

IRAN

Mr M R Taheri Shahrain,
Ahwaz Steel Complex

1. General condition of steel industry in Iran :

A- The steel making capacity completed as follows :

Blast furnaces	:	1.5	million tons per year
Scrap melting	:	360 000	" " "
(Purofer) Direct Reduction	:	330 000	" " "

B- Projects under construction and nearing completion :

3 module Midrex DR Plant with a total capacity of 1,200,000 tons per year

3 module-Hyl DR Plant with a total capacity of 1,000,000 tons per year.

C- Project under bid evaluation :

3-Million ton sponge iron per year

2. Planning : For the First Period of our 4 steps of 20-year planning (Next 5 years) we have in mind to :

a. complete the existing projects
b. bring them to the designed production capacity
c. adjust sponge iron production and melting capability by adding new melting facilities.

3- Problems :

a- The licensing companies after having supplied the first engineering drawings and equipment show reluctance to keep up posted with new improvements which would result in better process and efficiency.

b- A large amount of fines (Metallic 4 oxide) and slurry will be wasted in the Midrex. Purofer and Hyl plants of Ahwaz steel complex which were not considered in the initial engineering stages of the companies are involved.

c- While our country in this period of revolution needed to produce steel for its developmental programmes, Iraq attacked on the South-Western part of the country where about half of our steel industries are located. It cost us a large amount of money and took a long time to reemploy them again after pushing back the aggressor.

4. Result and Proposals :

a- Since the problems of the countries of the ESCAP region are likely to be similar to those of our country, I would suggest that UNIDO and/or RCTT attend to these problems instead of each country investing in separate research and development establishments.

b- I suggest that UNIDO/RCTT gather enough information about raw materials and products of sponge iron, oxide pellets and steel from the countries of the ESCAP region, study and recommend required adjustments.

KOREA, REPUBLIC OF

Mr Chun Heating Cho
Assistant Director, NF Metals Div.
Ministry of Commerce and Industry

Since Korean Government policy emphasises the promotion of heavy industries including machinery, automobiles and shipbuilding, the demand and supply of steel has increased rapidly. Crude steel production in 1982 was about 11 million metric tons, making Korea the second largest steel making country in Asia, next to Japan

Parallel with a rapid increase in steel production, iron scrap requirements also increased to 3.7 million metric tons in 19 1, about 50% of which has been imported.

Domestic demand for iron ore and coal used as raw material in iron and steel industries has been met with imports, and natural gas and oil are not produced in our country. The limit cost of production of electricity is higher than is the case in the energy-rich country.

Our country neither has a unit producing sponge iron nor does it have plans or programmes for development of sponge iron industry in the near future, as we do not have any natural gas, oil and iron-ore. When the price of iron scrap increases, we will try to expand the use of sponge iron and consider the possibility of starting sponge iron industry. So we desire to have information about properties, price and of the details regarding sponge iron in various parts of the world.

Supply and Demand of Steel

	1981	1987 (estimate)
	(million tons)	
Demand	12.4	18.4
Export	5.3 (43%)	
Domestic	7.1	
Production	10.8	14.1
Import	1.6	4.3

Supply and Demand of Raw Material in 1981

	Demand	Domestic Production	Import	
Iron ·re	11.6	0.4	Australia India	40% 25%
Scrap	3.7	1.8	U.S.A.	80%

MALAYSIA

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Heavy Industries Corporation of Malaysia
Berhad/Perwaja.

1. Introduction

The Malaysian economy is traditionally agriculture oriented. In the past, the growth of the manufacturing sector was minimal with the economy being heavily dependent on the income from the export of rubber, tin, palm oil, timber and of late, crude oil (see Appendix 1 on Basic Data of Malaysia). In recent years there has been a marked shift in the national planning strategy, with growing emphasis being laid on the creation and development of a strong and modern industrial base together with the simultaneous creation of diverse infrastructure facilities needed to sustain the pace of the planned industrialisation programme.

Steel is synonymous with industrial progress and the level of steel production in a country is often considered as the yardstick of that country's industrialisation. Further, the benefits that accrue to the national economy as a whole through the development of the national steel industry, by virtue of the exceptionally high backward and forward linkage effects of this industry, are well-known. The crude steel consumption in Malaysia is estimated at around 1.85 million tons per year in 1981 with demand growing at 8 to 10% annually over the past seven years. However it is expected that the future growth will be between 6 and 7%. It is projected that the total crude steel consumption will reach 3 million t/y by 1990 which is equivalent to per capita steel consumption of about 200 kg. Viewed against these considerations, the decision of the Malaysian Government to take concrete measures for augmenting steel production capacity within the country, at a time when the economy is poised for rapid growth, could not have been more opportune and justified. Hence the establishment of direct reduction plants in Trengganu (capacity 600,000 t/y) and Sabah (700,000 t/y)

2. The Resources Situation in Malaysia

The two major input requirements for the steel industry are iron ore and energy.

The iron ore resources of Malaysia are very limited and not adequate for sustaining a local steel industry. There are some deposits of relatively low grade ore in Kedah, being mined for the Malayawata Steel Plant. Therefore, under the present circumstances, new iron and steel capacity in the country would have to depend on imported iron oxide feed.

In regard to the energy situation, Malaysia has large reserves of off-shore natural gas but no known deposits of metallurgical-grade coal. In addition, there are substantial reserves of oil. Therefore, from the energy resources situation, creation of new steel making capacity in the country should be logically based on the adoption of direct reduction (DR) of iron ore/pellets using natural gas, and use of direct reduced (DRI) as metallic charge in the electric arc furnace. This route of iron and steel making is commonly referred to as the DR-EF route.

3, The First DR-EF Plant in Malaysia

In early 1982 a contract was signed for the first DR-EF plant in Malaysia. The project is a joint venture between the Government of Malaysia and Nippon Steel Corporation (NSC) which is also the leader of the Japanese Consortium that will supply and erect the plant on a turnkey basis.

The plant is located at Kemaman in Trengganu State on the east coast of Peninsular Malaysia. The major plant facilities are:-

i) A captive jetty for import of iron ore/pellets and scrap, and despatch of billets.

ii) DR plant of about 0.6-million ton annual capacity from a single shaft furnace.

iii) Steelmelt shop comprising three 75-ton (43 MVA) arc furnaces and two 4-strand billet casters.

iv) Calcining plant for burnt lime.

v) Air separation plant for generation of oxygen and nitrogen.

vi) Storage yards for raw materials, scrap and billets.

vii) Electric power receiving and distribution facilities.

viii) Water, natural gas and other utility systems.

ix) Maintenance shops, stores, laboratory and other plant auxillaries.

The DR plant will be based on the NSC-DR process and will be the first commercial plant to adopt this recently developed process. The DRI from the shaft furnace will be hot briquetted. About 0.52 million tons of DRI briquettes will be consumed in the plant and the balance will be sold to various arc furnace plants in Malaysia.

The electric arc furnaces will use only 20% scrap in the charge and 80% DRI briquettes through the well established continuous charging method. The plant is capable of producing 0.56 million t/y of steel billets mainly for local consumption.

Construction work on the project commenced in October 1982, and the plant is scheduled to go on stream by mid-1985.

4. Scope of Regional Cooperation

Amongst the ASEAN countries, Indonesia and Malaysia are the only countries with DR plants in operation or under construction. The DR processes are based on the use of gaseous reductant, namely natural gas, although the reduction units are different. It is understood that plans for an integrated steel plant in the Philippines based on the rotary kiln DR process are in an advanced stage of implementation. The only other country in the neighbouring region where rotary kiln DR plants (producing steel making grade DRI) are in operation is India.

The Trengganu DR plant perhaps can make significant contribution towards regional cooperation in the following areas:-

1. Industrial-scale testing of iron oxide feed material from new deposits in the region to ascertain their suitability for DR products.

2. Assistance to other countries planning DR facilities on likely problem areas faced by developing countries and

and significant measures for overcoming such problems, namely financial and technical.

3. Provide facilities for on-the-job training of personnel in the operation and maintenance of DR/EF facilities.

4. Exchange of operation experience amongst DR planners with a view to achieve improved planned performance and high productivity.

5. Suggested Activities for Regional Centre for Technology Transfer (RCTT)

On the higher level, RCTT could play a major role in the following areas:-

1. Information exchange pertaining to current practices, statistics from both technical and commercial data.

2. Provision for training programme with emphasis on on-the-job training at existing plants. This also includes study tours, workshops, seminars, etc.

3. Sharing of experience in in-plant energy conservation programme.

Appendix 1

Malaysia - Basic Data

Area : 330,434 sq. km.

Population in 1982 : 14.16 million (estimated)

Composition of exports for 1981

Rubber 16%	16 %
Saw logs and sawn Timber	12 %
Palm Oil	10 %
Tin	8 %
Petroleum	24 %
Manufactured goods	24 %
Others	6%
Total exports (100%):	$28,012 million

Gross National Product (at constant 1970 prices)

1980		1981 f*		1982 f*	
$ million	% growth	$ million	% growth	$ million	% growth
22,294	8.2	27,037	6.9	28, 34	7

Natural gas reserve : 49 trillion cu. ft.

Petroleum : Product 32(,000 barrels per day
Reserve 2.. billion barrels
Reserve to last for about 20 years
at current production

No *f - foreca

PAKISTAN

Mr M A Qazi and Izharul Haque Khan
Pakistan Council of Scientific and
Industrial Research

At the time of the creation of Pakistan in 1947, the production capacity of steel in the country was about 20,000 t/year. With the gradual industrialization, the tempo of steel utilization as also steel production started building up. By 1974, the total domestic steel production was recorded at 224,000 t, which increased to 550,000 t by 1982, showing an increase of over 12 per cent in eight years. The demand for iron and steel, however, almost doubled during this period.

Present Status of Ferrous Industry in Pakistan

The local steel industry up to 1981 was characterized by electric scrap melting furnaces with rated capacity of over 600,000 t/year. Home market could meet less than 50 per cent of the scrap material requirement. The remaining had to be imported. The Pakistan Steel Mills at Karachi, the first integrated iron and steel works in the country, has gone into production in 1982. The mill is designed to produce 1.1 million tonnes of steel based on imported iron ore and coking coal. It has been estimated that at the present rate of industrialization the demand for iron and steel in Pakistan by [illegible] would be about 1.7 million tonnes/year. This means that additional capacity using electric furnaces would have to be fully utilized.

Future of Sponge Iron in Pakistan

The supply of good quality scrap has been a continuing problem for the electric steel melters. The public sector is seriously considering the establishment of a sponge iron plant based on local iron ores. In this connection, the Resource

Development Corporation has already contacted Allis Chalmer, who prepared a pre-investment feasibility study for a DR-iron plant of capacity 100,000 t/y, based on the by-products magnetite and pyrite cindre (from proposed copper mill). Besides, Pakistan Industrial Development Corporation is also considering a DR-plant for sponge iron using local iron ore concentrates. Preliminary studies in this direction have been carried out by the Pakistan Council of Scientific and Industrial Research (PCSIR) as well as by the ARMCO in USA. It looks quite probable that a public sector sponge iron module of 400,000-600,000 t/y capacity would be set up to meet the needs of iron and steel in the near future.

Iron Resources

Iron-bearing deposits of Pakistan are conservatively estimated at 450 million tonnes. These reserves generally belong to two major classes (1) Igneous, metamorphic and metasomatic type ; occurring in small ore bodies assaying 40 to 62 per cent Fe, mainly as magnetite, and (2) sedimentary ore deposits of relatively large size containing 20 to 34 per cent Fe, in the form of siderite, goethite etc. Table I shows some of the significant deposits of iron-bearing materials.

The ores as such contain prohibitive amount of impurities rendering them unsuitable for iron and steel production by direct or indirect (B/F practice) methods. A systematic R&D project was undertaken at the Pakistan Council of Scientific and Industrial Research Laboratories, Lahore, in order to evaluate and beneficiate the domestic iron ore to make them useful for B/F & DR iron making practices.

TABLE I : IRON RESOURCES OF

Deposit	Reserves Mt	Fe %
Sedimentary		
Chichali	165 - 335	32.5
Kutch	34.0	33.1
Makerwal	52 - 200	33.4
Rakhi Munh	14.5	37.5
Pezu	12	31.0
Langrial	28	40.2
Galdanian	60	20.0
Igneous & Metamorphic		
Dammer Nissar	6.5	59.43
Swat	300	14.5
Chilghazi	2.5	45.3
Chigendik	5.2	39.2
Pachinkoh	25.0"	46.8

Lim Limonite　　Cham Chamosite　　Sid
Ilm Ilmenite　　Mag Magnetite

" Probable 100 Mt

PAKISTAN

SiO_2 %	Minerals
21.2	Lim Sid Gla
23.2	Cham Sid
24.5	Lim Sid Cham
13.9	Lim Sid
-.	Sid Lim Hem
14.8	Cham Lim Hem
9.9	Hem Claystone
9.9	Mag
32.1	Mag Ilm
12.0	Mag Hem
20.0	Mag
15.6	Mag

Siderite   Ham Hematite
Gla Glauconite

The iron ore deposits are of low grade, average chemical compositions of some typical ores are given in Table II.

TABLE II : Average Chemical Analyses of Some Pakistani Iron Ores (%)

	Kalabagh	Chitral	Chigendik	Pachinkoh
Fe (t)	32.5	59.43	39.16	46.80
FE (II)	14.3	-	5.6	14.62
SiO_2	22.4	9.94	20.01	15.6
Al_2O_3	5.8	0.80	3.19	4.41
CaO	3.0	3.36	9.19	4.86
MgO	3.2	0.80	0.83	1.39
Na_2O	0.14	-	-	-
K_2O	2.34	-	-	-
P	0.34	-	0.02	0.10
S	1.58	-	1.07	3.96
LOI	15.91	0.91	7.76	2.72

Beneficiation studies at the PCSIR

The ore samples from Chichali, containing siderate and goethite as the principal iron containing minerals were separated from gangue using fatty acid flotation. The samples from Chitral, Chigendik and Pachinkoh were concentrated using magnetic separator. The chemical analyses of various concentrates are given in Table III.

TABLE-3: Chemical Analyses of Iron Ore Concentrates Test (Wt%)

	Chichali (indurated)	Chitral	Chigendik	Pachinkoh
Fe (t)	54.7	66.72	65.30	68.20
Fe (II)	-	23.38	14.77	26.39
SiO_2	9.5	3.47	3.28	2.10
Al_2O_3	0.5	0.71	0.51	-
CaO	3.6	0.66	0.85	-
MgO	4.41	0.22	0.04	-
Na_2O	0.04	0.09	0.03	-
K_2O	0.09	0.05	0.01	-
P	0.15	0.01	0.07	-
S	0.11	0.01	0.56	0.66

The composition of the Chichali indurated pellets did not conform to the physical and chemical requirements of a DR-process. The other concentrates, however, were used for laboratory pelletizing and reduction tests.

Pelletization and Reduction Tests

The ore concentrates were ground in a ball mill to achieve: Chitral samples A Chitral Sample B, Pachinkoh and Chigendik with specific surface areas of 731, 1700, 1280 and 950 cm^2/g respectively. The powders were pelletized using 0.8% bentonite. The green pellets had strength of 2 to 2.7 kg/p. The green pellets were indurated at 1250°C.

The heated pellets of the ore concentrates were reduced using (CO, CO_2, CH_4) gaseous mixtures in static bed, under load and in Linder furnace. The test results are given in Tables IV and V.

TABLE IV : Reduction Tests of Chitral, Pachinkoh and Chigendik Ores

	Chitral A	Chitral B	Chigendik	Pachinkoh
Fe (t)	65.31	66.49	65.58	68.34
FeO	0.38	0.53	1.18	0.15
Static bed reduction				
Direct reduction %	97.67	98.31	95.05	97.36
Compression Strength (kg/p)	82	110	101	60
Clustering test				
Shrinkage %	21.3	21.1	7.3	17.5
Pressure drop (mm)	4.8	4	3	4
Cluster Strength (2min)	8.8	8.9	80	18.1
Fines %	3.75	2.04	1.2	12.1
Linder test				
Direct reduction%	98.28	98.26	93.24	97.05

TABLE V: Reduction Properties of Indigenous Ore Pellets

	Chitral A	Chitral B	Pachinkoh	Chigendik
Chemistry				
Iron contents	Little low for DR feed	Acceptable DR feed	good for direct reduction feed	Acceptable DR feed
Phosphorous	very low	very low	very low	very low
Sulphur	low	low	very low	very low
Physical properties	good	good	good	excellent
Reduction Properties				
Reducibility	good	good	good	excellent
Fine generation	little	little	little	little
Clustering	little	little	little	little

The concentrates and pellets were sent to the Japan Consulting Institute (JCI), Tokyo and to ARMCO in USA for rechecking their suitability for a DR process. Both the organizations have corroborated the results and have recommended the use of concentrate for sponge iron manufacture.

Choice of Reductant

Among the number of DR-processes developed, only a few have achieved reasonable degree of commercial success. The more important ones are those based on gaseous reduction. Considerable progress, however, has been reported in the alternate processes using solid reductants.

Pakistan has sizeable proven reserves of natural gas which at the present rate of consumption may not last long. Though, work on the development of new gas fields is in progress, the government is not inclined to support the use of natural gas for sponge iron production, because of its utility in fertilizers and other high-value products.

The choice left would be locally available, rather low-ranking coal, as such or after gasification, for the production of sponge iron.

Total estimated coal reserves of Pakistan including indicated and probable are slightly over 500 million tonnes. The coals are generally non-coking type, and contain high ash (3-30%) and sulphur (1-7%). There is only one washing plant in the country producing clean coal; over 80% of the domestic coal produced is used unwashed.

Technological requirements

The R&D work at the PCSIR is directed at the use of low-grade coal for the preparation of sponge iron. It would be of great value to learn from the experience of the countries using solid reductant, especially from those of ESCAP region. In this context, it is hoped that ESCAP/RCTT and UNDP will be of much assistance if :

1. Technical information and data on R&D as well as on the production levels on DR iron is made available to the ESCAP countries.

2. Short courses and in-plant training facilities are extended to the scientists and technicians of the member countries so desiring.

3. For a situation, as in the case of Pakistan, R&D facilities on laboratory and pilot plant scale may be strengthened, so as to enable the scientists to carry out preliminary evaluation and testing of domestic raw materials. Also, technical guidance for the production of low-sulphur iron ore concentrate may be provided.

4. Frequent workshops are held to exchange ideas and to disseminate information.

5. A panel of experts is organised to assess and advise a country on the sponge iron manufacture, and assist in preparing techno-economic feasibility reports.

SRI LANKA

Lalith Wijesinghe,
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Ceylon Steel Corporation

With the implementation of several large scale development projects, the steel making industry in Sri Lanka has received a great impetus due to an increased demand for steel products, especially the reinforcing steels. The present requirement for reinforcing steels in the country is about 150,000 MT/year.

The largest manufacturer of reinforcing steels in the island is the Ceylon Steel Corporation which has a rolling mill of capacity 100,000 MT/year. The Corporation has also recently commissioned a 25 MT electric arc furnace (EAF) with an associated 4-strand continuous billet casting facility of capacity 60,000 MT/year. The next phase of development is the installation of another 25 MT EAF which would bring the total capacity to 120,000 MT/year. In addition to these facilities the Corporation also has a steel foundry and a wire mill.

The feed material for steel making at present is a 100% scrap charge, and at the projected levels of production, the Corporation's stockpile of scrap would be depleted by mid-1984. As with most developing countries scrap is not widely available in Sri Lanka too, necessitating imports involving precious foreign exchange. In the circumstances, the Ceylon Steel Corporation has been actively considering alternative feed material to scrap. With the acceptance of the direct reduction electric arc furnace (DR/EAF) route for lower capacities, the viability of sponge iron as feed material has grown. Hence Sri Lanka is keenly interested to study the experience of others in the region in the use of sponge iron in steel making.

The Island, though not endowed with large mineral deposits, has discovered a magnetite ore body with an estimated 7 million MT of ore extending to a depth of about 50 metres. The metallic iron content of the magnetite is about 40% and compares well with other magnetite ores of the world. This ore is also associated with a copper bearing chalcopyrite, with a metallic copper content of 1%. Preliminary laboratory studies on the behaviour of the local magnetite to direct reduction with a solid reductant such as coconut shell charcoal has been promising.

The major problem Sri Lanka faces in producing sponge iron is the non-availability of a gaseous reductant most widely used in well established DRI plants of the world. Sri Lanka wishes to share the experience of countries in the region which use a solid reductant to produce sponge iron.

THAILAND

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Director
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Development of the Sponge Iron Industry in Thailand

The sponge iron industry in Thailand was initiated when commercial quantities of natural gas were discovered in the Gulf of Thailand. The natural gas is good in quality and qualifies to feed various types of industries. Moreover, there are semi-integrated steel plants which need scrap as raw materials for electric arc furnaces in order to produce non-flat steel. Thailand imports about 300,000 tons of scrap per year. It is feared that a few years later steel scrap will become comparatively scarce and expensive.

Therefore, in the year 1978 the Ministry of Industry received technical assistance from the Austrian Government in the form of a pre-feasibility study for the establishment of sponge iron plant based on natural gas. It is recommended in the report which was submitted to the Ministry of Industry in May 1978 that a 600,000 t.p.a. sponge iron plant be established. This plant will need natural gas to the tune of 22 million cubic feet per day and need to import iron ore of the order of one million ton per year. The total investment is about US$ 100 million. The sponge iron produced can substitute the imported steel scrap and feed the local semi-integrated steel plant. From the balance amount of sponge iron, billets can be produced for use in re-rolling mills. It is anticipated that the sponge iron plant will become operational in 1983.

The Ministry of Industry perceived that this project is essential to the economic development of the country. Therefore, it encouraged the local investors to form a company, named, the Siam Ferro Industry Co. in 1979. Concurring with this project, the Government participated an eleven percent shareholding investment. Besides, the Government supported the project by providing necessary infrastructure.

In 1979, a detailed feasibility study for the establishment of a sponge iron plant was conducted. After that, the project was proposed for Board of Investment (BOI) for incentives in January 1980. The project was pending for the final decision on site location. Later on, the cabinet decided that the sponge iron plant should be established on the eastern coast of Thailand which should be adjacent to natural gas-related industries such as the chemical fertilizer plant, the soda-ash plant and the gas separation plant.

However, because of the site selection and the upward trend in gas price, cost escalation of about 30%, depression in the steel industry, the Siam Ferro Industry Co. reviewed the Projects in 1981 and kept it in abeyance.

The Ministry of Industry has consideredthe production of natural gas in the Gulf of Thailand as expensive and fixed its price at US$ 3.50 per thousand cubic feet. This is higher than optimum natural gas price which could be used in the production of sponge iron with steel scrap at competitive price. Therefore, the Ministry is considering alternative process routes and is interested in solid reductants such as lignite in producing sponge iron.

In 1982, Lurgi Chemie and Huttentechnik GmbH of the Federal Republic of Germany submitted proposals for the establishment of the Sl/RN/direct reduction plant based on Thai lignite as solid reductant with the capacity of 400,000 tonnes annually. The Ministry is interested in an indepth study (inculding laboratory testing) of the availability and quality of lignite in main sources of Thailand.

The Ministry considers the German engineering companies as leaders in direct reduction process based on solid reductant, and plans to approach the Federal Republic of Germany for financial assistance in the form of technical co-operation funds for conducting a feasibility study to establish a lignite-based Direct Reduction plant to produce sponge iron (as substitute for imported ferrous scrap). The Ministry likes to compare this with other process routes. The most economically viable and promising process route will be selected, and this should be the most important step in the development of sponge iron industry in Thailand.

PHILIPPINES

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The domestic iron and steel industry in the Philippines is mainly involved in the manufacture of flat steel products, steel billets and billet-derived products. There is no gainsaying that these commodities buttress the foundation of industrial activities in the country.

At present, there are 70 iron and steel product manufacturers in our country with a total annual rated capacity of about 3.7 million metric tons. The history of the steel industry may best be unravelled by recalling the birth of each sector culminating with the more sophisticated flat steel products in which the Philippines has been established as the leader in the ASEAN region.

Steel bar sector. The first bar mill in the country was completed in 1951 and became operational in 1952 with an initial capacity of 10MT for an 8-hour shift. Since, then additional rolling mills were established one after the other. Today, there are 27 rolling mills in the country engaged in the manufacture of merchand bars with an aggregate annual rated capacity of 1.07 million MT. The country now boasts of self-sufficiency in its rebar requirements. As a matter of fact, imported merchant bars account for only 10% of the total consumption.

Wire rod sector: Domestic wire rod production started in 1952. However, it was only after 14 years that the company equipped itself with a rod mill acquired from England. To date, there are some five firms engaged in the rolling of wire rods with an actual rated capacity of 227,500 MT, a big percentage of which is dependent on imported billets.

Billet sector: With the realization of scrap iron as a potential raw material for steel making, the country's first melting plant was established in 1953 by operating on a three-ton electric arc furnace. Not to be outdone, several companies followed the trend with one company having a 40-ton electric furnace, the biggest in the country. The country's melting plants have noticeably proliferated bringing to ten the total number of firms engaged in the business. Of these, nine have rolling facilities. With these equipment, scrap is melted to produce billet-sized ingots for the manufacture of rebars, small sections and wire rods.

Pipe and tube sector: The local tube industry started in 1957. The International Pipe Industries Corporation (IPI) later joined the sector as the producer of spiral-welded pipes. In April 1970, IPI was given authority to carry the American Petroleum Institute (API) monograms. IPI is the only firm in Asia, excepting Japan, which carries this approval. Today, pipe and tube manufacturers number about 8 with an annual rated capacity of 218,000 MT.

Hot-rolled flat steel sector: Between 1962 and 1968 the demand for these products increased even as these continued to be wholly imported. In 1969 IISMI started to run its hot rolling mill for the production of flat steel products. Imported steel slabs were used as raw materials. Although the versatile combination mill of National Steel Corporation (NSC) was designed for rolling steel slabs to plates, it was only in 1978 that rolling of both medium and heavy plates became possible. However, the cold-rolling mills necessitated more hot-rolled coils. Thus, the bulk of hot-rolled flat steel materials is still imported.

Cold-rolled flat steel sector: Imports were the sole source of cold-rolled sheets and coils up to 1962. In 1964, the increase in indigenous production of cold-rolled flat steel was 113%, followed by a sudden drop in the succeeding years due to shutdown of several units. The country then had no local supply in 1968. In 1970, a 96% production increase as compared to the previous year was recorded. Between 1973 and 1978, NSC produced 250,000 MT of cold-rolled sheets and coils enabling it to export some of its products and gain worldwide recognition.

Galvanized iron sheets and color coating sector: The Philippines has always been a major user of zinc products with the galvanizing plants as the largest consumer. Practically all local galvanizing plants have been using the old conventional hot-dip process batch and continuous. The latest in the sector is using the modern electrolytic process giving high quality and economical steel-coated sheet product. These manufacturers use both local and imported cold-rolled coils. Zinc together with lead and tin come from Australia, Canada, Japan, and Malaysia.

Tinplate sector: Production of tinplate started in 1962 using a Japanese-manufactured hot-dip tinning lines with a capacity of 12,000 MT per year. A year later, an electrolytic tinplate was produced using the halogen line developed by E.I. du Pont de Nemours & Co. In 1969, a US-made ferrostan line with a production capacity of 50,000 MT/year. However, it should be noted that the country's pineapple canners have always been heavy importers of tinplate because of its special quality which cannot be produced locally.

The Five-Year Expansion Programme of the Government

It has been the consuming desire and aspiration of the country's industrial sector to set up an integrated steel mill plant complex. Finally, the dream is about to unfold as one of the government's eleven major projects is programmed to generate substantial net foreign exchange earnings for the country and propel its industrialization.

After a series of feasibility studies conducted since early 1960, the government was seriously considering the construction of an integrated iron and steel mill complex. Then, shortly before March 1981 the Industry Minister made an announcement that the government has decided to defer the project and instead expand and modernise the existing facilities.

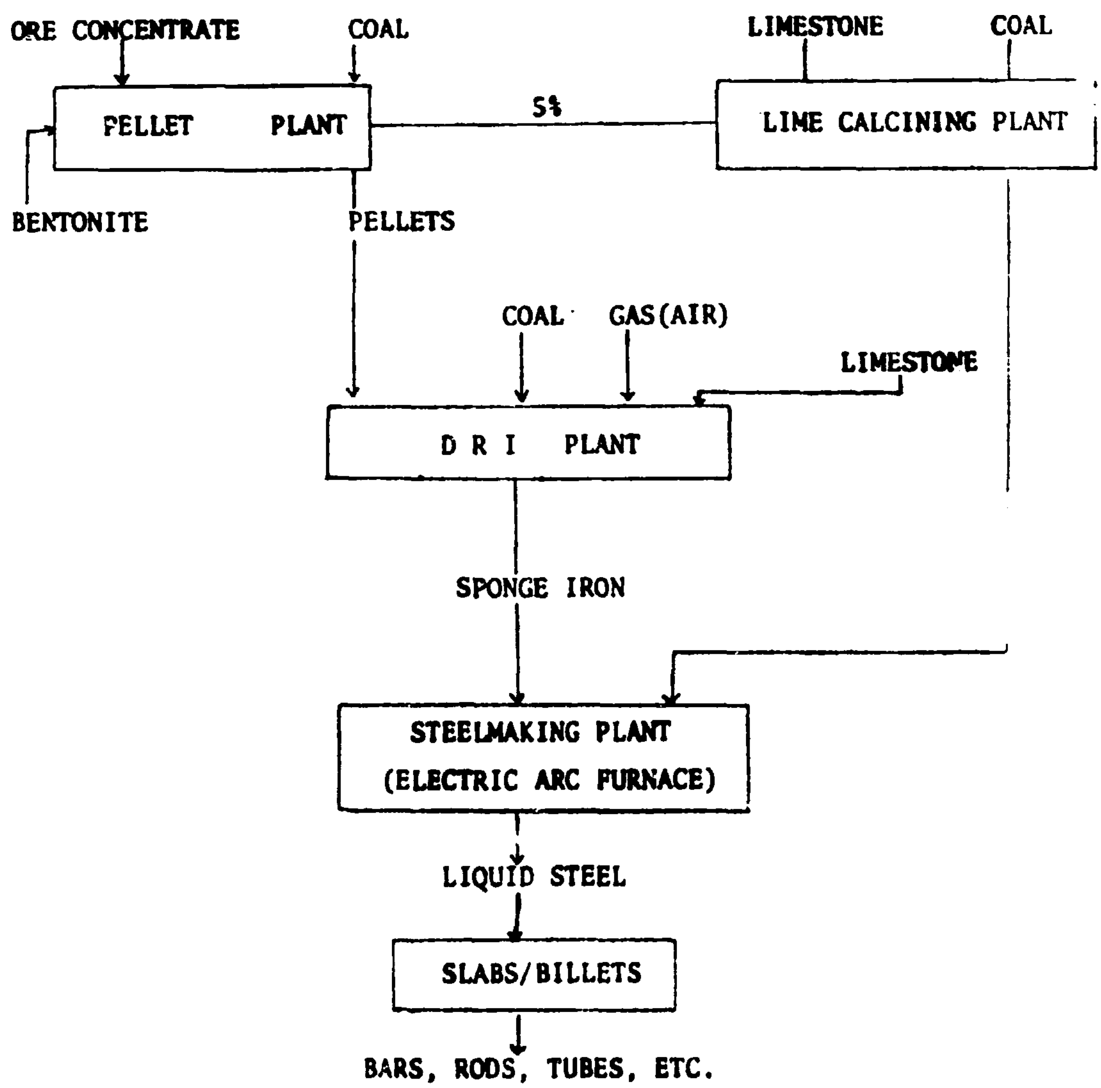
The project initially invited criticism aimed at previous plans featuring an expensive and therefore, Capital Intensive Scheme - the so called conventional "Coke oven-blast furnace" to produce iron and steel. Considering inflation and faced with rising costs and the need to import both iron ore and coking coal, the Industry Ministry began investigating other methods of producing iron and steel.

The new project was spelt out in a Five-Year Expansion Programme. Within the established time frame, new technology would be introduced in the plant site to effect backward integration to the iron ore stage.

A significant aspect in the new plan, apart from the change in location, was the shift in the choice of steel-making technology route. The Greenfield Project, as previously proposed by JICA was based essentially on the blast furnace and the basic oxygen converter. In contrast, the envisioned mill shall be integrated via the solid reductant direct reduction route. Integrating through direct reduction would cut investment from the level of nearly $ 2 billion required for the blast furnace project to less than half while maintaining the capability to achieve the same projected first stage capacity. Construction time would be brought down from the 4-5 years required for the blast furnace project down to 2-3 years. A strong argument in favour of the direct reduction process is the possibility of using 100% local raw materials. While the blast furnace requires imported high-grade iron ore and coking coal, direct reduction will use Philippine iron ore and non-coking coal, resulting in substantial savings of foreign exchange. Finally, direct reduction offers more flexibility in capacity building by allowing smaller increments in capacity compared to the blast furnace.

The plan had called for a greenfield location in an industrial state in Northern Mindanao. Substantial savings could be made by moving the locations from a greenfield site, where many new infrastructural facilities would have to be built, to a brown site where an existing company already has some of the required infrastructure and mills that need only modernization and expansion. The greenfield site would probably be reserved for much expected bigger demand for steel by the end of the decade or early 90's when the conventional blast furnace route could give full play to the economy of scale.

The new project plan as decided calls for an integrated plant complex with an annual capacity of 1.5 million metric tons. The plant could be opened in units of 300,000 metric tons until full capacity is reached in 1985.



PROPOSED INTEGRATED IRON & STEEL COMPLEX

Technical Aspects

Pelletizing: Ore concentrates and coal available locally are mixed with some additives like lime and bentonite in a mill. The mixture is passed through drums or discs to form balls or disc-like pellets. The green pellet which is mostly magnetite is further reduced to Fe_2O_3 in a travel grate furnace the product of which is called indurated hard pellet, an input to the DRI Plant.

Direct reduction: Defined in simplest terms, direct reduction is the conversion of an oxide iron ore into a metal form called sponge iron without passing the liquid state (in iron making). Rotary kilns will be established to supply the sponge iron. A kiln is about 100 m in length by 5-6 m in diameter. The proposed plant will have 6 kilns with a total capacity of 1.5 million.tpy. Within these kilns, the raw materials - pellets, coal and limestone are continuously fed into one end of the refractory-lined kiln and conveyed through its length while being reduced. Coal has been chosen as the solid reductant in view of the absence of natural gas in commercial quantities in the Philippines. The kiln rotates at less than one rpm. Combustion air is supplied via air tubes. The charge is heated at about 900°C by counter-curr nt flow of hot kiln gases and metallised into sponge iron. Depending on gas content, part of the fuel is blown into the kiln from the discharge end using air, and/or charged together with the ore. Coal is blown in from the discharge end to supplement the heat generated by the combustion of CO escaping from the bed. The material discharged from the kiln is a mixture of sponge iron, surplus fuel and ash. The product is cooled in a rotary cooler and passed through magnetic separators and screens to isolate sponge iron, return char, coal ash, etc. DRI can be used for the production of a wide range of steel products - billets, bars , rods and flat products such as deep drawing quality sheets, coils and plates. To convert sponge iron into slabs and billets, the new plant will be furnished with electric arc furnaces and continuous casting machines. Slabs will be fed to the hot and cold mills to be rolled.

Conclusion

As we go into full integration, we usher in an era of new industries, employment opportunities, bustling communities, and unlimited prospects for economic growth. We shall set the pace for added momentum in various industrial fields - manufacturing, transportation, communication, shipbuilding, mining; the impact is tremendous.

The project points to a large and dynamic growth company using new technology having additional multi-million assets, increased production and sales; offering employment opportunity to thousands of men.

The project will help build a recognized industrial state, not only in the Philippines but also in the ASEAN and the whole world.

More than these, the project is a commitment to the people. The integrated steel mill shall be the country's engine for industrialization, a goal that has eluded the past generations of Filipinos. With the integration programme, we shall lay out best bet for alleviating a poverty-ridden nation.

VIETNAM

Mr. Pham Chi Cuong
Metallurgical Engineer
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Sponge iron production in the Vietnam

Iron and steel industry is quite new to the Socialist Republic of Vietnam. Our country has just passed through a long period of war. Almost all the steel plants and the Metallurgical Institute were heavily damaged in the war.

In 1975, after the reunification of the whole country, we have activated these steel plants and the institute for metallurgy.

In fact, the study of sponge iron production in Vietnam has been started in early 1970 and the Metallurgical Institute was assigned the reponsibility of this task.

I. Background

The industry in SRV* is encountering two difficulties. They are:

- Shortage of coking coal for blast furnace.
- Shortage of steel scrap for steel-making arc furnace.

In order to overcome these difficulties, we have to study the production processes of sponge iron in the context of natural resources available in the country. At first, we have chosen the production of sponge iron in rotary kiln using coal of anthracite, mostly exploited in the country.

II. Technical characteristics of rotary kiln (Small scale production)

Based on the technical documents of sponge iron production in laboratory and in order to assure the study quite similar with the production in plant with industrial equipments.

* SRV - Socialist Republic of Vietnam

The metallurgical institute has built the rotary kiln for sponge iron production. Technical specifications of the equipment are as follows.

- Inside diameter of kiln [illegible].1 m
- Length of kiln 14 m
- Capacity of motor for turning kiln 22 kW
- Rotating speed of kiln 0.5-4.5 round/min.
- Inclination of kiln 1.5 %
- Total weight of kiln 49 tons
- Refractory brick (thickness 190 mm): weight 29 tons
- Yearly output 1.8-2.0 t.

Cooling unit for sponge iron :

- Length 10 mm
- Diameter 600 mm
- Rotating speed 1 round/min.
- Capacity of motor 7 kW.

These equipment have been designed and totally built in Vietnam itself, and put into operation in November 1978.

III. Technical data regarding production of sponge iron By rotary kiln (small scale)

a/ Raw materials and fuel used were :

- Iron ore 8-15 mm 63-64 %
- Iron ore 15-25 mm 65-66 %
- Reducing agent : Hongai anthracite 1-6 mm 87 %
- Limestone 0-5 mm CaO 53 %

b. Temperature regime : t°max limited below -1.050 °C

c. Rotary kiln gas composition (%):

Place of gas	$H_2O + CaO$	CO	O_2	H_2	CH_4
At the end of the kiln	15-16	3,5-4,0	0,2-0,4	1,4-1,6	0,1
In the middle of the kiln	9	67	1,2		

- Volume proportion of raw materials in the rotary kiln: 15 - 20 %

- Time taken for the materials to last in the rotary kiln: 4 hr.

d/ Production rotary kiln:

Iron ore		Sponge iron				
		Fe% Tot	Fe% met	C%	S%	% metallic
Iron ore 8 - 15 mm	63	87	77	0,3	0,08	88
Iron ore 15-25 mm	66	88	77-78	0,3	0,04	90

e/ Main parameters of the rotary kiln:

- Consumption rate of iron ore : 1.4-1.45 tons/t.sp.iron
- Consumption rate of anthracite coal 0.65-0.70 - „ -
- Consumption rate of heavy oil 120 - 130 kg/t - „ -
- Daily output 4.5 - 5 tons
- Collected Fe in the sponge iron 8 mm : 91 %
- Total percentage of iron collected : 98 %
- Losses 2 %

IV. Use of sponge iron in the steel making arc furnace

Products of rotary kiln production were used in the steel making arc furnace.

- Mark of steel : Carbon steel for construction
- Weight of steel ingot : 74 kg
- Size of the steel ingot (100 x 100; 120 x 120; 700 x 1450) mm
- Main parameters of steel-making arc furnace 10 tons.

When using sponge iron:
Proportion of sponge iron in the charge : 50-100 %
Time taken for steel-making:
Using 50 % sponge iron : 4 hr
Using 100 % sponge iron : 6 hr

- Consumption rate of electrical energy : 700-1200 kWh/T
- Consumption rate of electrode : normal
(Similar to the use of scrap)

Conclusion

From the results of sponge iron production in rotary kiln, we have proposed a new design for the rotary kiln with 30,000-60,000 ton output per year, using domestic raw materials and anthracite and to supply the sponge iron to the steel-making arc furnaces.

To improve the technology of sponge iron as well as the steel-making arc furnace technology, and to overcome difficulties of shortage of coking coals and scrap, we wish to obtain assistance, technology and equipment from foreign countries in the field of sponge iron production.

We hope that the UNIDO will provide opportunities for training of specialists in the production of sponge iron by study tours and training programmes abroad.

ESCAP

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Introduction

The Lima Declaration and Plan of Action has pointed out that in order to give concrete content to the process of industrialization in the developing countries, studies must be undertaken and specific measures must be formulated in different sectors of industry with special attention being given to priority sectors. One of the priority sectors identified for study was the iron and steel industry, the development and extent of which are generally accepted to be the prime indicators of the level and maturity of a country's industrialization.

It was noted that the iron and steel industry provided vital inputs not only for the industrial sector but also for other sectors such as construction, transportation, agriculture, energy, etc.

It should be stressed that during last decade ESCAP had initiated action to focus attention on problems and potential of developing viable iron and steel industries in the developing countries of the region. ESCAP has sponsored studies on specific regional projects such as the possibility of establishing a regional steel billet plant. At the meeting of top planners and government executives, entrepreneurs and representatives of financial institutions held in Bangkok in May 1975, the Steel Action Group was constituted. However, in spite of all these regional efforts, the integration achieved was still far from ideal, largely because of different socio-political conditions, and also owing to numerous technical and financial problems faced by the concerned countries.

Later, in order to explore ways and means of increasing regional steel production by application of modern steel making technology and, in particular the direct reduction processes, ESCAP/RCTT in collaboration with UNIDO, organized a workshop on Small-Scale Iron and Steel Making including Sponge Iron Production in May 1978.

The workshop, recognizing the deep interest of a number of developing countries in establishing steel capacity based on sponge iron, emphasized the urgent need for assistance in strengthening their technological capabilities for the purpose, in assessing the demand for sponge iron and techno-economic feasibility in setting up of production units, and in selecting appropriate technology to suit their condition and their resources in the development of skills, etc.

The next step was a workshop on "Problems of Technology Transfer for the promotion of Sponge Iron Industry in the countries of the ESCAP Region" organized by UNIDO, ESCAP and RCTT with assistance from UNDP and the Government of the Netherlands in November 1979 in Bangkok, Thailand. As a result of this workshop, a working group consisting of several countries of this region was formed to exchange information on developments in the area of sponge iron. Since that time RCTT has begun to function on a network basis in regard to the direct reduction technology to bring the proper institutions in the region into co-operative arrangements for the mutual benefit of the countries.

It should be noted that the present Study Tour and Workshop on Sponge Iron is also a very good example of cooperation among different international agencies on the subject referring to the vital needs of the ESCAP countries. This follow-up action reflects that several important developments in the area of sponge iron have taken place in the region since the last workshop.

The establishment of new sponge iron units in the region and experience gained in the operation of the units in Indonesia and India give the best opportunity to planners, policy makers and experts to obtain information on the planning, establishment and operation of DR units based on gaseous and solid reductants and discover the certain prospects of TCDC in the development of the sponge iron industry in the ESCAP region.

1. The Global Steel Situation

World production of crude steel in the developed countries has been static over the past eight years, falling from 709 million tonnes in 1974 to 707.5 million in 1981.

The study prepared by UNIDO for an international meeting of steel producers, experts and representatives of governments and labour, indicates that steel production has continued to decline in the industrialized countries.

Demand for steel in the developing countries, however, rose steadily at an annual rate of 4.7 per cent between 1971 and 1981. Third World demand in 1981 was around 145.2 million tonnes of crude steel out of 715.2 million tonnes the global demand figure.

Production in the developing countries has also increased at the rate of 7.4 million annually, bringing the 1981 figure to 100.46 million tonnes of the world total - 707.59 million.

The changing pattern of world steel production is associated with a fall in industrial investment and the continuing recession in the developed countries.

II. Changes and trends in iron and steel technology

There is general agreement that during 1980s there may not be any new technological breakthroughs of the kind of the Bessemer process, or LD oxygen steel-making and continuous wide strip mill and predominance of the main route, coking plant/blast furnace/ oxygen converter, supplemented by the scrap/electric furnace route, will be confirmed and extended.

Within the overall stability of the main route, modernization and intensification will increase, thus improving control of operations and conversion of the installations.

Modification and intensification will involve the use of dry quenching in the manufacture of coke right up to controlled temperature rolling, inculding more accurate control of the blast furnace (pressure, temperature, distribution of the charge and gas flow, etc.), and more efficient refining of steel, etc. These developments will allow the efficiency and profitable nature of the main process to be improved.

The following table summarizes some long-term technological forecasts:

Table 1

Radically new processes	Possible transition to a significant industrial stage		
	1985	1990	2000
Production of steel using plasma arc			?
Direct Steelmaking		?	?
Continuous steel production 1/		?	?
Hydrometallurgical production of cast iron		?	X
Steel production using nuclear energy			[illegible]
Various systems using hydrogen		?	[illegible]
Top casting of steel		?	X
Coke substitute (formed coke)		?	X
Direct fabrication of rolled products from powder	?	X	[illegible]
Direct reduction process	X	X	[illegible]

Source : Report from Office of Technology Assessment (OTA) in Metal Bulletin Monthly, October, 1980.

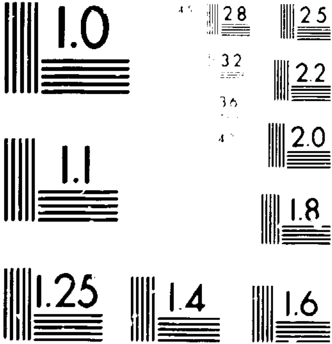
1/ "Industrial World" of July 1976, cited [illegible] that this process could be economically feasible [illegible] stage) in 1990, becoming a standard process in [illegible].

At the same time more than 99 per cent of Japanese steel (1980, [illegible]ity) is produced using oxygen converters (LD) and electric furnaces; approximately 60 per cent of this steel is continuously cast, whilst automation of production has made rapid progress.

This example shows that nothing is automatic, especially in the field of technological forecasts.

Tendency towards quality

Steel production downstream is, and will be, increasingly



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

drawn towards quality, in view of the persistent demand of users searching for products, that would provide a reduction in weight and corrosion (cars), have the ability to withstand very low temperatures (transportation of hydrocarbons in arctic regions, or transportation of LNG), or very high pressures and temperatures (nuclear chemistry), etc. In addition, this tendency is linked with the willingness of manufacturers to provide cheaper steel products of a given quality such as stainless steels with a lower nickel content (By economising on metals, such as nickel, with a high energy content), which are easier to work, and sheet steel for cans without tin (tin-free steel), silicon-free sheets for electric motors, etc.

So, recent development in the iron and steel industry has shown, under the pressure of higher quality requirements:

- stagnation (or decrease) in ordinary steels,
- but considerable progress in high-grade and special steels.

In Japan the respective indices for the production of these two categories of products have developed as follows*/

	1973	1979
Ordinary steels	100	84.[illegible]
High grade and special steels	100	122.9
Heavy sheet	100	56.4

*/ Source: S. Hosoki and T. Kono - Amsterdam Conference 1979.

More particularly the production of stainless steel has ceased to increase, despite the crisis, since 1973.**/

	1973	1979	Index 1973 =100
	In 1,000 tonnes		
EEC	1,748	2,324	132
Spain	52	156	300
USA	1,714	1,905	111
Japan	2,0[illegible]8	2,289	115

**/ Source : "World Stainless Steel Statistics" Inco 1979. A recent report forecast that the demand for stainless steels would increase up to 1990 at a rate of 8% per year in the developing countries.

This pressure towards higher quality has resulted in research into new steels based on:

- resistance to corrosion (offshore oil constructions),
- uses at very low temperatures (Arctic oil),
- requirements resulting from mass production of engineering products using steels with more stable properties (higher purity).

This development highlights the inadequacy of any evaluation of the iron and steel industry in terms of crude steel, which reflects, decreasingly, the true nature of the evolution of the iron and steel industry. Evaluations in terms of crude steel, which have been useful and suitable for many years, today, tend to mask the possible rapid increases in effective capacity (evaluated in terms of weight as well as in the quality of the finished products).

There is also the risk of masking new differntiations between the iron and steel industries in the industrialized countries and the new ones in the developing countries. This question is directly related to the implementation of the Lima objectives: Would it be, in effect, advantageous to produce 25% or even 30% of crude steel if this production is not directed towards the manufacture of an increasingly wide range of rolled products and high-quality steels, whilst at the same time effecting economies in energy and raw materials? From this point of view the Lima objective needs to be qualified, from the general viewpoint of a new method of evaluating the progress of the iron and steel industry and give preference to calculations in real terms, of final products rather than under a vague terminology of crude steel.

The importance of the Direct Reduction Method

At the beginning of 1980 several indices suggested that the optimistic forecasts relating to the development of direct reduction processes could be questioned. It seemed in fact that direct reduction had run into:

- technical difficulties in commissioning;
- the rapid rise in the price of energy and, in particular, of natural gas, resulting in the closure of the American Oregon Steel plant, the freezing of the British plant at

Hunterston and certain Spanish projects, etc.

In fact these hesitations and withdrawals affected the iron and steel industries of the North much more than those of the Third World countries where, on the contrary, there has been a vigorous revival of the direct reduction process in recent months as is shown by the following examples:

- the launching of the improved HYL III process, more economic in energy consumption, adopted since its introduction in Mexico (SICARTSA), in Argentina (the SIDESUR project) and the improved MIDREX processes which are also more economic in energy;
- the increased interest of the major international iron and steel groups in the direct reduction process: SWINDEL DRESSER, DAVY DRAVO Corp., and KAWASAKI HEAVY INDUSTRIES in the case of the HYL process, and KORF, VOEST ALPINE, KOBE STEEL and MITSUI in the case of NIPPON STEEL MILDREX process.

In this context the following could be listed as highlights of the direct reduction projects:

- Most of the direct reduction projects have been frozen or abandoned in the <u>industrialized countries</u> where only the following projects are still operational:
    - Australia (Hammersley)
    - Bulgaria (Burgas)
    - Canada (Alberta)
    - USST (Koursk)
- Direct reduction projects are multiplying in the <u>developing countries</u> (projects under construction or new projects).

Whilst projects based on direct reduction processes were, until recently, of low unit capacity and integrated into a production of long products (concrete reinforcing bar), a considerable number of new projects are, on the contrary, characterized by:

- their size, which normally exceeds 1.0 million tonnes in Algeria, India, Indonesia, Iran, Iraq, the Libyan Arab Jamahiriya, Nigeria and even more in Mexico (SICARTSA ,HYLSA, SIDERMEX) and Venezuela (SIDOR);

- their integration into complexes which produce both long and flat products in the case of the projects in Iran, the Libyan Arab Jamahiriya, Mexico, Nigeria or Venezuela (SIDOR).

Numerous direct reduction processes are now available, using either natural gas or a solid reducing agent (non-coking coal). In fact, now there is a preponderance of reduction processes using natural gas, in particular the MIDREX processes (which has been the subject of successive improvements) and the HYL process (the dynamism of which has now been renewed by the launching of the new HYL III variant) which represent more than 90% of the direct reduction projects in the developing countries.

It can be seen from this fact that the advance of the direct reduction processes is linked to the availability of hydrocarbons and, in particular, the toxic gases which up to now have remained unused: 90% of the direct reduction projects are in fact located in oil or gas producing countries.

- 100% of the projects in the oil-producing countries of Africa and the Middle East,
- 90% of the projects in the oil-producing countries in Latin America (Argentina, Colombia, Ecuador, Mexico, Venezuela, etc.),
- 66% of the projects in the oil-producing countries of Asia (Indonesia, Malaysia, etc.)

It will be noted that the renewal of interest in oil fields which are deeper and hence more expensive to work will result in the probable discovery of oil resources in many other developing countries, as is the case today in Africa, on the Ivory Coast, in Cameroon, etc.

This opens up new possibilities for the utilization of direct reduction processes in new zones which will in this way have the necessary bases to acquire an iron and steel industry.

In conclusion it should be noted that this paper does not include the description of concrete technological DR processes as well as their significance for the ESCAP developing countries because of a very good presentation of these theme in numerous ESCAP/RCTT papers devoted to the problems mentioned above.

It is noteworthy that UNIDO/ESCAP/RCTT project on the establishment of a regional network for metallurgical research and development institutes has already been included in the working plans of ESCAP for implementation in 1984-86.

The project is aimed at the promotion of co-operative research and development among metallurgical research and development centres in the ESCAP countries to expand their metallurgical industries through selection and adoption of appropriate technologies, dissemination of relevant information, exchange of knowledge and experience.

I do hope that the present workshop will generate other proposals as to both national and regional activities to be undertaken to give further impetus to strengthening existing and establishing new sponge iron enterprises.

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MIDREX CORPORATION

1.0 Introduction

Since 1969, MIDREX Direct Reduction Plants have produced more direct reduced iron (DRI) than any other process. In fact, MIDREX Plants currently produce more than half of the world's supply of DRI.

The success of the MIDREX Direct Reduction Process has added a new dimension to ironmaking and steelmaking in both developed and developing economies. By providing a more energy efficient environmentally attractive and less capital intensive alternative to the traditional methods of ironmaking based on the coke oven and balst furnace. Midrex is taking a key role in modernizing the world's steel industry.

The MIDREX Process, now in its fifth generation of operational design, is the choice of steel makers around the world. Forty-two MIDREX Direct Reduction Modules are either installed or under construction, contract or agreement. Midrex is responsible to the operators of its plants to assure that the latest innovations in process technology are readily available.

This paper presents the latest design features of the MIDREX Process and discusses the method of technology transfer developed by Midrex, which has been instrumental in the successful operation of MIDREX Plants.

2.0 Process Description

2.1 General

The MIDREX Direct Reduction Process converts iron oxides (in pellet or lump ore form) to high purity direct reduced iron.

The major components of a MIDREX Direct Reduction Plant include the shaft furnace, reformer, recuperatory and process gas preheater. These components are supported by ancillary systems for handling iron ore, gas, water and direct reduced iron (See Figure 1).

2.2 Reduction

Reduction is carried out continuously in the shaft furnace. Iron oxide is fed to the top of the shaft furnace, flows downward by gravity and is discharged from the bottom in the form of direct reduced iron. The shaft furnace has two separate gas circuits. In the upper circuit, iron oxide is preheated and reduced by counterflowing reducing gas containing hydrogen and carbon monoxide. In the lower circuit, the reduced product is carburized and cooled by a counterflowing cooling gas.

2.3 Reforming

Reducing gas is generated in the reformer by catalytically reforming a mixture of fresh natural gas and recycled top gas from the shaft furnace. The reformer is a refractory-lined furnace containing alloy tubes filled with catalyst. The gas mixture flows upward through the catalyst bed where it is heated and reformed. The reducing gas leaves the reformer at near equilibrium condition, containing 90 to 92% hydrogen plus carbon monoxide. Therefore, the gas can be used directly in the shaft furnace.

2.4 Heat Recovery

The thermal efficiency of the reformer is greatly enhanced by the recuperator and process gas preheater. These units consist of two shell and tube heat exchangers in the flue gas ducts coming from the reformer. The heat exchangers recover the sensible heat from the reformer flue gas to preheat combustion air (used in the reformer burners) to 675°C and to preheat the process gas (mixture of top gas and natural gas fed to the reformer tubes) to 540°C.

3.0 Process Features

3.1 Simple Design and Operation

One of the most noticeable benefits of the MIDREX Process is that it requires less equipment than other gas-based direct reduction processes. The patented design of stoichiometric top gas reforming eliminates the need for steam generation systems, auxiliary boilers, boiler feedwater treatment systems, reformed gas quenching systems, CO_2 removal systems, reducing gas heaters and, in some cases, natural gas desulfurization systems.

3.2 Low Pressure Operation

The MIDREX Reformer is unique in that it can produce a high quality reducing gas at relatively low pressure without compromising plant energy efficiency or productivity. Operating at low pressure has several advantages. The shaft furnace does not require complex mechanical seals for feeding and discharging material. Therefore, capital and maintenance costs are lower, plant availability is higher, and generation of product fines is minimized. In addition, overall plant safety is improved.

3.3 High Unit Productivity

Productivity at MIDREX Plants has been optimized to very high levels. Midrex has demonstrated that high quality reducing gas, optimum reduction temperature and effective gas distribution in the shaft furnace eliminate the need for high pressure operation to achieve high unit productivity. The reductant to oxidant ratio in the reducing gas of the MIDREX Process is higher than other gas based processes. Thus less reducing gas is required to do the same amount of reduction. Table 1 shows the specific production rates achieved at MIDREX Plants. It should be noted that these are the highest commercial production rates in the industry.

3.4 Low Fuel Consumption

The combination of top gas recycling, stoichiometric reforming and waste heat recovery inherently makes the MIDREX Process the most efficient direct reduction process available. MIDREX Plants have consistently achieved the lowest fuel rate in the direct reduction industry. This is clearly shown in Table II.

3.5 Uniform Reducing Gas Distribution

Unlike other gas-based processes which use a plenum for injecting reducing gas into the shaft furnace, the MIDREX Process uses a series of equally spaced tuyeres around the periphery of the furnace. The tuyeres provide deeper penetration of gases into the bed, better controlled distribution of gases around the periphery of the furnace and help prevent gases from chaneling along pathways of least resistance.

Figure 2 shows isobar readings in a model of the MIDREX Shaft Furnace which indicate uniform gas velocity across the whole cross section. Determination of reducing gas utilization efficiency on a commercial scale, confirms that uniform gas distribution is achieved throughout the scale-up range of the MIDREX Shaft Furnace.

3.6 Uniform Cooling Gas Distribution

Early in the development of the MIDREX Process, it was determined that uniform cooling gas distribution could not be obtained by injecting cooling gas into the shaft furnace along the periphery. This problem was overcome by developing a patented internal cooling gas injection system which has worked exceptionally well. Since that time, other shaft furnace DR processes have followed the Midrex lead and have adopted similar internal injection systems.

3.7 Uniform Solids Flow

It is well established in industry that solid particles flowing through a vertical cylinder in plug flow will have a tendency to bridge. Bridges can be broken by slight movement of one or more particles in the bed (See Figure 3). Once the bridge is broken, the bed flows freely again until another bridge is formed.

Bridging is a problem for most shaft furnaces. However, Midrex has patented a unique burden feeder inside the shaft furnace which has extended "fingers". These fingers rock back and forth to cause a very slight, gentle movement of particles in the bed. This motion is sufficient to eliminate bridging, provide uniform flow and assures that fines generation within the shaft furnace is minimized.

3.8 Uniformly High Metallization

Uniform distribution of high quality reducing gas in the MIDREX Shaft Furnace has resulted in very uniform product metallization even when ore supplies change. For example, the MIDREX Plant owned by Dalmine in Argentina maintained metallization at 93.5 per cent over a one month period with a standard deviation of only 0.57 per cent. This was accomplished while processing a blend of three different ores (one pellet and two lump ores) in six different combinations.

Metallization is adjustable up to 95 per cent. Table III shows the range of metallization levels maintained at MIDREX Plants along with the corresponding standard deviation in daily values over a one year period. Most of these plants operate on several different iron oxides each year and blend oxides to optimize overall economies.

3.9 Uniform Carbon Content

Average carbon content in product from various MIDREX Plants is shown in Table IV. The standard deviation corresponds to daily values over a one year period. The values indicate that carbon can be readily adjusted and maintained within tight limits. Typically, 90 to 96 per cent of carbon in MIDREX Iron is in the form of iron carbide.

3.10 Independent Control of Metallization and Carbon

The high quality reducing gas in the MIDREX Process allows metallization to be completed in the reduction zone. The cooling zone is used only for adjusting carbon content and cooling the product. Thus, independent control of metallization and carbon is easy to achieve.

In processes with low quality reducing gas, only part of the metallization is achieved in the reduction zone. The remaining reduction must take place in the cooling zone, which inherently must occur at lower temperatures. This is somewhat self-defeating since the reduction rate slows significantly as temperature drops and it is virtually impossible to achieve optimum metallization levels for steelmaking grade DRI. The fact that final metallization and carburization take place at the same time allows a little or no independent control.

3.11 High Product Yield

Total iron unit recovery at MIDREX Plants has increased in recent years. Instead of stockpiling oxide fines, plants such as Georgetown Steel, Hamburger Stahlwerke, Sidbec and ACINDAR feed sized oxide fines (3mm to 6mm) directly into the process in amounts up to 10 per cent without affecting productivity. Georgetown Steel also briquettes the minus 3mm oxide fines and feeds them into the process in amounts up to 10 per cent. Thus, at Georgetown Steel, total use is made of all oxide materials.

Metallized fines are normally recovered by cold briquetting at MIDREX Plants; however, technology for injecting fines directly into the electric arc furnace is also being used. Figures 4 and 5 show the material balances for typical 100 per cent pellet operation and 100 per cent lump ore operation. Metallized fines briquetting represents approximately 4 per cent of total production with 100 per cent pellets and 14 per cent of production with 100 per cent lump ore.

Carefully documented tests have shown that less than 0.2% product fines (-4.76mm) are generated in the shaft furnace while operating with high quality pellet feed.

3.12 Raw Material Flexibility

MIDREX Plants have successfully processed more than 35 different types of oxide pellets and lump ores (See Tables V and VI) including 100 per cent lump ore, 100 per cent pellets and any mixture of the two. The MIDREX Alternate Flowsheet (Shown in Figure 6) allows use of high sulfur ores, thus permitting a choice from a wider range of oxide materials.

Optimum pellet/lump ore ratios have been established, which enable high temperature furnace operation, resulting in high productivity. Typical feed blends used in MIDREX Plants are shown in Table VII.

3.13 Alternate Fuel Compatability

The MIDREX Process is compatible with most major coal gasification processes such as Lurgi-Totzek, Winkler and Texaco. The process is also compatible with coke-oven gas utilization. Details on these technologies have been published previously.

3.14 Capability of Hot Discharge/Hot Briquetting

Since metallization is completed in the reduction zone in the MIDREX Process, it is possible to modify the cooling zone and integrate a hot discharge/hot briquetting system into the process.

3.15 Low Water Consumption

In the MIDREX Process, water is used for direct and indirect cooling of gases and equipment. Water consumption for a typical plant is approximately 1.5m^3/tonne of DRI. However, in arid regions, such as Qatar, sea water heat exchangers have been utilized to lower water consumption to less than 0.2m^3/tonne of DRI.

3.16 Unit Capacities Exceeding 1 Million TPY

The MIDREX Process is now available in modular capacities from less than 400,000 tpy to over 1 million tpy. Multi-modular plants can be built to meet any desired capacity.

4.0 Technology Transfer

4.1 Overview

The successful operation of a direct reduction plant is equally dependent upon good equipment and well trained operators. Therefore, Midrex places great emphasis on both the areas. In addition to designing equipment that will operate reliably and efficiently, Midrex provides an effective "technology transfer" programme.

Midrex licenses its technology to construction and process licensees. The construction licensees are those companies with responsibility for marketing, selling and constructing MIDREX Plants in specific areas of the world. These companies are: Korf Engineering GmbH of Duesseldorf, West Germany; Lurgi Chemie and Huettentechnik of Frankfurt, West Germany; and VOEST-ALPINE AG of Linz, Austria.

The process licensees are those companies which operate MIDREX Plants. Each company purchasing a MIDREX Plant signs a Process License Agreement directly with Midrex.

4.2 Midrex Construction Licensing

Through the construction licensing program, Midrex maintains close collaboration with all its construction licenees and provides technical assistance and know-how so that each construction licensee can carry out its commitments on the design and commissioning of MIDREX Plants in its respective territory. The experienced and capable engineers of each construction licensee have undergone extensive training programmes at Midrex facilities to make them experts in the design of components comprising the MIDREX Direct Reduction Process. Through the Midrex Construction Licensing Department, each construction licensee is continually informed about all design, engineering and process improvements. In addition, Midrex technical personnel are made available to provide any required technical assistance.

The effectiveness of the construction licensing programme is best demonstrated by the performance achieved in executing projects. Midrex and its construction licensees have an excellent record within the industry of commissioning plants on schedule and meeting all performance commitments. The same excellent performance, in terms of contract execution and plant start-ups, has been evident whether the MIDREX Plant was constructed by Midrex or a construction licensee. Table VIII lists MIDREX Plants and indicates whether the plant was provided by Midrex or a construction licensee, and whether the project was provided was provided on a turnkey or equipment and services basis.

4.3 Midrex Process Licensing

Through the process licensing programme, Midrex provides its licensees exchange of process improvements, operational information on other MIDREX Plants, periodic seminars, plant audits, computerized operating data compilation, raw material testing, spare part supply, operating assistance, engineering support, consulting on various aspects of MIDREX Plant operation, maintenance management, direct reduced iron marketing and market development and any additional personnel training.

Transfer of technology for Midrex does not stop with plant commissioning. Midrex technical representatives visit operating plants on a periodic basis to provide assistance, and, on request, perform operational audits. Daily performance data collected from individual plants is computerized by Midrex and compiled into monthly and annual production reports that are distributed to all operating plants.

Midrex promotes the exchange of data and operating experiences by conducting annual plant operating seminars. Midrex provides follow-up engineering and in-plant services, to operating plants, for projects involving repair and maintenance, modification, or capacity expansion. In addition, Midrex has the capability of providing worldwide spare part supply. Thus, process licensees are assured that any request for assistance or information is addressed in a timely and direct manner.

An additional function of the process licensing programme is the sharing of future technological improvements among Midrex licensees. Each Midrex process licensee has access to new MIDREX Direct Reduction Technology, even after its plant has been constructed. As a result, Midrex process licensees have the ability to upgrade their plants to the latest technological status.

4.4 Midrex Training

The general Midrex philosophy on training is to tailor programmes to help plant personnel meet the specific operational and production goals set by the process licensee. The simplicity of operation of a MIDREX Plant, combined with effective training of plant personnel, allows the plant operator to rapidly and consistently maximize operating efficiency of the facility.

The specific training programmes required are dependent on the background of the process licensee's plant personnel, the level of their previous exposure to industrial environments and the management objectives set by the process licensee. Midrex training programmes place heavy emphasis on "hands-on" experience as the best means of learning. A typical programme for Midrex plant operating and maintenance personnel is as follows:

- Management orientation

  This four-week orientation programme is designed to expose key administrative, engineering, operating and maintenance managers to the general aspects of MIDREX Direct Reduction Technology and operation of MIDREX Plants. Normally, this programme is conducted shortly after contract signing, so that the process licensee's personnel can quickly integrate into the design, engineering and construction phase of the direct reduction facility.

- Management training

  This programme is tailored to meet the particular process licensee's needs relative to training of specific management personnel in areas such as administration, operations, maintenance, engineering, etc. This programme includes theoretical and class-room instruction, as well as exposure and integration of the management trainees into the organization of an actual operating plant.

- Operations Training (Phase I - Classroom Training)

  This programme consists of six weeks of theoretical instruction on MIDREX Direct Reduction Technology, the operation of MIDREX Plants, the description of equipment and sub-systems comprising MIDREX Plants as well as exposure to the ultimate uses for DRI.

- Operations Training (Phase II - Hands-On Plant Training)

  This ten-week programme is conducted at an operating MIDREX Plant whereby the process licensee trainees will participate in actual plant operation under the guidance of Midrex and/or construction licensee experts, as well as the operating personnel of the particular MIDREX Plant. During this programme, the trainees will be assigned to counterparts of their particular discipline in the operating plant and will work closely in the actual operation of the facility.

- Operations Training (Phase III - Hands-On Participation During Commissioning and Start-Up)

  This twelve to sixteen-week programme is conducted on site at the process licensee's facility and normally occurs during the final stages of erection and commissioning of the direct reduction plant. The process licensee's personnel work closely with Midrex and/or construction licensee personnel to obtain a thorough understanding of their particular plant design and equipment. This allows them to rapidly take over complete operation of the plant after commissioning.

4.5 Results of Effective Technology Transfer

As a result of good plant design and effective technology transfer, MIDREX Plants have consistently achieved the fastest start-ups and shortest learning curves in the direct reduction industry with plants rapidly reaching full capacity at desired product quality level.

For example, the MIDREX Plant owned by QASCO in Qatar reached continuous hourly production at design capacity and product quality within ten hours after initial start-up. Performance tests were completed 13 days after start-up. The plant operated at 93 per cent availability and produced MIDREX Iron at an average rate of 60 tonnes per hour. Metallization was 94 per cent and carbon content averaged 1.26 per cent.

The MIDREX Plant was turned over to the QASCO personnel three weeks after start-up. Production easily met steelmill demand for MIDREX Iron in the first calendar year of operation, reaching 322,366 tonnes. As the steelmill demand for MIDREX Iron increased, the plant produced 420,179 tonnes in the following year, five per cent above rated capacity and 458,735 tonnes in the next year, fifteen per cent above rated capacity.

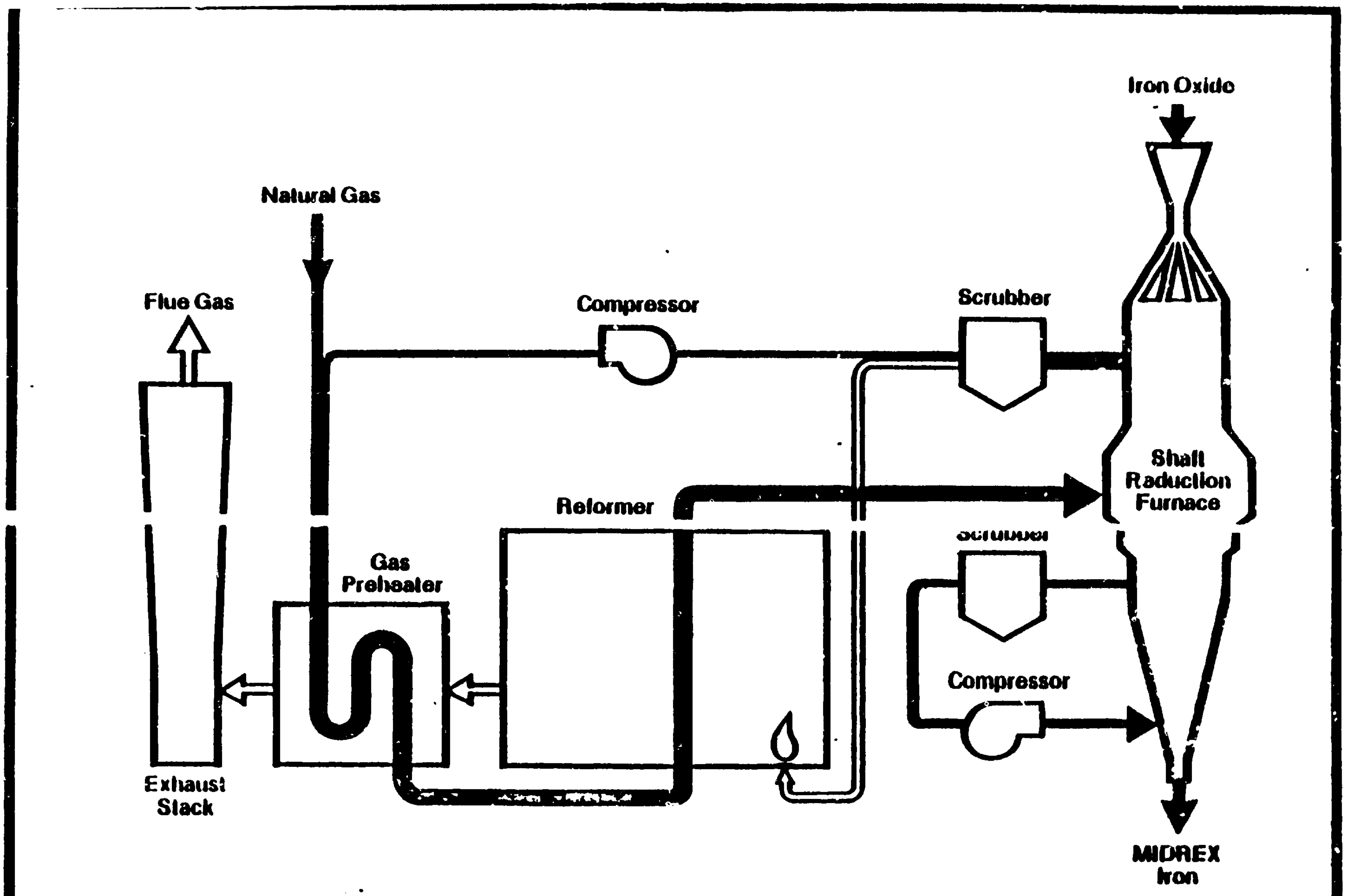
The MIDREX Plant owned by ACINDAR in Argentina reached full capacity one day after initial start-up. In its first calendar year of operation, the plant produced 558,227 tonnes of MIDREX Iron. This was 33 per cent above the nominal capacity of the plant, which was 420,000 tonnes per year. The learning curve in Figure 7 shows the rapid increase in production achieved without the use of expatriate labour.

Similar fast start-ups and short operator learning curves have been achieved at the most recent MIDREX Plants to start-up in Venezuela, Trinidad, West Germany and Nigeria. Table II shows the recent performance of MIDREX Plants under steady state operating conditions compared to the original plant-rated performance. Note that in all cases the original plant ratings have been surpassed.

5.0 Conclusion

The proven experience of MIDREX Technology is well documented and observable at plants located throughout the world. All the equipment utilized in the MIDREX Process has been demonstrated to be reliable and efficient.

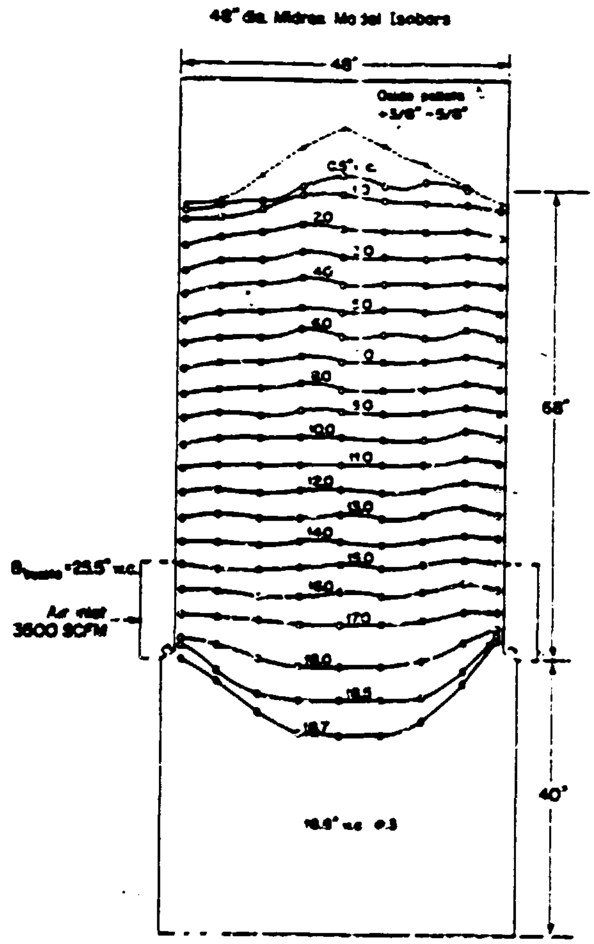
The success of the MIDREX Process can be attributed to good plant design and effective technology transfer. Midrex places strong emphasis on both these areas and maintains an on-going inter-relationship with all MIDREX Plant operators. This inter-relationship has helped rapidly implement new technology improvements in all MIDREX Plants. As a result, MIDREX Plant operators can be assured that they have access to the most advanced technology available in the industry.



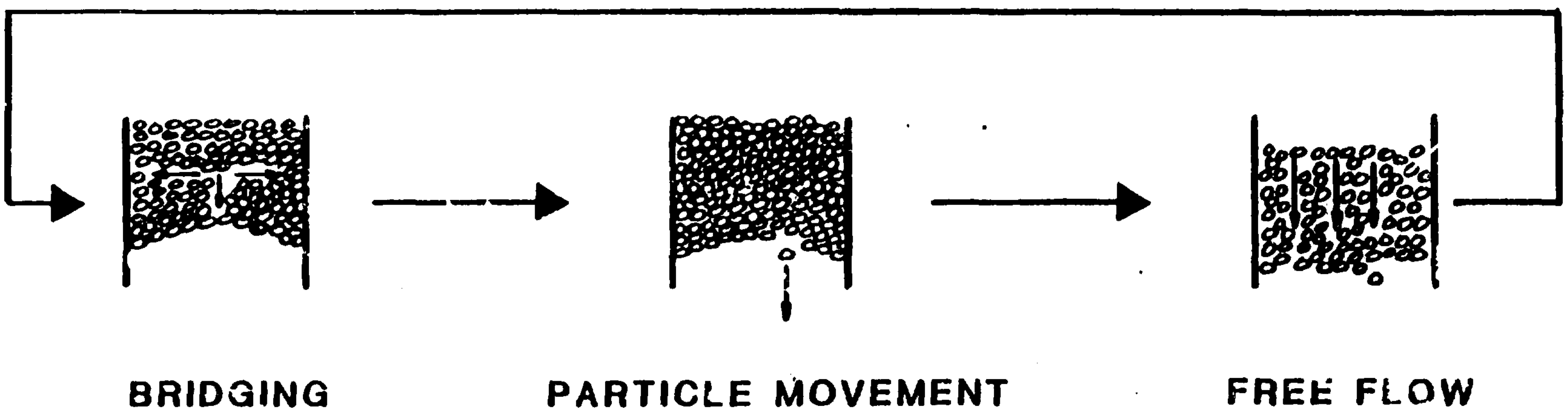
MIDREX

MIDREX Direct Reduction Process
Standard Flowsheet

FIGURE 1



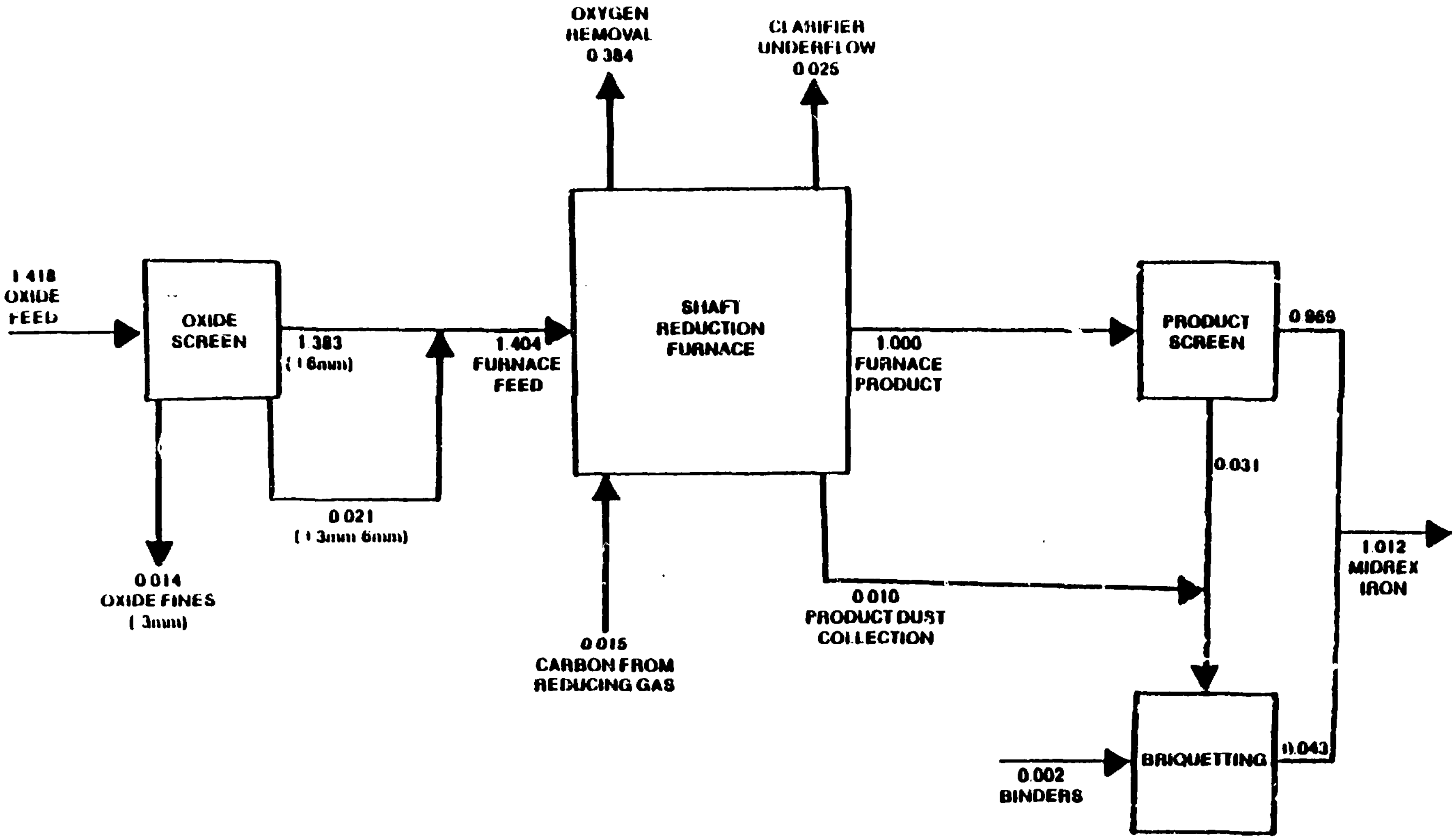
MIDREX	Isobar Readings in a Model of a MIDREX Shaft Furnace	Figure 2



MIDREX

Plug Flow of Solids in a Shaft Furnace

Figure 3

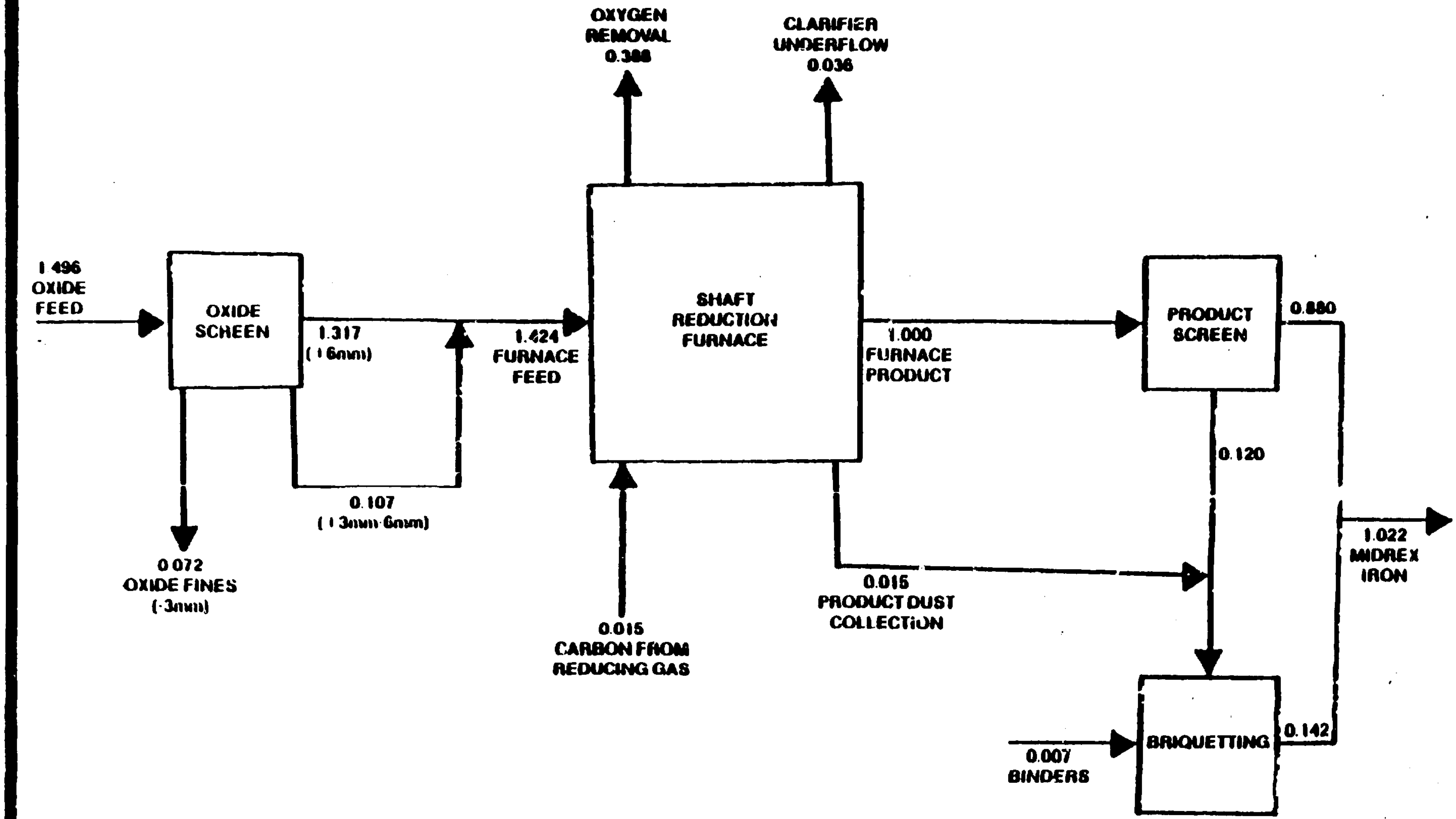


MIDREX

Typical Material Balance For 100 Percent Pellet Operation

FIGURE 4

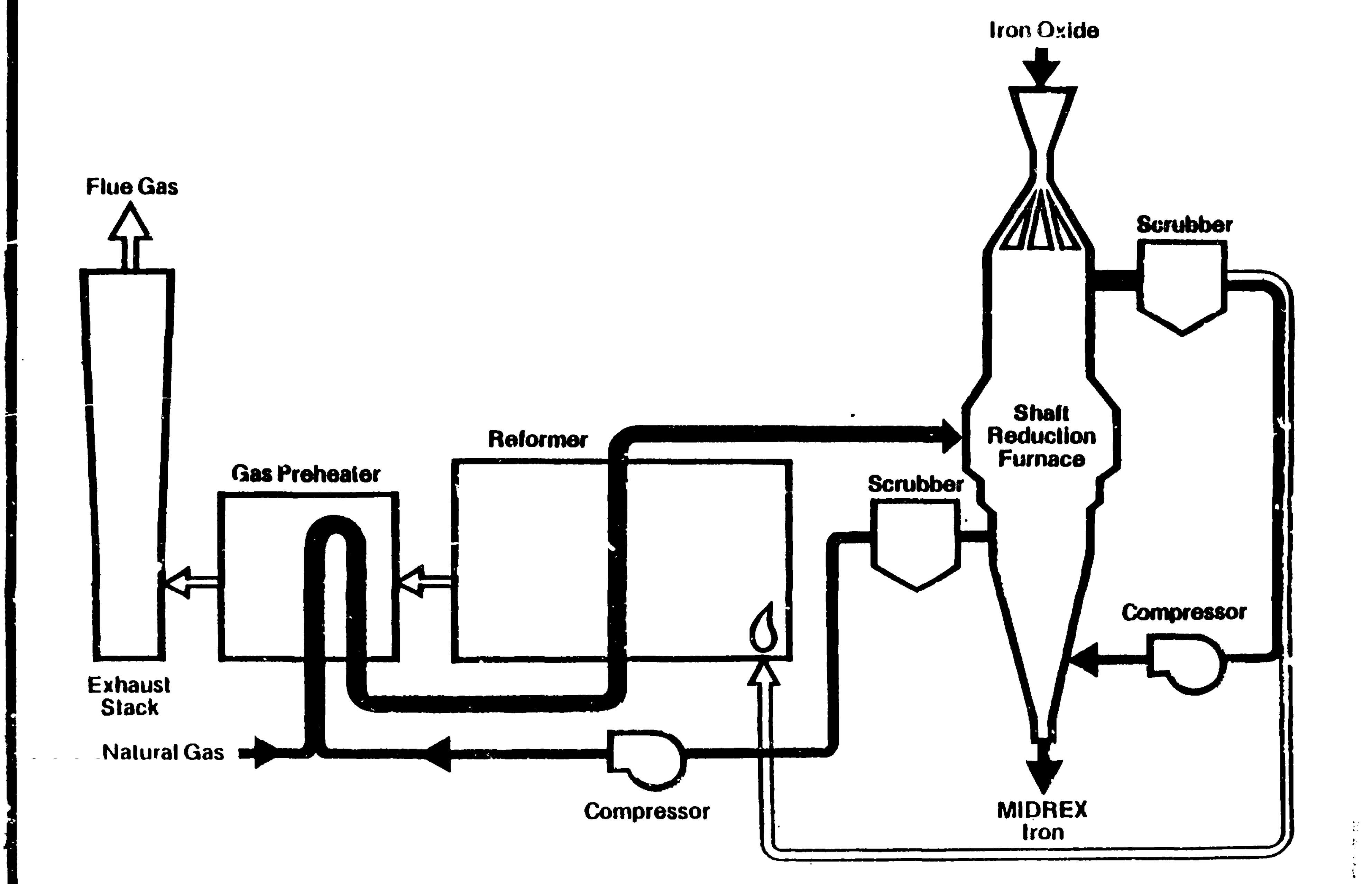
- 118 -



MIDREX

Typical Material Balance For 100 Percent Lump Operation

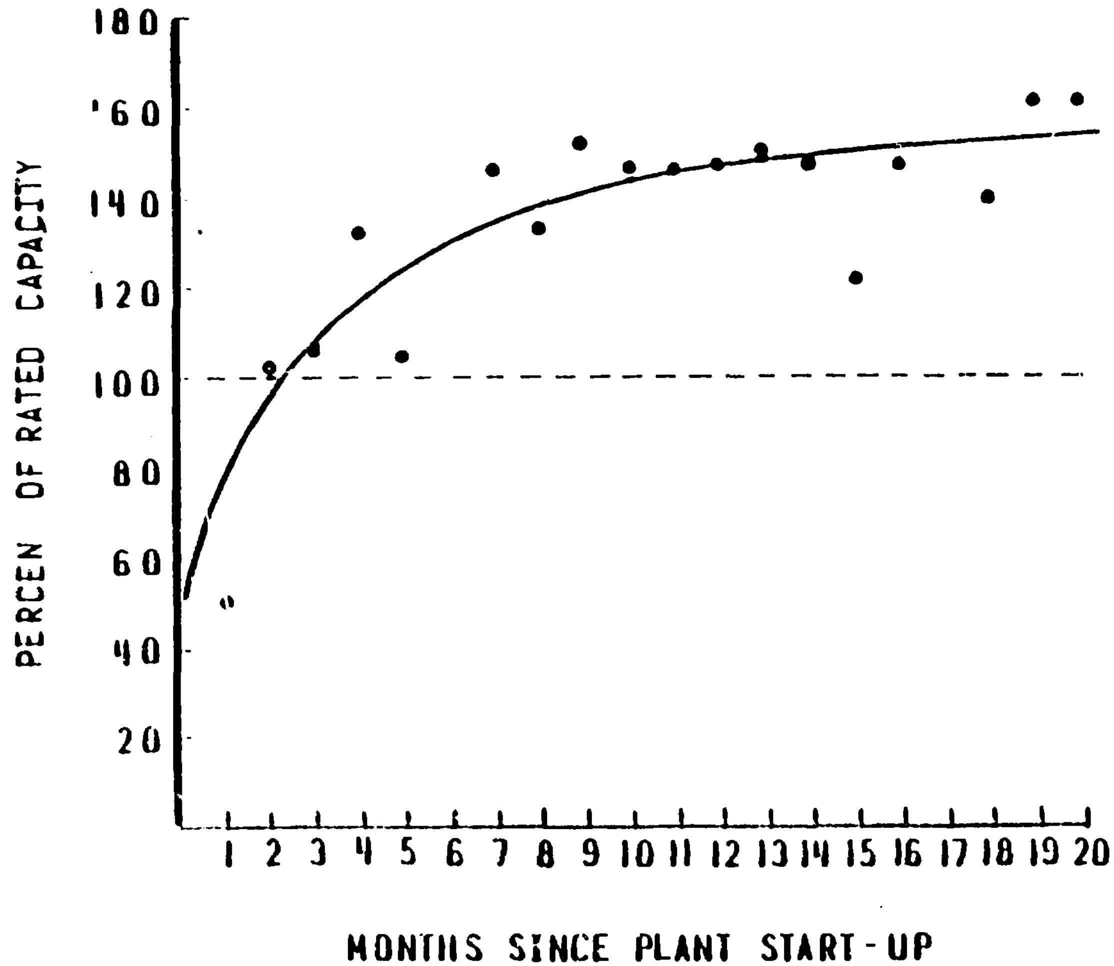
Figure 5



MIDREX

MIDREX Direct Reduction Process
Alternate Flowsheet

Figure 6



MIDREX	ACINDAR D.R. PLANT OPERATION	FIGURE 7

PLANT	t/m²d *	t/m³d **
GSC	91	11
HSW	99	12
SIDBEC I	87	11
SIDBEC II	106	11
DALMINE	81	10
SIDOR I	80	9
SIDOR II	82	9
QASCO	82	9
ACINDAR	84	9
ISCOTT	80	9

*M^2 = CROSS SECTIONAL AREA OF SHAFT FURNACE
**M^3 = VOLUME OF REDUCTION ZONE

MIDREX

Table I: Specific Production Rates Achieved By MIDREX Plants

PLANT	PRODUCTION (TPH) Rated	Actual	FUEL RATE (net Gcal/t)	ELECTRICAL POWER (kWh/t)
GSC	52	71	2.37	106
HSW	52	77	2.38	119
SIDBEC I	52	71	2.36	94
SIDBEC II	85	105	2.51	113
DALMINE	45	63	2.84	117
SIDOR I	49	65	2.56	88
SIDOR II A,B,C*	55	65	2.57	124
QASCO	53	69	2.52	111
ACINDAR	58	83	2.46	108
ISCOTT	58	65	2.61	121
NORDFERRO**	57	66	2.40	120

*AVERAGE OF 3 UNITS
**AVERAGE OF 2 UNITS

MIDREX

Operating Performance Achieved at MIDREX Plants

TABLE II

Plant	Average Metallization*	Standard Deviation
	(%)	(%)
GSC	93.3	1.0
HSW	93.4	1.9
SIDBEC	92.2	1.4
DALMINE	93.1	1.1
SIDOR	88.7**	2.8
QASCO	93.9	1.3
ACINDAR	91.5	1.1
NORDFERRO	94.3	1.0

*Mercuric Chloride Method
**Client's Requirement

MIDREX

Table 11: Metallization Levels for MIDREX Iron

Plant	Average Carbon	Standard Deviation
	(%)	(%)
GSC	1.4	0.3
HSW	2.1	0.5
SIDBEC	1.6	0.2
DALMINE	1.9	0.2
SIDOR	2.6	0.4
QASCO	1.9	0.4
ACINDAR	1.9	0.5
NORDFERRO	1.5	0.2

MIDREX

Table IV: Carbon Levels For MIDREX Iron

ORE SOURCE	COUNTRY
Carol Lake	Canada
CVRD	Brazil
Fire Lake	Canada
Hierro Peru	Peru
Hilton	Canada
Knob Lake	Canada
LKAB	Sweden
Portland	United States
Oskol	Russia
Samarco	Brazil
Sidor	Venezuela
Sydvaranger	Norway
Wabush	Canada

MIDREX

Table V : Oxide Pellet Sources Used Commercially In MIDREX Plants

ORE SOURCE	COUNTRY
Aguas Claras	Brazil
Alegria	Brazil
Brumadinho	Brazil
Caue	Brazil
Cerro Bolivar	Venezuela
Conceicao	Brazil
Corumba	Brazil
CVRD	Brazil
El Pao	Venezuela
Esperanca	Brazil
Feijao	Brazil
Ferteco	Brazil
Hamersley	Australia
Jangada	Brazil
Mount Newman	Australia
Mutuca	Brazil
Norore	South Africa
Pao Branco	Venezuela
Pico	Brazil
Postmasburg	South Africa
San Isidro	Venezuela
Sischen	South Africa
Tamandua	Brazil

MIDREX

Table VI: Lump Ore Sources Used Commercially In MIDREX Plants

Plant	% Pellets	% Lump Ore
GSC*	55	30
HSW	70	30
SIDBEC	85	15
DALMINE	40	60
SIDOR	100	0
QASCO	100	0
ACINDAR	70	30
ISCOTT	70	30
NORDFERRO	70	30

*GSC – feeds 5% sized oxide fines plus 10% oxide briquettes

MIDREX

Table VII: Typical Feed Blends Used in MIDREX Plants

TABLE 8

MIDREX® DIRECT REDUCTION PLANTS INSTALLED OR UNDER CONSTRUCTION, CONTRACT OR AGREEMENT

MIDREX

Customer	Location	Series No.*	No. of Units	Type of Work	Start-up Date
	NORTH AMERICA				
Gilmore Steel	Portland, Oregon, U.S.A.	100	2	1	1969
Georgetown Steel	Georgetown, South Carolina USA	400	1	1	1971
Sidbec-Dosco I	Contrecoeur, Quebec, Canada	400	1	1	1973
Sidbec-Dosco II	Contrecoeur, Quebec, Canada	600	1	2	1977
	LATIN AMERICA				
Dalmine Siderca	Campana, Argentina	400	1	2	1976
SIDOR I	Matanzas, Venezuela	400	1	1	1977
ACINDAR	Villa Constitucion, Argentina	400	1	2	1978
SIDOR II	Matanzas, Venezuela	400	3	1	1979
ISCOTT I	Point Lisas, Trinidad & Tobago	400	1	2	1980
ISCOTT II	Point Lisas, Trinidad & Tobago	400	1	2	1982
ECUASIDER	Machala, Ecuador	400	1	2	1987
	EUROPE/ASIA				
HSW	Hamburg, West Germany	400	1	1	1971
British Steel	Hunterston, Scotland	400	2	1	1979**
Nordferro	Emden, West Germany	400	2	1	1981
O.E.M.K. I	Kursk, U.S.S.R.	400	4	2	1983
O.E.M.K. II	Kursk, U.S.S.R.	400	8	2	1987
Sabah Gas Industries	Labuan Island, Malaysia	600	1	1	1984
	MIDDLE EAST/AFRICA				
QASCO	Umm Said, Qatar	400	1	2	1978
NISCO	Ahwaz, Iran	400	3	2	1984
Delta Steel	Warri, Nigeria	600	2	1	1982
HADEED	Jubail, Saudi Arabia	400	2	1	1982
Iron & Steel Projects	Misurata, Libya	600	2	1	1984

Type of Work: 1=Turnkey 2=Equipment & Services

Series number indicates the base case annual capacity in thousands of metric tons. Projected annual capacity may vary above or below the base case, due to such factors as raw material mix, process equipment variation or local conditions. The installed capacity for the 42 units listed equals approximately 17,650,000 tpy.

* Plant accepted but not started due to British Steel market and financial situation.

ev. 14 6/82

P.T. KRAKATAU STEEL

1. Introduction :

Indonesia is one of the countries that have adopted the HYL Direct Reduction process to meet its raw material requirement for steel production as billet plant raw material.

The installed capacity of each of the two D.R. Plants is one million ton total iron (Fe) annually; one is plant is on stream and the other, will be commissioned soon.

Each plant consists of two modules with common facilities like material handling, pumps and turbines, cooling towers, etc. for each module. As there are no iron ore resources in Indonesia the raw material is imported from countries like Sweden and Brazil.

II. The Integrated Steel Plant and Facilities :

P.T. Krakatau Steel, an Indonesian Government owned steel company, is located on the Sunda Strait approximately 120 km west of Jakarta. This integrated steel plant after the completion of expanded phase I consists of :

	Production Unit	Capacity, thousand tons/year
1.	Direct Reduction Plant	2,000 ton Fe *
2.	Billet Plant	540
3.	Bar Mill	150
4.	Section Mill	85
5.	Wire Rod Mill	220

* As already mentioned the second DR plant is yet to be commissioned.

Infrastructure Facilities

	Facility	Capacity
1.	Steam Power Plant	400 MW
2.	Harbour	Max ship of 50,000 Dwt.

3.	Belt Conveyor incoming	Max. 1,500 ton/hour
4.	Water Supply out going	Max. 2,000 ton/hour 2.000 lts/sec

Spiral weld steel pipe plant has been floated as a joint venture of the Krakatau Steel, Konnkliyke Nederlandsche Hoogovens en Staal fabrichen NV, Netherlands, and the International Pipe Industries Corporation of Pasig, Philippines.

III. The D.R. Plant of PT Krakatau Steel

The iron ore pellets, unloaded from the ship by two ship unloaders of total capacity of 1,500 tons per hour, are conveyed to the DR Plant and stored in the pellet stockyard by using a boom stacker. There are two iron ore pellet stockyards with a capacity of more than 150.000 tons each.

From the stockyard. the iron ore pellets are transported to the reactors by a series of equipment, starting with a bucket wheel reclaimer, conveyors, hopper with weigh scale bin, vibration screen and sampler, reactor hopper with weight scale bin, conveyor, reactor travelling - tripper, and otary chute.

There are three sponge iron storage buildings : storage no.1 has a capacity of 12.500 tons for he billet steel plants, storage no. 2 with a capacity of 25.000 tons for the future slab steel plant, and the storage for export with a capacity of 120.000 tons.

The sponge iron from the reactor, is collected on a conveyor below the reactors, passed through a series of equipment which consists of cluster breaker, magnetic separator, primary heat sensor, secondary heat sensor, conveyor, travelling tripper and distributed into the compartment o storage nos. 1 or 2.

There is also a direct conveyor from the storage building no. 1 to feed electric arc furnaces of the Billet Steel Plant.

The purpose of the primary and secondary heat sensors is to divert any hot material from going directly to storage buildings.

Hot material will be cooled down on the patio and or in the cooling building first.

From the export storage, sponge iron is transported to the harbour by outgoing conveyor consisting of rotary feed charge. conveyors, surge bin, screening station, sampler, control tower and ship loader. As is well known, every direct reduction plant consists of two main sections : the reformer area and the reactor area.

In the reformer section, the natural gas and the superheated steam are introduced to the mixing point and passed through the mix, preheater in the convection section of the reformer before entering the nickel catalyst tubes in the radiant section of the reformer.

The reformed gas is then introduced through a series of reactors as a cooling and caburizing medium, reducing agent and at the end the spent fas is used as fuel as shown in figure no. 1.

For each module of the HYL DR plant, there are four reactors each in the stages of loading or unloading, cooling, primary reduction and secondary reduction.

When the reduction is complete, the sponge iron is cooled down in the cooling stage. In the event where one reactor is loaded or unloaded that reactor itself is isolated from the other three rectors.

The train of each reactor consists of gas preheater where the process gas is preheated in order to attain the required temperature for the optional yield of reduction, the reactor itself and the direct contact coolers where the water produced by reduction is removed in order to regenerate the reducing potential of the gas.

The operation of both the modules is monitored and controlled in one single control room.

Also there is a jumper line in order to make the plant flexible and run the reformer no. 1 with reactors of module 2 or vice versa when required for major repairs.

The sponge iron produced by PT. Krakatau Steel is used for internal consumption (Billet Plant) and some quantity is marketed inside and outside Indonesia.

The ratio between sponge iron and scrap used in the electric arc furnace depends on the quality of steel to be produced,melting facilities available, consumption of energy and consumables and other economic considerations such as scrap price and availability, etc.

Due to non-availability of quality scrap in Indonesia and since the billet plant has a continuous feeding system to the E.A.F., PT. Krakatau Steel uses 85% sponge iron and 15% scrap.

Most of th PTKS clients make normal carbon steel and special steel from 30% / 40% sponge iron and 70% / 60% scrap.

Since the first trial export shipment on September 16, 1979, and until October 1981 about 150,000 tons of sponge iron was exported to various countries in Asia, e.g. Taiwan, Japan, South and North Korea, India and Singapore.

IRON ORE SUITABILITY FOR P. T. K. S. DIRECT REDUCTION PLANT

In general terms the characteristics of iron ore pellet required for D.R. Plant are :

- High Fe content (65%)
- Low gangue content
- Basic type of pellet
- Low residual elements (Cu, Sn, As, P, S)
- High reducibility
- High porosity
- No agglomeration of sticking tendency during reduction
- High compressive strength
- Size between ½" 5/8"

Since the iron ore pellet characteristics and specifications for D.R. feed are different from blast furnace pellet, the pellet producers have had to develop a special method in the laboratory to test pellet suitability for each kind of D. R. Process.

The characteristics of the pellet to be observed during laboratory tests are :

- Sticking tendency
- Swelling during reduction
- Compressive strength
- Reducibility

Some companies like CVRD and LKAB have established their own special test methods e.g. for pellet used in HYL and Midrex D.R. Processes.

Although such kinds of tests give good results, due to difficulties to duplicate the actual operating conditions in the plant, it appears from PTKS experience that for a new type of pellet or raw pellet sources, the commercial test should be conducted in the plant itself. So far, PTKS has conducted several commercial tests on new types/sources of pellet.

The commercial test is divided into three steps.

1. Basket test
2. Mixed Reduction test
3. Full load with 100% new type of pellet and optimization.

1. <u>Basket Test</u>

The purpose of basket test is to determine whether the pellet could be reduced at the actual operating condition and whether it would give good metallization or not.

The test is done at four or five levels of the reactor each level having five baskets of new pellet. The performance of these is compared with reference pellets. Each basket contains about 5 kg of pellet.

The pellet that is used as reference/standard should yield metallization of 90% at the normal operating-condition.

As the temperature profile across the reactor declines from the top to the bottom of the reactor, and since the temperature itself is a function of time during the process, the percentage of metallization and percent of content obtained from each level will be different.

Some pellets like the standard pellet are not affected much, at higher and lower reduction temperatures.

The temperature difference between top and bottom varies at least 280°C from time to time during the reduction cycle.

Table I gives some idea of the differences in metallization on each level of the reactor.

TABLE I

Level of reactor	Type of Pellet	% Fe tot	% Fe met	% Metz	% C
First level	x	87,67	79,51	90,68	1,79
idem	s_1	86.38	72.12	83,49	1,86
Second level	x	87,39	80,11	91,67	1,85
idem	s_1	87,41	74,88	85,67	1,98
Third level	x	89,55	84,75	94,64	2,35
idem	s_1	90,22	82,57	91,52	2,18
Fourth level	x	88,62	82,13	92,68	2,87
idem	s_1	89,65	81,84	91,88	2,79
Full load, reduction no.11914.	s_1	88,68	79,37	89,50	2,16

Level of reactor	Type of Pellet	% Fe tot	% Fe met	% metz	% C
First level	y	81,60	41,80	51,60	1,67
idem	s_2	87,86	71,45	81,32	1,40
Second level	y	84,02	53,05	63,15	1,69
idem	s_2	88,43	71,84	81,24	1,63
Third level	y	88,41	71,82	81,23	1,83
idem	s_2	90,95	86,89	95,55	1,96
Fourth level	y	90,95	86,89	95,55	2,42
idem	s_2	92,29	90,34	97,89	2,56
Full load Red. no. 16170	s_2	89,05	81,43	91,44	1,69

Note : S_1 and S_2 were chosen as reference/standard pellet
X, Y type of pellet being tested.

From the above table we can conclude that :

- pellet x has good uniformity of reducibility at the top and bottom reactor, and high reducibility.

- pellet y has large difference in reducibility at top and bottom of the reactor.
- both standard pellet s_1 and s_2 have good uniformity of reducibility at the top and bottom of the reactor and high reducibility.
- the average metallization from the top down to the bottom of the reactor for standard pellets s_1 and s_2 in comparison with full load reduction is quite close.

2. Mixed reduction tests :

The tests are carried out with pellets to be tested at four locations. Three locations, ottom, middle and top will constitute 1/3 of the total reactor load. The remaining 2/3 of the total reactor load consists of 50% of standard pellets and 50% pellets under test.

The purpose of these tests is :

- To find out at which part or level of the reactor sticking and aglomeration tendency exists.
- To confirm on full scale the results of the basket test.

The results of Mixed Reduction tests for both types of pellet to be tested and standard pellet are tabulated below.

TABLE II

x type of pellet & standard pellet (s_1) level of reactor	% Fe tot	% Fe met	% Met	% C
1/3 pellet x at the bottom	92,30	82,49	89,37	1,9
1/3 pellet x at the middle	91,82	82,81	90,79	2,12
1/3 pellet x at the top	91,63	81,70	89,16	2,12
Completery mix 50% of standard pellet (s_1) & 50% pellet X	88,18	82,45	93,50	2,35

y type of pellet & Standard pellet (s_2) level of reactor	% Fe tot	% Fe met	% Metz	% C
1/3 pellet y at the bottom	86,55	68,57	79,02	2,72
1/3 pellet y at the middle	88,53	74,86	84,56	2,17
1/3 pellet y at the top	90,18	81,50	90,37	2,22
Complotely mix. 50% of standard pellet (s_2) & 50% pellet y.	86,14	72,83	84,45	2,22

Conclusion of mixed reduction tests :

a. As already expected from the basket test pellet x would give good results of metallisation at all parts of the reactor and pellet y would give poor results at the lower part of the reactor and good results at the higher part of the reactor.

b. It is advised not to mix pellet y completely with other standard pellets; in other words, pellet y must be kept separate from other types of pellets in the stock yard, in order to put pellet y always at the top of the reactor where high metallisation is expected to take place.

5. Full load test & Optimisation .

The results of basket tests and mixed reduction tests would lead the operations personnel to conduct 100% full load tests of the new type of pellet.

Any operational difficulties during mixed reduction tests such as sticking and agglomeration channelling of gas flow inside the reactor, high dust and fines generation of sponge iron during reactor discharge, high percentage of hot diverted product, etc, must be taken into consideration to continue or discontinue making 100%/full load test.

The results of 100% full load test to both types of pellet (x & y type) confirm the results from basket and mix reduction tests. At least 4 consecutive discharges have to be waited before optimization steps are commenced.

During optimization, some of the operating variables such as the flow rate of reformed gas, reactor cycle time, reduction temperature, etc., are changed.

To make an economic evaluation of commercial tests for the new type of pellet, some date have to be collected after optimum conditions are found.

The most important data are :

- Percentage of pellet fines collected before entering the reactor.
- Percentage of sponge iron fines after reactor discharge.
- Total net gas consumption per ton Fe at 90% metallization.
- Percentage of hot diverted material
- Frequency of using kelly tools at reactor discharge.

The quantity required for commercial test :

The minimum amount of iron ore required for each step of commercial testing is :

- Basket test : 0,250 ton
- Mixed reduction test : 1,200 ton
- Full load & optimization : 4,800 ton
- Approximately 4 - 5% of the quantity above has to be added for iron ore pellet fines.

References :

1. PT. Krakatau Steel Bulletin/Catalog 1977 & 1979

2. HYL Engineering, May 1980, "Recommended characteristics of iron ore pellets for use in the HYL Direct Reduction Process".

3. Goran Mathisson "LKAB DR Pellets Research and Development", DR pellet Symposium Sept. 16 - 20, 1979 Kiruna - Malmberget, Sweden

TYPICAL PT. KRAKATAU STEEL SPONGE IRON SPECIFICATIONS

CHEMICAL	TYPICAL
Metallization	90,02 %
Total Fe	91,50 %
SiO_2	1,59 %
Al_2O_3	0,57 %
Mno	0,066 %
P	0,017 %
CaO	0,212 %
MgO	0,424 %
S	0,053 %
TiO_2	0,397 %
V_2O_5	0,28 %
Na_2O	0,145 %
K_2O	0,057 %
Cu	0,013 %
C	1,55 %
Fe as Oxide	9,13 %
Fe as metal	82,37 %

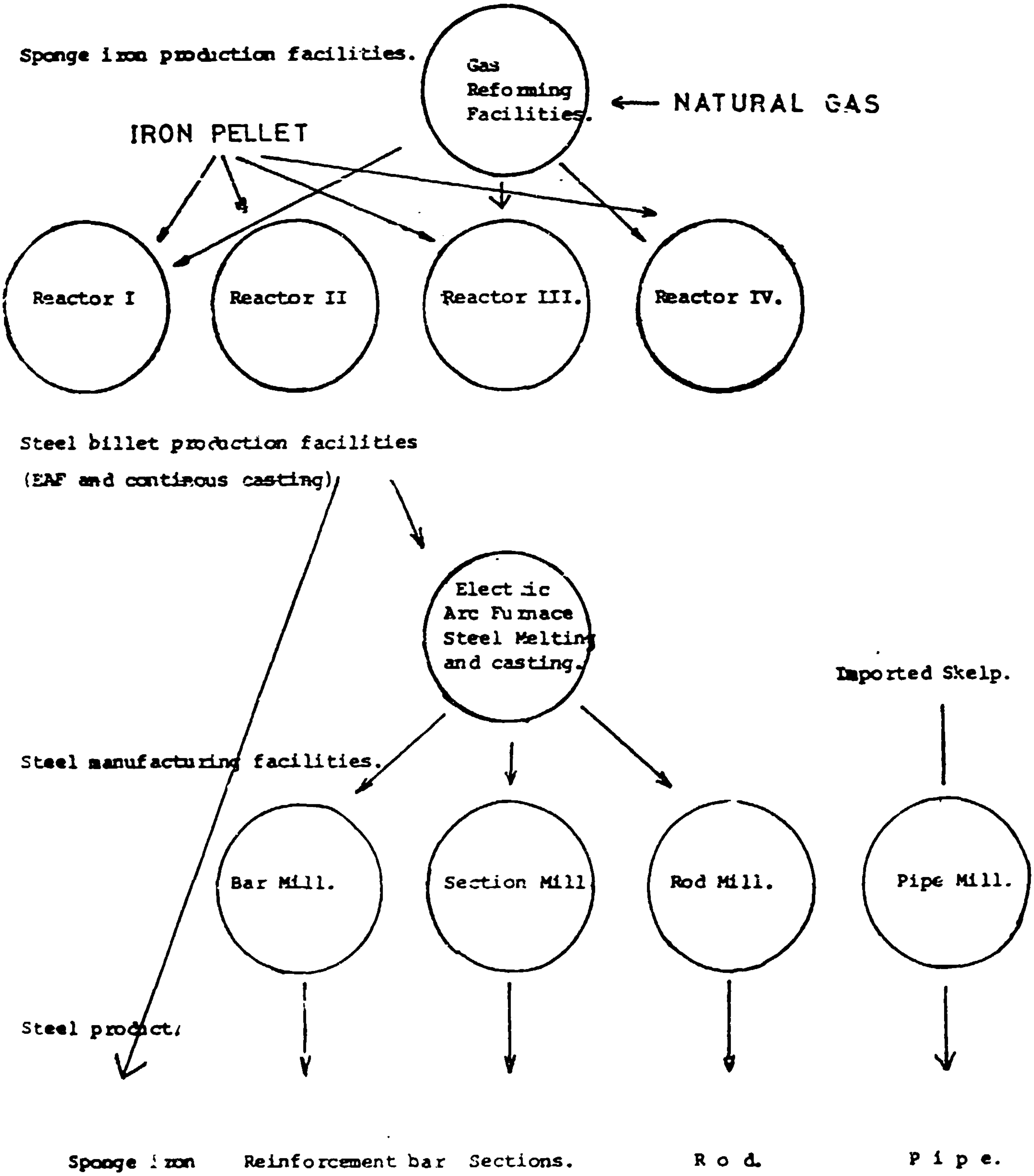
PHYSICAL

Particle size

Over 18 mm	18 % Max
Under 5 mm	5 % Max
Apprarent Density	2.6 T/M^3
Bulk Density	1.6 T/M^3
Crushing Strength	50 kg. min.

INTEGRATED STEEL PLANT FACILITIES
P.T. KRAKATAU STEEL
1982

Process flow



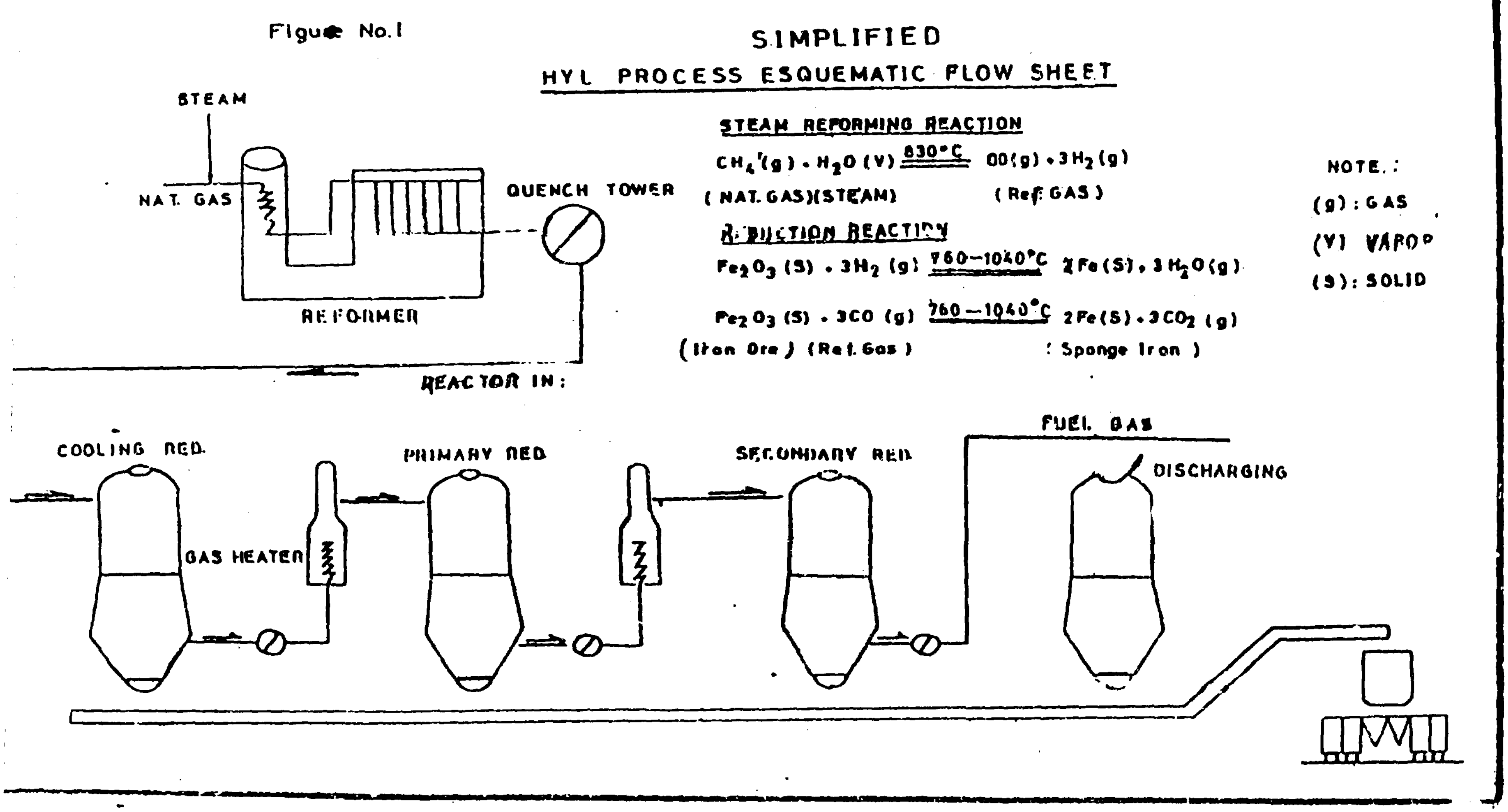
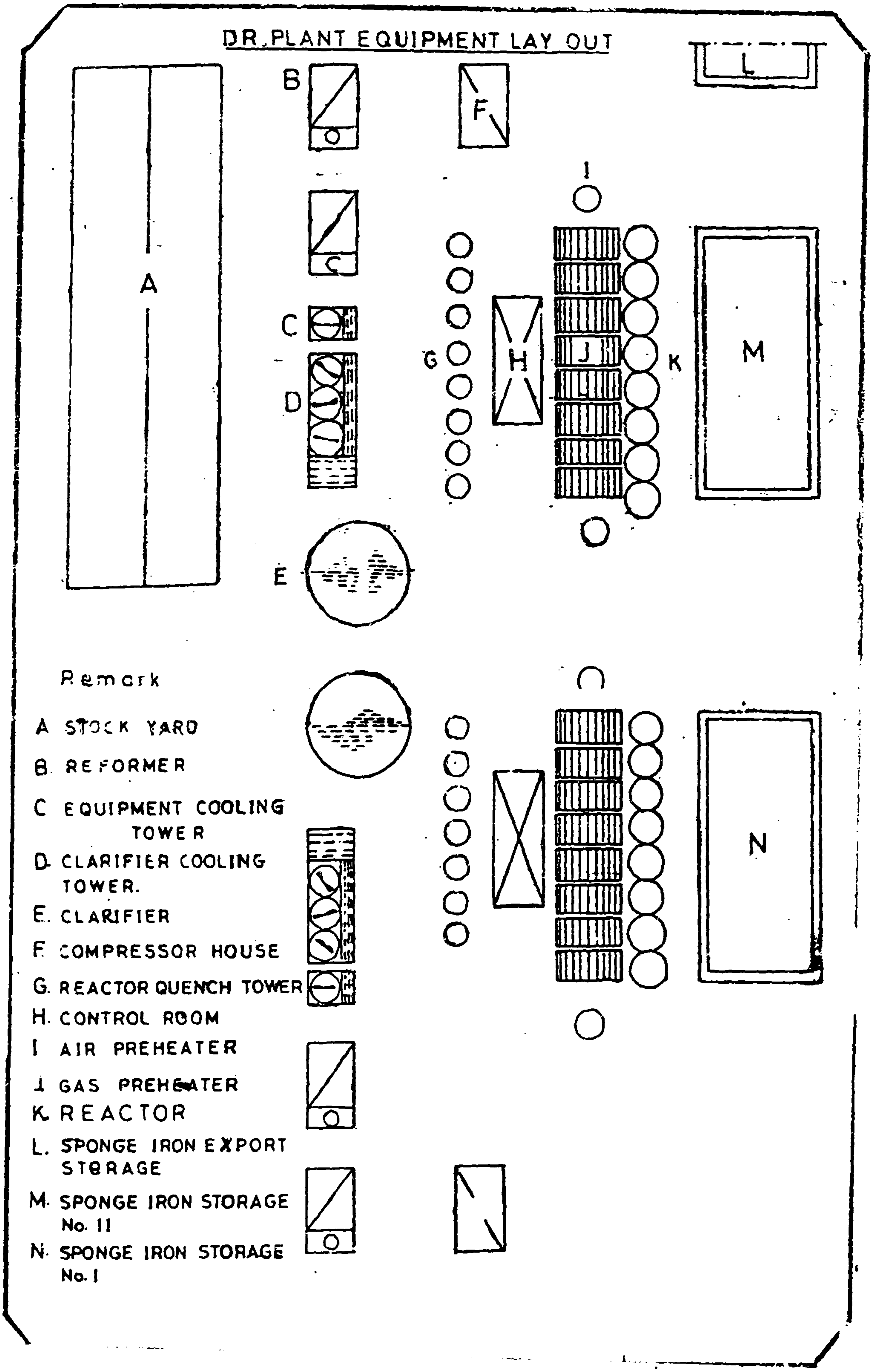


Figure No. 1
SIMPLIFIED
HYL PROCESS ESQUEMATIC FLOW SHEET
STEAM REFORMING REACTION
CH4(g) + H2O (V) 830°C CO(g) + 3H2(g)
(NAT. GAS)(STEAM) (Ref. GAS)
REDUCTION REACTION
Fe2O3 (S) + 3H2 (g) 760–1040°C 2Fe(S) + 3H2O(g)
Fe2O3 (S) + 3CO (g) 760–1040°C 2Fe(S) + 3CO2 (g)
(Iron Ore) (Ref. Gas) (Sponge Iron)
NOTE:
(g): GAS
(V) VAPOR
(S): SOLID
STEAM
NAT. GAS
REFORMER
QUENCH TOWER
REACTOR IN:
COOLING RED.
GAS HEATER
PRIMARY RED
SECONDARY RED
FUEL GAS
DISCHARGING


DR. PLANT EQUIPMENT LAY OUT
A
B
C
D
E
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J
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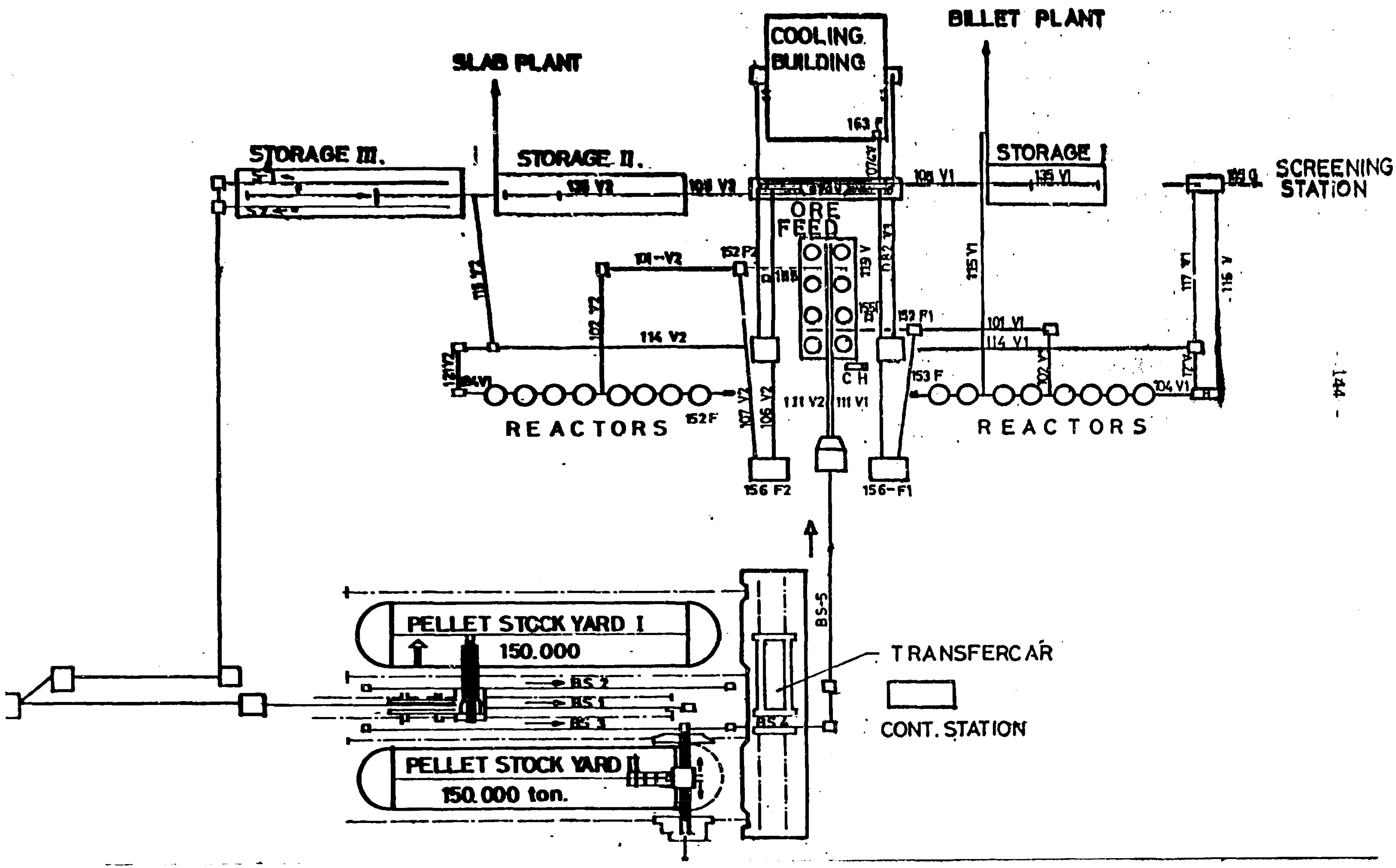
L
M
N
Remark
A STOCK YARD
B REFORMER
C EQUIPMENT COOLING TOWER
D CLARIFIER COOLING TOWER.
E. CLARIFIER
F COMPRESSOR HOUSE
G. REACTOR QUENCH TOWER
H. CONTROL ROOM
I AIR PREHEATER
J GAS PREHEATER
K REACTOR
L. SPONGE IRON EXPORT STORAGE
M. SPONGE IRON STORAGE No. II
N. SPONGE IRON STORAGE No. I

MATERIAL HANDLING SYSTEM



P.T. KRAKATAU STEEL

P. T. Krakatau Steel is an Indonesian based integrated steel plant which produces DRI through HYL process.

Billets, that are produced in the electric arc furnaces and continuous castings, are used for producing low carbon steel wire rods, mild steel rebars, sections and weldable high strength rebars in the rolling mills.

The important aspects of using high ratio of DRI (80-90%) in the charge) in the electric arc furnace will be explained specially in relation with the weldable high strength rebar (yield strength = 40 kg/mm^2 minimum and carbon 0.29% maximum) production.

These aspects are : charge design and charging, melting, carbon control, slag basicity control, energy consumption and vanadium recovery from vanadium oxide (V_2O_5) that is contained by the DRI.

I. Plant Characterization and Product Mix

By far the largest steel producer in Indonesia is P.T. Krakatau Steel, a government owned steel plant which is located in west Java at Cilegon, 120 km West of Jakarta.

The integrated steel plant combines HYL II direct reduction of iron ore pellets with electric arc furnace steel making.

The rated capacity of the DR-Plant is 2.000 t/a (Fe) of DRI, large quantity of which is consumed in the Billet and Slab Steel making plants. The balance is sold in the domestic market and abroad, mostly to India.

The billet steel making plant, which has been in operation since November 1978 consists of four 65-ton electric arc furnaces having power input of 36 MVA, and two four-strand continuous billet casting machines having 4-meter radius which produce 100 mm and 110 mm square of billets.

Most of those billets are rolled to finished product in Krakatau's own mills :

a) A bar mill, started in 1977, has 150.000 t/a of capacity and produces concrete reinforcing bars.

b) A medium section mill, which began production in 1977, having 85,000 t/a of capacity produces a variety of angles, channels and beams.

c) A two-strand continuous rod mill, which began rolling in 1979 having 220.000 t/a of capacity, produces wire rods and bars in coil.

The slab steel making plant consists of four 120-ton electric arc furnaces having power input of 66 MVA and two single strand slab casting machines having 9,8 m radius which produces 20 cm thick 1,6-2,2 m wide slabs.

All of these are rolled on Krakatau's hot strip mill having 1.000.000 t/a capacity to produce coils for light plate, skelp and for cold rolled products.

The electric arc furnaces, either in the billet or in the slab plants, are equipped with the continuous feeding facilities through the roof to feed the DRI into the delta of the electrodes.

The main rebar qualities produced by Krakatau Steel are shown in table I.

Table I

Principle qualities of rebars produced by Krakatau steel

EEL ADE	Minimum yield Strength (KG/ MM^2)	Chemical Composition (Max) % C	% Mn	% Si	% V	%Σr	Benda-bility	% Elo-ngation	Diameter (MM)
015	24	0.18	0.70	0.30	-	0.60	3 d	22	Upto 16 mm
020	24	0.23	0.70	0.30	-	0.60	3 d	22	Upto 25 mm
025	24	0.28	0.70	0.30	-	0.60	3 d	22	Upto 32 mm
325	40	0.29	1.50	0.45	-	0.60	5 d	16	Upto 20 mm
320 V	40	0.25	1.50	0.45	0.06	0.60	5 d	16	Bigger than 20 mm

Σr = 1% (Cu + Ni + Cr)

The KS 1325 and KS 1320 V are the weldable high-tensile rebar qualities which the last is micro alloyed by means of vanadium.

The KS 1325 is used for producing rebars up to 20 mm and the KS 1320 V is used for those up to 36 mm diameters.

The market demand for these types of rebars during the last months of 1982 represented about 60% of the total rebar production.

II. Characteristics of HYL - DRI

HYL I is a fixed bed direct reduction process which reduces high quality iron ore pellets in a - relatively high temperature (1000°C - 1050°C) in the reactors.

The DRI produced by the HYL reactors before being stored in the steel making storages, is passed over 5 mm screen. From these storages it is then transported to the steel making plants by means of conveyors to be stored in the bunkers above the furnaces, from where it would be fed either continuously or conventionally by bucket into the furnaces.

The DRI, to be sold either within the country or overseas, is stored in a special storage and will be passed over 5 mm screen in the harbour before being shipped.

Krakatau uses pellets from several sources like LKAB, Samarco and CVRD and plans to use Indian pellets and Australian lump ore.

The physical and chemical characteristics of the DRI will certainly be dependent upon the quality of iron ore pellets used.

II.1. Physical Characteristics

Table II gives the size distribution, bulk density, apparent density and compressive strength of Krakatau's DRI.

Table II
Physical Characteristics
of Krakatau's DRI

a) Size distribution

+ 18 mm	:	0,0	- 0,46	%
+ 16 mm	:	0,	- 2,76	%
+ 12,5 mm	:	24,70	- 45,17	%
+ 6,3 mm	:	49,84	- 70,51	%
+ 5 mm	:	1,75	- 3,85	%
- 5 mm	:	0,77	- 1,94	%

b) Bulk density : 1,75 - 1,93 T/M^3

c) Apparent density 2,82 - 3,48 T/M^3

d) Compressive strength :99,94-137,51 Kg.

As can be seen from table II, Krakatau's DRI is relatively homogenous in size and density, and it is worth mentioning again that the handling and storage of these materials is relatively simple since it can be transferred on conveyor belts and stored in silos.

Since the excessive quantity of DRI fines (-5 mm sizes) would considerably affect the longevity of the roof and the dedusting system, it is worth limiting the quantity of fines to as minimum as is possible by avoiding excessive handling.

II.2. Chemical characteristics

In the direct reduction process a large part of the oxygen contained in the original iron oxide pellets is removed at temperatures below the melting points of iron and its oxides.

Since no melting and refining takes place during this reducti[illegible] the gangue of the iron ore pell[illegible] each type of the iron ore pellets producing its typical DRI.

The main chemical characteristics of the DRI are :

a. Metallization and carbon content

b. Gangue content and basicity

c. Impurities and other oxides.

Table III gives the range of chemical characteristics of Krakatau's DRI.

TABLE III
Chemical Characteristics of
Krakatau's DRI

Items	%		
Total Fe	88	-	91
Mettalic Fe	76	-	82
Metallization	86	-	92
Total Carbon	1,80	-	2,50
Iron Oxide (FeO)	6	-	15
SiO_2	1,25	-	2,5
Al_2O_3	0,60	-	1,30
CaO	1,50	-	2,80
MgO	0,31	-	1,25
P	0,014	-	0,040
S	Traces		
Impurities and other Oxides	0,10	-	0,50
Total Gangue	4,5	-	6,70
Index Basicity			
$\frac{CaO + MgO}{SiO_2 + Al_2O_3}$	0,90	-	1,29
V_2O_5	0,02	-	0,13

ad.a: Metallization and Carbon Content

The term metallization is used to express the degree of reduction of DRI and is the ratio of the metallic iron divided by the total iron.

Since the Hyl II direct reduction is a batch process, difference in metallization takes place between the lower and the upper part of the reactors.
The lower and the upper limit of metallization usually are 85% and 94% respectively, but the average metallization of the blended DRI is between 88% - 91%.

The higher the metallization of the DRI, the lower is

the iron oxide (FeO) content in it.
The amount of the residual FeO is between 6% - 15%.

The total carbon in the DRI, which can be adjusted within certain limits (1,80 - 2,50%), is mostly in the form of cementite (80 to 95% in the form of Fe_3C).

During melting in the electric arc furnace, the carbon in the DRI will reduce the residual FeO according to this reaction :

$$Fe_3C + 1.14\ FeO = 4{,}14\ Fe + 0{,}86\ CO + 0{,}14\ CO_2$$

This reaction will raise a good boiling effect during melting.
From the above reaction, 1% of carbon in Fe_3C will raise 6% of effective metallization during melting, or in other words higher metallization will result in when additional reduction takes place during melting in the E.A.F. i.e.,
% Effective metallization = (% Metallization) + 6 (%C).
By adjusting the effective metallization (or a equivalent metallization), or the ratio between the residual FeO and total carbon in the DRI, the required opening carbon balancing with the quantity of FeO in the slag will be obtained.
This DRI is called a balanced DRI.

ad. b. <u>Gangue content and its basicity</u>

Gangue is all non-ferrous material (except impurities and other oxides) present in the DRI (i.e. : CaO, MgO, SiO_2 Al_2O_3).
As mentioned earlier, all the gangue in the iron ore pellets will be found in the DRI.
Since Krakatau uses several types of pellets like LKAB, Samarco and CVRD, the DRI gangue will vary for each type of the iron ore pellet..
From table III, Krakatau's DRI have 4,5 - 6,70 % gangue content and its index basicity

$$\left(\frac{CaO + MgO}{SiO_2 + Al_2O_3}\right) \text{ is } 0{,}90 - 1{,}29.$$

The gangue content and its index basicity will determine the quantity of the basic materials (CaO,MgO) to be added during the steel making process to obtain the ratio $\frac{CaO}{SiO_2} \geq 2$.

ad. c. Impurities and other oxides

The impurities and other oxides that can be found in the DRI are : P,S, alkalies (K_2O and Na_2O), titanium oxide and vanadium oxide. From table III), it can be seen that phosporous, sulfur and alkalies are found very low in the DRI and there is no need to draw special attention to those in the steel industry.

Since vanadium micro alloying is used in the production of the weldable high tensile rebars, special attention is to be paid to the vanadium oxide contained in the DRI. By recovering vanadium from this oxide the consumption of vanadium micro alloying element can be economized.

LKAB pellets have the highest vanadium oxide content (ranging from 0.054 to 0.135%) in the DRI.

The impurities that are usually found in steel scrap (Cu, Ni, Cr, Pb, Zn, Sn, As, Mo), are found only as traces in the DRI.

III. IMPORTANT ASPECTS OF HIGH RATIO DRI MELTING PRACTICE FOR THE PRODUCTION OF WELDABLE HIGH TENSILE REBARS

1. Charge Design and Charging

Since the maximum amount of residual elements in the weldable high tensile rebars is limited to 0.60% by using 85% DRI in the charge, any kind of carbon steel scrap can be used for that. It is not necessary to segregate the steel scrap based on their qualities. What is necessary is only to segregate the scrap into different densities light, medium and heavy scrap.

Charging depends on the availability of continous feeding equipment, but can be either bucket charged or continuously fed. Table IV gives the charge design normally used by Krakatau :

Table IV

CHARGE DESIGN

Bucket Charging			Continous Charging		
1st charge	:		1st charge	:	
scrap	:	10 tons	scrap	:	10 tons
DRI	:	21 tons	DRI	:	21 tons
2nd charge			Continuous	:	
DRI	:	21 tons	DRI	:	42 tons
3rd charge					
DRI	:	21 tons			

In the case of bucket charging, the top discharged buckets are used for the DRI. And the scrap, all charged in the first charge, is fed by using the conventional clamp shell bucket (see fig 1 and fig 2.)

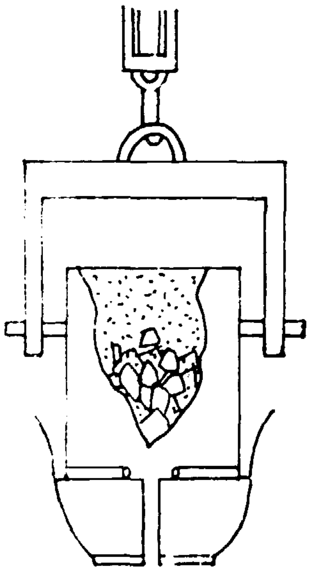
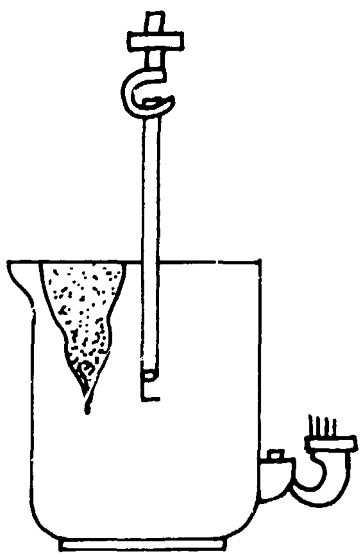


Fig. 1 Clamp shell bucket



Sponge iron bucket

The advantages of using the top discharged bucket for the DRI are :

a. The DRI can be regulated mostly to be placed on the hot spot areas which helps avoid the sticking tendency or agglomeration of the DRI on cold spot areas. (See Fig. 2).

b. The hot spot areas are protected from the arc during - melting by placing most of the DRI on them. This will help in refractory consumption.

Both the charging systems, either the bucket or the continous feeding, have the same method of carrying out the first charge. In this the scrap is placed on the furnace bottom using the clamp shell bucket followed by one third quantity of the DRI using the top discharged bucket. The advantages of using this method of first charging are :

a. Since the DRI will fill the empty spaces among the scrap pieces, higher charge density will be obtained which will have better conductivity than the DRI itself.

   As a result, compared to scrap melting, lower voltage fluctuations/lower flicker will be obtained with the same speed of melting.

b. Protects the furnace bottom, since higher density of the first charge will slow down the electrode boring movement during penetration.

c. Heat recovery from the previous hot will be better.

Since oxygen or gas burner equipment are not used in the Billet Plant, continuous feeding speed is limited to 1,9 ton/ MW-HR which is started when ± 50% of the charge is melted.

In fact, continuous feeding practice is preferable as back charges can be eliminated and time saved.

III. 2. Melting

Penetration of the electrodes starts at the lower voltage and short arc (280 V, 40 KA)and After making holes of 60 to 90 cm depth, maximum voltage (400 V, 50KA) can be applied.

By using this practice the charge will be melted from bottom to top and arc radiation to the roof and the wall can be reduced. (See Fig. 3).

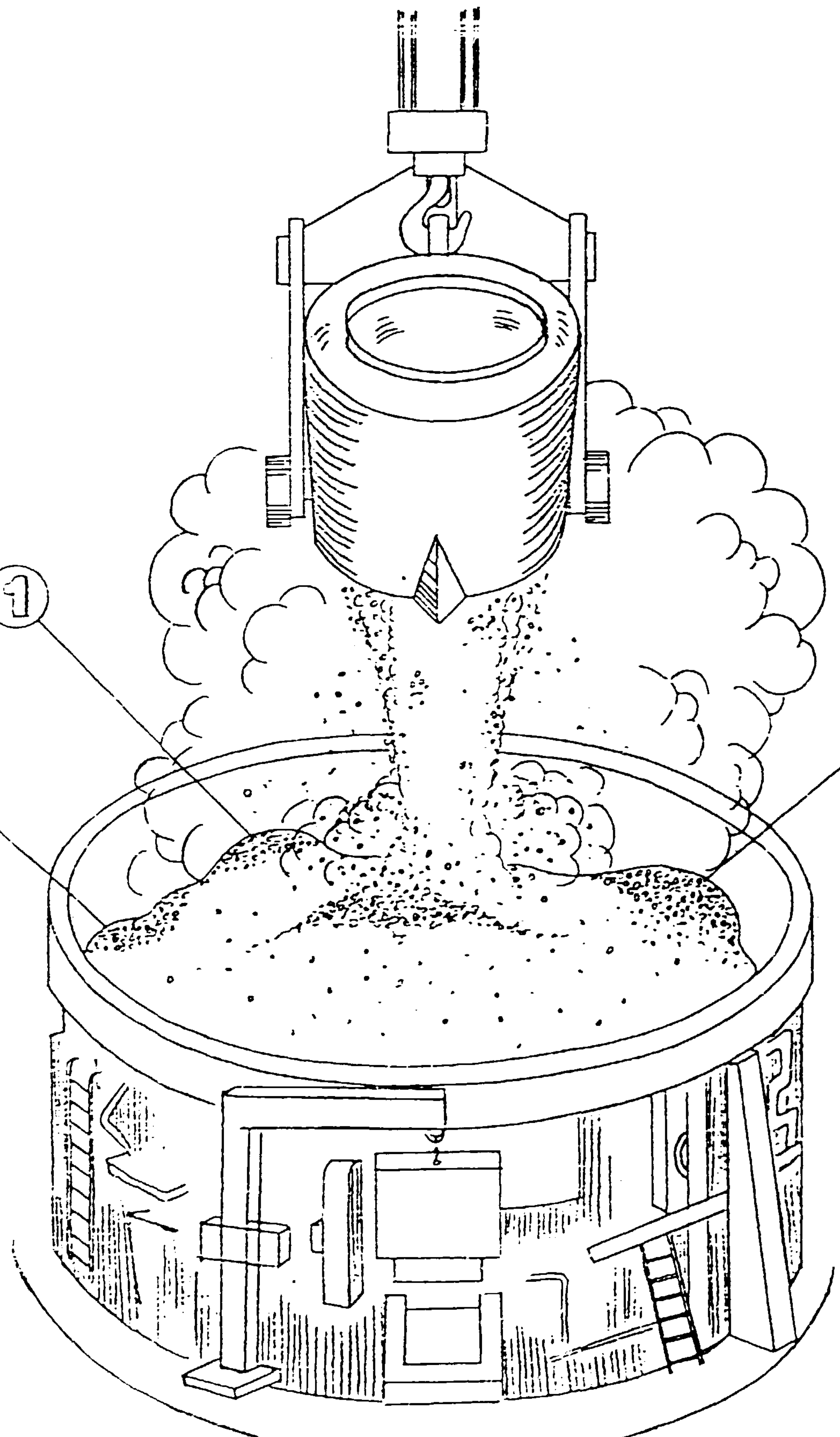


FIG 2.
Hot Charging.

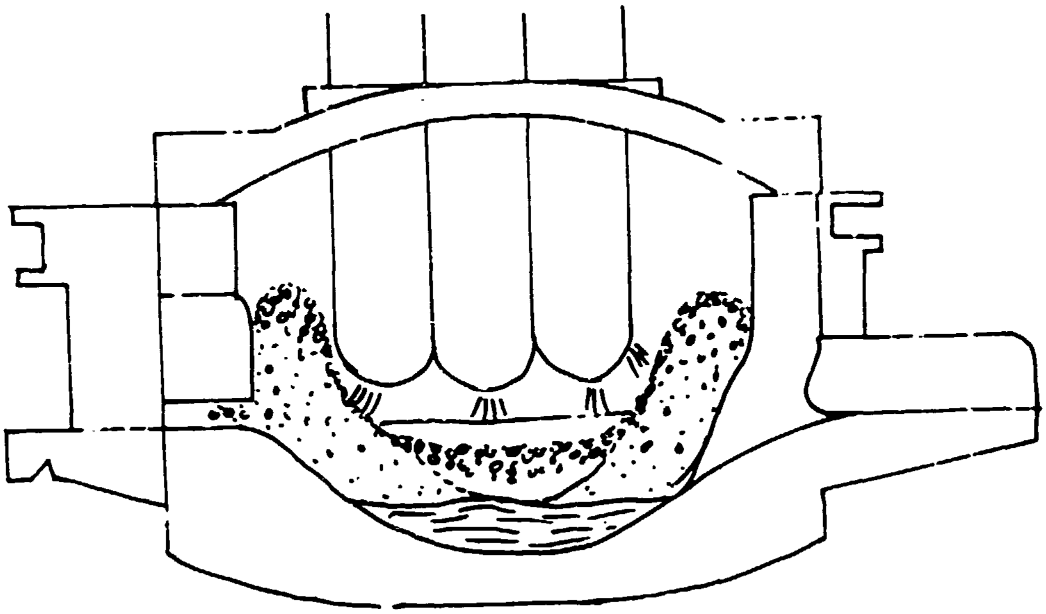


Fig. 3 Melting from bottom to top

In the case of continuous charging, it is worth keeping the slag door clean to allow the excess slag to flow freely out leaving the foamy slag in the furnace which will be enough to cover the Arc.

II.3. Carbon Control

By using high ratio of DRI, steel making practice becomes easier and can be simplified further since no controls are necessary for the P,S, residual elements and others.

What is necessary to control is only the opening carbon to obtain a better yield (charge to liquid steel) to lower the consumption of MgO refractory materials and to shorten the tap-to-tap time.

Figure 4 gives the relationship between the percentage of bath carbon and the percentage of FeO in the slag.

By controlling the bath carbon, the percentage of FeO in the slag can well be controlled, and Figure 5 shows that the yield can be well controlled by controlling the opening carbon.

Figure 6 shows the relation between the effective metallization of the DRI and the opening carbon. By knowing the effective metallization of the DRI which is fed into the furnaces, the steel maker can predict the opening carbon, and by comparing with the air bath carbon, he can decide whether the broken electrodes or iron ore pellets are required to be fed along with the charge to obtain the desired opening carbon, and minimize the time required to adjust the bath carbon.

Since the DRI have a relatively homogeneous chemical composition, the bath chemical composition at the end of melt down can be well predicted before hand. Therefore, the refining can be started at a stage when 80% - 90% of the charge is melted, and need not wait until all the charge is melted.

By doing the refining during melting the heat time can be shortened.

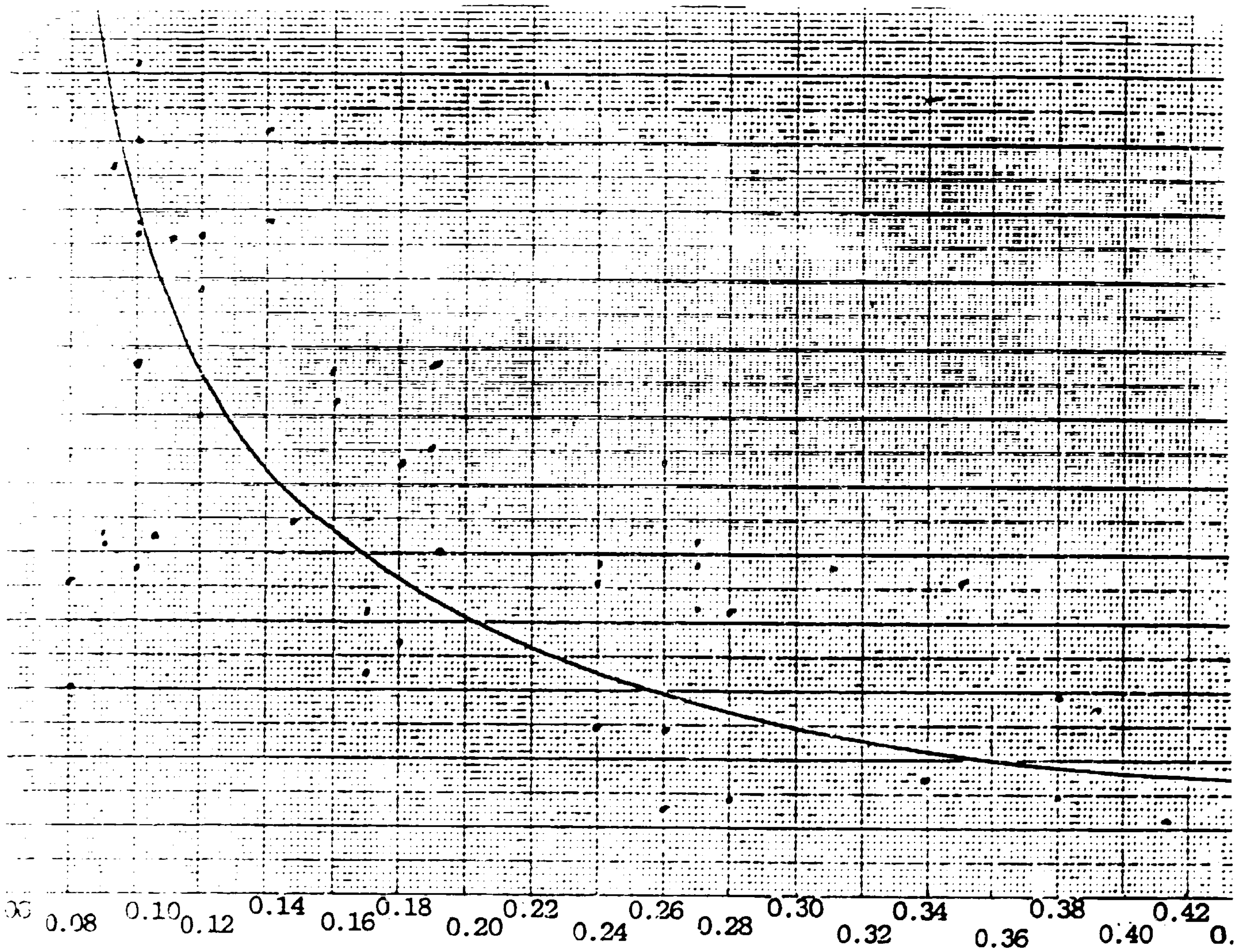


Fig. 4.

% Bath Carbon VS FeO in Slag

Since the P and S have already been low, refining here means the carbon adjustment to obtain the desired carbon block by injecting more grafit or oxygen, so that at the end of melt down, blocking or deoxidation can be carried out directly.

III. 4. Slag Basicity Control

In order to control the refractory consumption of bottom slag line and MgO gunning materials, it is necessary to control the slag basicity in each step of melting.

Figure 7 and 8 show amount of MgO in the slag which is a function of CaO/SiO_2 ratio and the FeO in the slag. It means that the V ratio and the opening carbon have to be controlled in order to economize the MgO refractory consumption.

By adjusting the V ration between 2 and 2,4 and FeO in the slag between 12% and 20% (it is correlated to 0.15% bath carbon minimum), MgO in the slag can be controlled in the range of 9-18% (Figs. 4,7 & 8).

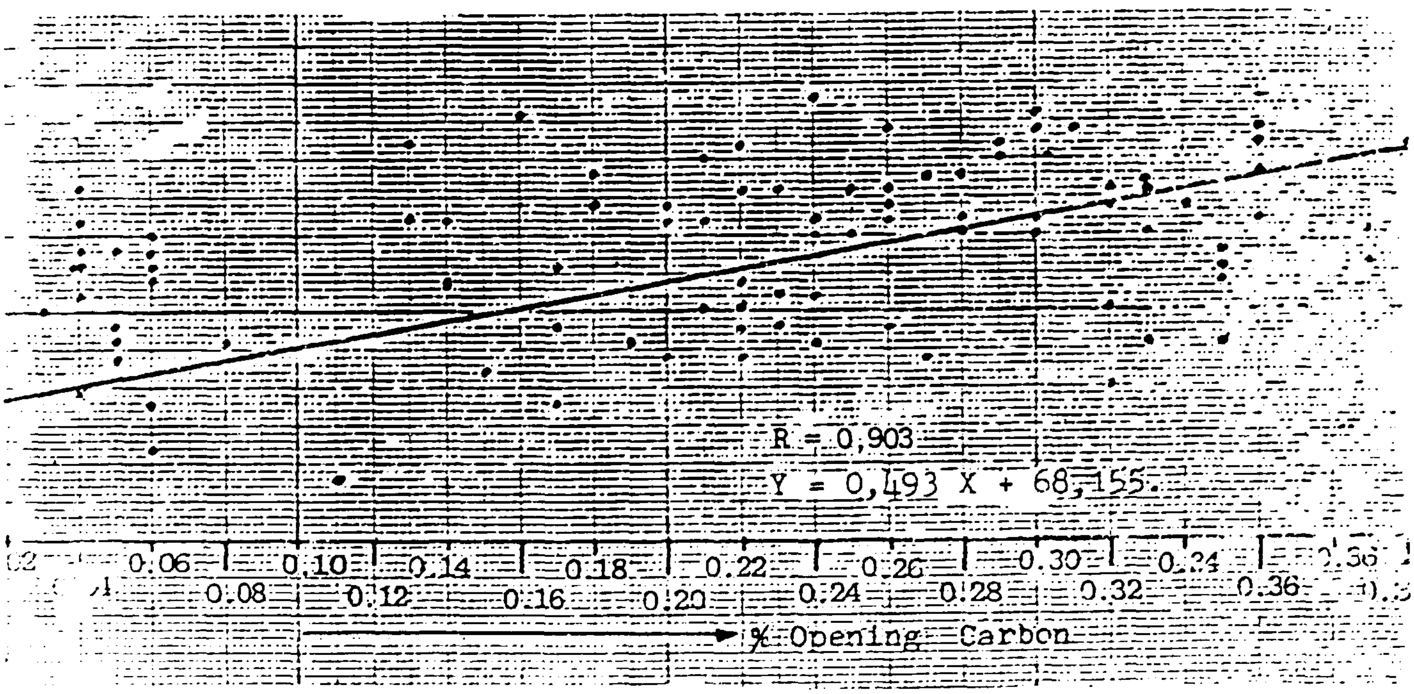


Fig. 5.
% Opening Carbon VS % Yield

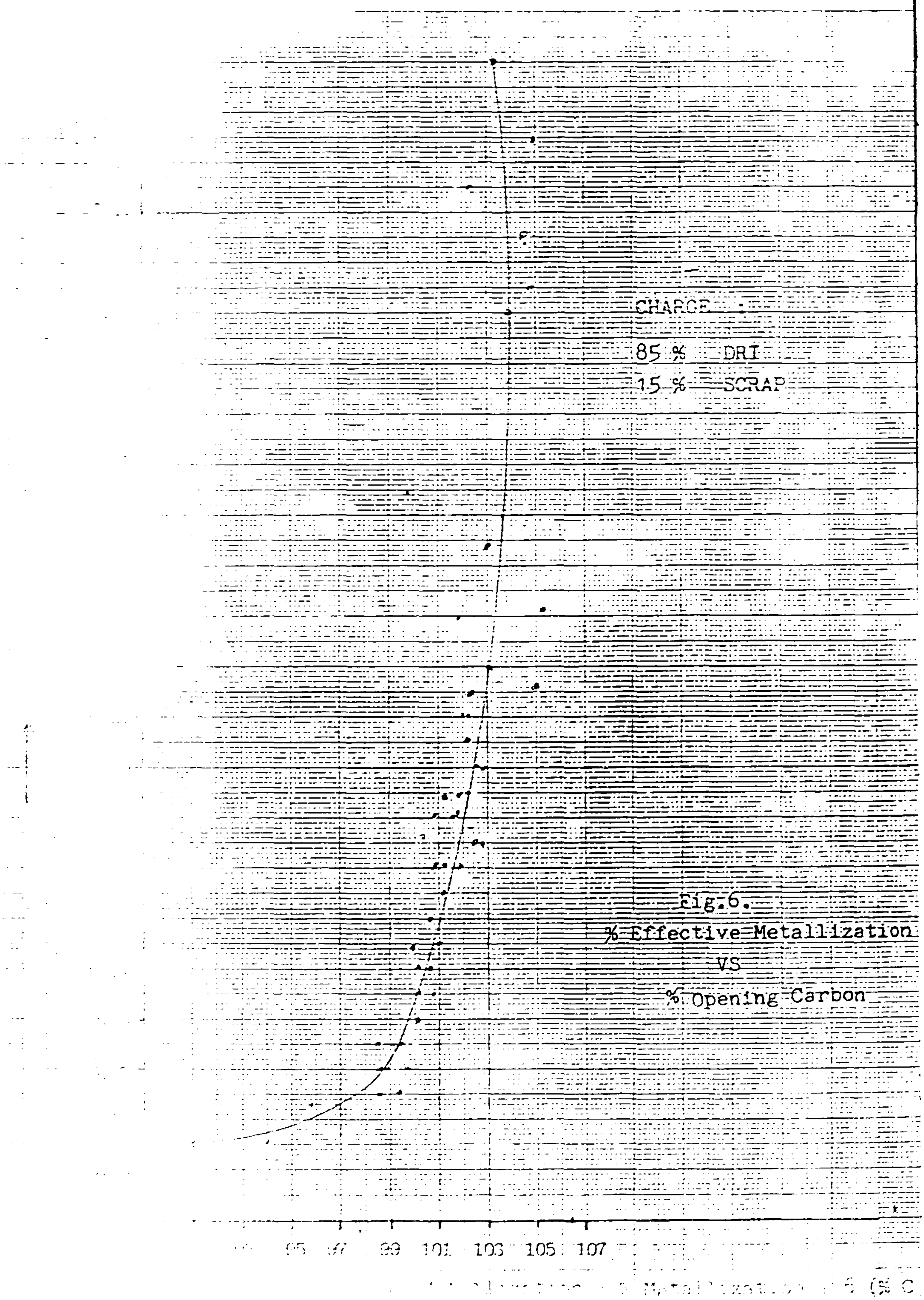


Fig.6.
% Effective Metallization
VS
% Opening Carbon

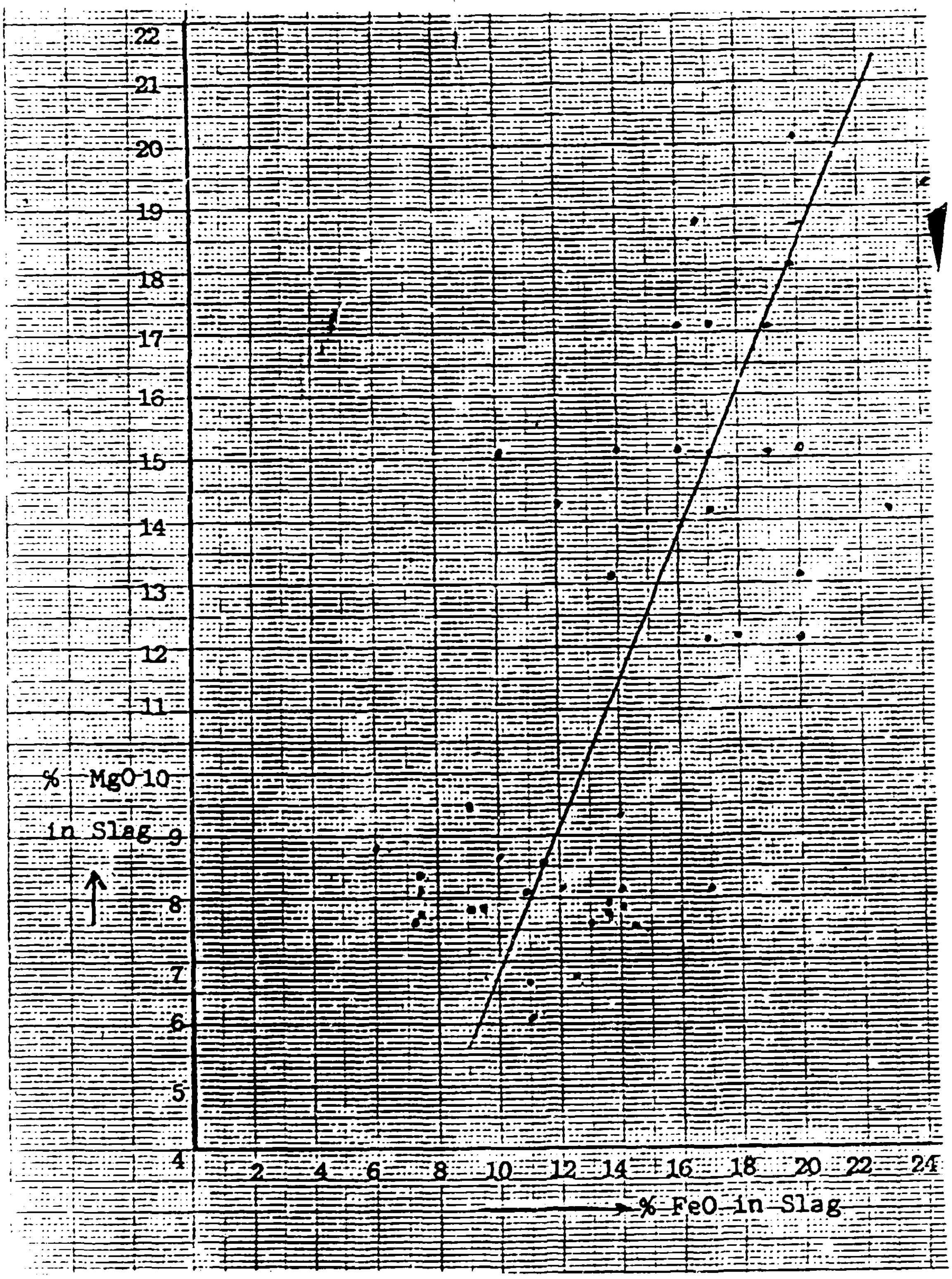


Fig. 7.
% FeO in Slag VS % MgO in Slag

Since in Indonesia burnt lime is available only in small quantity and the imported dolomite is expensive, Krakatau uses only limestone to control the slag basicity.

In fact, the limestone consumption will depend upon the type of DRI used.

In the case of LKAB DRI, 3 tons of limestone is needed to neutralize the gangue.

III. 5. Energy Consumption

As is well known the energy required to melt and heat up DRI is higher than that of scrap due to the following factors:

a) The gangue content and its basicity.
This factor will determine the quantity of limestone to be added in the charge which in turn needs additional energy to dissociate and melt the limestone.

b) The metallization or the quantity of the residual FeO in the DRI.
The lower the metallization, the higher is the residual FeO in the DRI. More energy is required to reduce this residual FeO.

From the practical data:

- The energy required to melt one ton of DRI (90% metallization and 2% carbon) is 520 KWH.
- The energy required to melt one ton of scrap is 480 KWH.
- The energy required to dissociate and to melt one ton of limestone is 1900 KWH.

The approximate power consumption can be calculated from the above data.

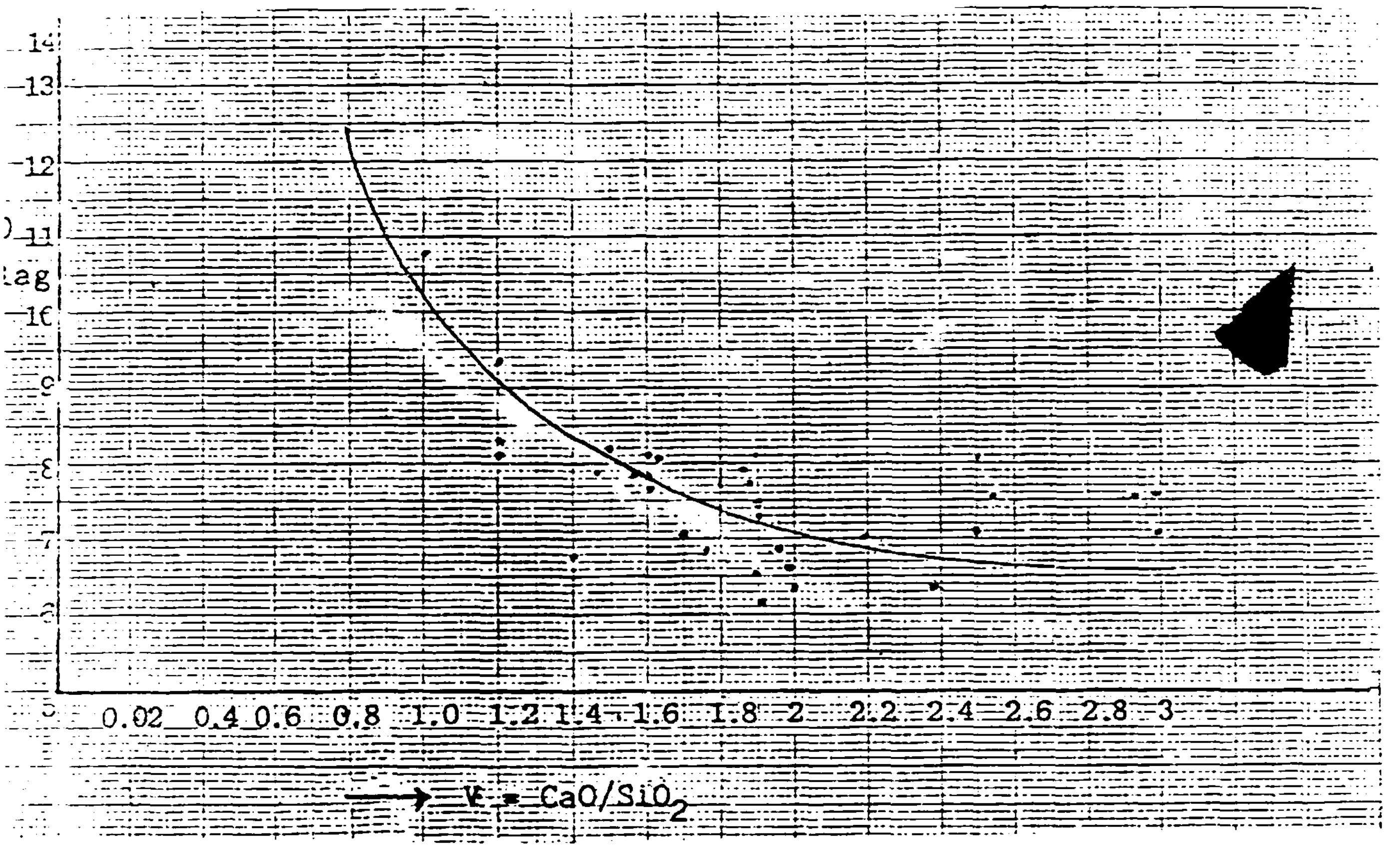


Fig 8

$\frac{CaO}{SiO_2}$ Of the Slag VS % MgO in Slag.

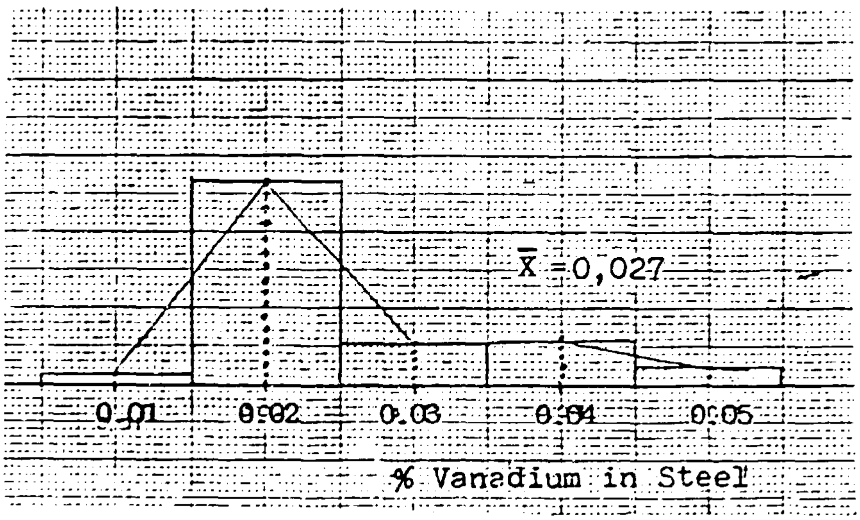


Fig.9.

% Vanadium in Steel From the bucket charged heats.

III. 6. Vanadium recovery from the vanadium oxide contained in the DRI and the vanadium micro alloying elements

Figures 9 and 10 show the amount of vanadium in the steel before adding vanadium micro alloying elements, which range between 0.02% and 0.05%.

The bucket charged heats show higher average percentage of vanadium in steel (that is 0.027% and it is related to 85% vanadium recovery from vanadium oxide) than that in the continuously fed heats (that is 0.016% and it is related to 51% recovery from vanadium oxide contained in the DRI).

It can be explained theoretically (Fig. 11). At high temperature (higher than 1600°C), V_2O_5 in the slag can be reduced by carbon and by avoiding the slag flowing out at temperatures below 1600°C, higher recovery of vanadium from V_2O_5 in the slag can be obtained.

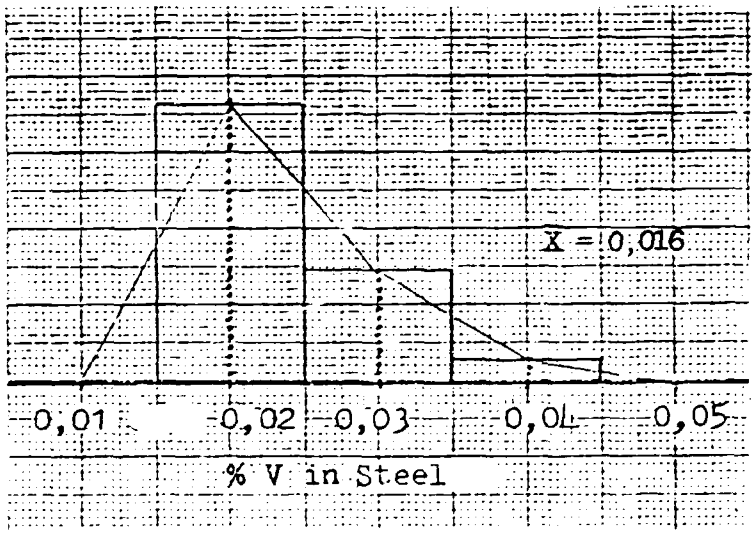


Fig. 10
% Vanadium in Steel From The Continously Fed Heats.

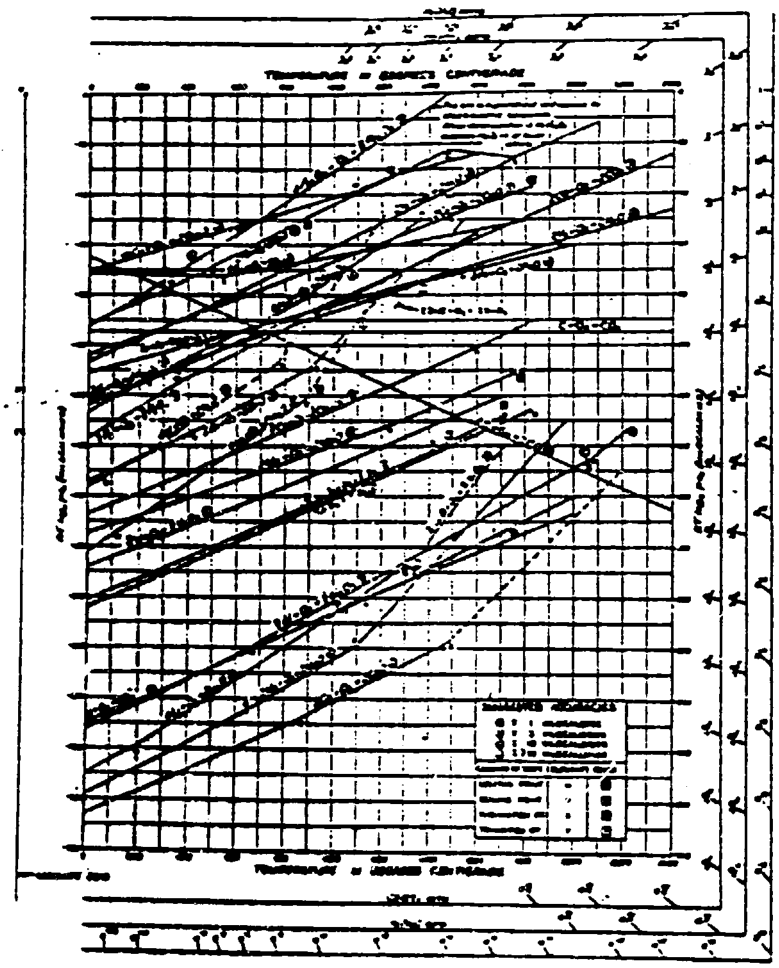


Fig. 11.
Free Energy Diagram For Oxides.

Since in the continuous feeding process the slag door is to be kept clean to allow the slag to flow out freely more slag flows out at lower temperatures and low quantity of vanadium is recovered.

Krakatau uses Nitrovan as Vanadium steel additive for which the recovery is about 85%. However, we also plan to use ordinary ferro vanadium to get a comparative picture.

V. Conclusions

The use of high ratio of DRI to produce weldable high tensile rebars is profitable, since the consumption of the vanadium micro alloying element can be reduced.

VI. References

1. "The use of Direct reduced iron in the electric Arc furnace", SF. TURCOTTE, AH Marquis, TE, Dancy Sidbec - Dosco Ltd., Montreal, the iron and steel maker, November 1980.

2. "Use of Hyl DRI in the electric Arc Furnace", Ing. R. Hinojosa G, Mexico, 1979.

IPITATA SPONGE IRON LIMITED

Introduction

The choice of the appropriate DR route for adopt.. in the Iron and Steel Industry of any country in the ESCAP region would depend on the following primary conditions:

i) Adequate reserves of high grade iron oxide (either lump ore or pellets) must be available.

ii) Correspondingly, there must be a lack of matching availability/reserves of coking coal - if there is adequate coal to back-up the iron ore, the conventional blast furnace route could be automatically adopted.

iii) Adequate quantities of an alternative reductant, either gaseous/liquid (i.e. natural gas or oil) and/or solid (i.e. non-coking coal) should be available to reduce the iron ore to sponge iron or direct reduced iron (DRI).

Judging from the fact that in 1983-84, the world production of DRI is expected to exceed 32 million tonnes, it would appear that on a global scale, many countries fulfil these conditions. This is perhaps more true of the ESCAP countries.

Classification of DR Processes and Other Variants Using Non-Conventional Methods of Making Iron and Steel

A large number of processes are available today for direct reduction and other associated applications. While many of these processes have already been commercially exploited with varying degrees of success, others are still in the demonstration plant/pilot plant/laboratory stage, but appear nonetheless to hold interesting possibilities. These DR and associated processes can be broadly classified into:

i) Continuous processes in a shaft furnace based on natural gas or other reducing gases.

ii) Retort processes using gas or coal as the reductant.

iii) Coal-based processes using rotary kilns.

iv) Coal-based processes using shaft furnaces.

v) Gas based processes using a fluidised bed

vi) Processes using steel plant wastes as the primary oxide feed to rotary kilns.

vii) Processes producing hot metal from nonconventional reductants - these are not strictly speaking DR processes, but constitute possible alternatives to the conventional blast furnace route.

Features of various DR processes required to be considered for appraisal

From a review of all the DR and other associated processes developed so far, it is obvious that amongst them, some have achieved a fair degree of acceptance whilst others have either not been very successful or are not as yet ready to be tried on a commercial scale. It is, therefore, necessary to analyse the details of those DR processes which can be considered as being commercially acceptable. The essential features of these processes are discussed below, particularly from the process metallurgy point of view, highlighting those aspects which have to be considered in a critical appraisal of the present status of technology in each case.

Midrex processes

Of all the gas-based DR process, the HyL and Midrex have gained widespread commercial acceptance so far; as mentioned earlier, these two processes account for over 90% of the total installed capacity of sponge iron in the world. The details of the Midrex process include :

a) Although originally developed for use with high grade pellets, the Midrex furnace has been found to be suitable for reduction of lump ores as well - either as part of the feed together with oxide pellets, or alone as 100% of the feedstock. The addition of lump ore to the feed mix reportedly reduces the sticking tendency thereby allowing higher reduction temperatures and consequently higher gas utilisation as well as increased process efficiency. Optimum process conditions are apparently obtained by mixing 30 to 50% of an appropriate lump ore in the burden with high grade pellets.

b) The reducing gas is generated by catalytic reforming of a mixture of fresh natural gas and recycled cleaned shaft furnace off-gas in a continuous operating reformer. Fuel utilisation in a Midrex module has steadily decreased from an average of 3.0-3.3 G Cal/t of DRI to 2.3-2.7 G Cal/t. This improvement in energy efficiency has been obtained through use of higher reduction temperatures, enrichment of the reduction gas with methane, utilising in situ reforming and preheating of the process gas utilising waste heat from the reformer.

c) As oxygen carriers from an external source are not required in the production of reformed gas, the investment and operating costs are minimised (the effect is rather minimal).

d) Water vapour content of the reformed gas is very low and this allows its injection directly into the reduction furnace without the need for quenching to remove excess water vapour. The use of hot reformed gases without quenching is an important energy saving factor.

e) Product cooling in the process can foloow two different routes depending on the the sulphur content of the burden. Raw materials containing high levels of sulphur (greater than 0.010%), may temporarily affect catalyst activity. This occurs because most of the sulphur in burden finds its way in the top gas and at a concentration above 10 rpm if the gas is recycled directly to the reformer, poisoning of the catalyst occurs and reforming efficiency is greatly reduced. Continuous poisoning may even result in permanent loss of the catalyst activity. However, following an "alternative flow" mode, raw materials, with sulphur levels upto 0.020% can be used. In this mode of operation, that portion of the top gas which has been recirculated to the reformer, is reintroduced into the lower portion of the reduction furnace as cooling gas (after quenching and cooling), prior to mixing with natural gas for reformation. By this means, the freshly formed sponge iron soavanges the sulphur from the gas, making it acceptable for reformation but not contaminating itself sufficiently to trouble the steelmaker.

f) The process can operate with a product metallisation anywhere within a range from 86 to 96%, as desired - compared to the Hyl process, the figures are higher.

g) The product is relatively active towards reoxidation, particularly when water is present. Hence, it must be "passivated" if it is to be stored or transported over long distances. Midrex has developed a proprietary treatment for large tonnage open storage and shipment of sponge iron known as the CHEMAIRE oxidation Inhibiting Process. The process is a combination of several chemical treatments, to inhibit reaction with air, which it is claimed, works satisfactorily, but obviously adds to csot.

h) Carbon, largely in the form of iron carbide, can be controlled at a specified level between one and three per cent.

i) Four standard plant modules are available (series 100, 400, 600 and 1000), with annual capacities ranging from 100,000 to 1,200,000 tpa. Developing countries may not be in a position to use such large amounts of DRI.

j) It is a proven process with 40 units currently on stream or under construction contract or agreement at 17 different locations in 13 countries.

<u>Hyl Process</u>

Since the commissioning of the first DR plant based on this process at Monterrey about 25 years ago, the growth of this technology has also been phenomenal. Presently, the worldwide production capacity of sponge iron by this process is around twenty two million tpa. (not all of its is utilised).

In 1980, based on continuous research Hyl announced the development of the new process called Hyl III.

The prinicpal change is the modification of the four-bed fixed reactors by a single moving bed reactor, but using the same gas reforming plant, auxiliary equipment and quenching tower. This development of the Hyl process has made it comparable to the Midrex process. The main process features can be summarised as:

a) Unlike the Midrex process, the gas reforming is done by steam.

b) The reducing zone in the upper part of the shaft furnace is separated from the cooling/carburisation zone in the lower part by an isoboric zone which prevents the gases from mixing in the reducing and cooling zones. This helps in independent control of metalisation and carbon content of sponge iron.

c) High pressure (4 or more atmosphere) operation enables effective control of process conditions, with smaller equipment size for gas handling and lower energy requirements.

d) The reforming section is independent of the reduction section, thus allowing the reformer to operate stably and conserve appropriate operating conditions reliably for long periods.

e) The process gas is not recycled through the reformer resulting in longer life of the catalyst. As a result, high sulphur inputs can be tolerated without any deleterious effects on equipment or quality or sponge iron using the basic hardware provided and without the need for an alternative route.

f) The reformer need not be as large as would be the case if top gas were recycled to it (this is a significant advantage).

g) A hydrogen-rich reducing gas is used as the make-up gas to the reduction zone. It is obvious that a hydrogen rich gas is a more efficient reducing agent than a lower-hydrogen gas because of the inherently higher reaction rate of hydrogen. This allows higher reduction temperature (950°C and more), better reduction efficiency and improved product stability.

h) It is claimed that the process is quite flexible as far as the raw material utilisation is concerned. It can operate with 100% pellets to 100% lump ore and any mixtures thereof.

i) The energy consumption in Hyl plants is rather low and varies at around 2.4 to 2.6 G Cal/t. The higher carbon content of Hyl DRI, could offer signifi nt advantages during melting.

j) Hyl plants are available for capacities between 200,000 and 750,000 tpa; plants totalling over 5 million tpa of sponge iron capacity are now in operation, under construction or committed to Hyl III alone.

Other Gas-based Processes

Amongst the other gas-based processes, both Purofer and Armco have closed down their operations, FIOR has only one operating plant and HIB produces a pre-reduced material suitable as a feedstock for blast furnaces only. None of these processes, therefore, are in the reckoning. The NSC process looks quite promising because of some novel features like high pressure operation (as in Hyl III), product cooling in an isolated chamber and addition of soot (unburnt carbon) for preventing the raw materials from forming clusters. The NSC process is of more recent origin and if the Malaysian plant, in which Nippon Steel is also participating in equity, is successful, this process can be considered to be at par with Hyl and Midrex, for evaluation from case to case.

Coal-Based Processes

Amongst the coal-based processes using shaft furnaces, only Kinglor Metor has been applied on a commercial scale. However, out of the three commercial plants installed based on this technology, the two in Italy have closed down and the one in Burma has not operated with coal alone so far. The process also has certain basic limitations as given below:

a) the process is suitable only for such plants where small scale requirement of sponge iron is envisaged and the capital cost is very high.

b) the main reduction reactor is made up of silicon carbide, which is a very costly material made by a few specialised suppliers from whom spare reactors would always have to be procured, the possible repercussions are obvious.

c) since the reduction reactor is heated externally, the thermal efficiency of the process is expected to be lower than most other DR processes.

d) the retention time of the material inside the vertical retort is 12-18 hours, which accounts for a high energy consumption and a low productivity per unit volume of reactor.

e) the volatile matter (while using non-coking coal as a reductant) evolved in the preheating zone of the retort is not effectively utilised.

A comparison between a single module 20,000 tpa Kinglor Metor (KM) Plant and a 100,000 tpa rotary kiln based sponge iron plant shows the direct cost of DRI to be Rs. 800 ± 20 and Rs. 730 ± 15 respectively. It can be seen that the viability of the rotary kiln-based plant is better than that of the KM plant; for these two typical scales of operation, of course, at 20,000 tpa production in both, the KM process would definitely be more advantageous.

The Midrex coal based process, though not yet commercially exploited, looks attractive particularly because of its low energy consumption. NML's (National Metallurgical Laboratory, India), VRF is similar to the KM process and as such has its inherent weak points except that the NML reactor is made of either stainless or mild steel. However, being a research organisation, NML is likely to face some limitations in providing the basic engineering back-up required for setting up commercial plants. As such, NML's reported tie-up with MECON for the project engineering of this vertical reactor technology is a positive approach and a step in the right direction for long term exploitation of this process.

As far as the processes utilising plant wastes in rotary kilns are concerned, they are of no immediate relevance in developing countries. On the other hand, processes producing hot metal, like INRED, ELRED and K-R, look promising but none of them can be said to be as yet ready for commercial exploitation. Nonetheless, developing countries must look towards these processes very closely since they would form the ideal method to process fine ores while conventional DR processes utilise the lumps.

In the area of conventional coal-based processes, SL/RN has led the way. Though it is claimed that the process can work equally efficiently with all types of iron oxide feed (lump ore, pellets, fines, etc.), the operation of the Accor Finos Piratini plant in Brazil - the first plant to use 100% lump ore - was initially quite troublesome. The plant never achieved its rated capacity of 60,000 tpa and was continuously producing around 40,000 tpa, till the submerged injection system was incorporated.

Further, the "track record" of the SL/RN process, as whole, has not been particularly impressive. The Highveld plant in South Africa is of no relevance to steelmaking DRI in general and to developing countries in particular since it is only used for producing prereduced iron from vanadium-bearing ores. While kilns have been added at Highveld in view of the world market, many other plants based on this process such as Hocla Mining (USA), Fukuyama (Japan), Inchon (South Korea) and both Stelco and Falconbridge (Canada) have been closed down. Amongst these, the closure of Stelco's plant at Griffith Mine built only recently and intended to be one of the world's largest rotary kiln based DRI unit even before it was fully stabilised, was the most glaring set back. Among the plants now in operation, New Zealand Steel is characterised by its unique iron oxide feed consisting of a titani ferrous beach sand and hence cannot be cited as a general case. Even this plant had a very difficult and troublesome start-up and only when some fundamental changes were made, did the plant really go on stream and is now being expanded. It is only after the latterly successful operations of the Piratini plant and more recently the Kothagudem plant - the first SL/RN plant to start off successfully from the very beginning - that SL/RN technology can be considered to have "come of age". The Kothagudem plant is of 100 tpa capacity and it must be highlighted that rotary kiln processes always perform better in smaller kilns because of considerations involving heat transfer from the gas to the charge bed. Thus, it is to be considered whether there is a real large scale successful SL/RN operation (300-500 tpd) even now.

As stated earlier, the CODIR-Krupp process is quite similar to the SL/RN process, but since the only commercial plant is located in South Africa, it is not easily approachable by all. As per reports, this plant is now running to capacity, though earlier, some problems were encountered; another Krupp plant is under consideration in the Philippines. Until recently DRC is a new entrant in the field of coal-based DR processes and has only one demonstration plant at present which runs intermittently and a commercial plant is due to go on stream in the next few months in South Africa. Under the circumstances, nothing more can be said about these processes at present - their future in developing countries would appear to be as good as the more widely accepted SL/RN process. All these processes emanate from highly developed countries where the socio-economic conditions are quite different.

The ACCAR process is somewhat different and has a different track record which is very limited. After operating a 100 tpd demonstration unit in Canada for a number of years, the ACCAR process has just been successfully commercialised in a 500 tpd unit in India. In the ACCAR process, injection of oil directly into the charge results in higher degree of metallisation in a shorter time. The reductant being in more intimate contact with the charge, lower operating temperatures are possible for the same throughout because of greater intensity of reduction - this is indeed a significant advantage particularly if the coal has a low ash fusion temperature or a high ash content as is the case in India and other ESCAP countries. The carbon content of the product is higher than all other processes in this group - carbon contents up to 2.5% can be obtained which makes electric furnace melting of ACCAR DRI easier. However, all these advantages accruing because of the addition of oil, have to be judged from the point of view of overall economics of the process, particularly because of the recent exorbitant rise in oil prices.

The TISCO Direct Reduction TDR process - patented by Tata Steel in India with patent applications also filed in Australia and New Zealand - is the first and the only sponge iron process to be developed so far in India. The process, though macroscopically similar to SL/RN, Krupp and DRC processes has some novel features including thermal drying of coal. A part of the kiln's waste gases or the reject coal fraction from the counter current coal, can be used for coal drying which is a must in countries like India during the rainy season if any coal-based DR plant is to run uninterruptedly.

The fact that TDR is an indigenous process developed in a low technology country like India makes it different from other processes in the field. Further more, a large number of Indian iron ores and coals from different parts of the country, particularly eastern India have already been tested in the TDR pilot plant and their suitability established. The sponge iron produced has been melted in various arc furnaces in the country as well as in cupola furnaces - thus parameters for reducing Indian raw materials and norms of melting DRI under Indian conditions are available in this case. However, the process has yet to be tried on a commercial scale - this will no doubt be a major milestone to be crossed. The first commercial plant of 300 tpd based on this process is scheduled to be commissioned in the latter part of 1985 - its success or otherwise, could have a significant bearing on the future of coal-based DR in India and other ESCAP countries. It is felt that the TDR technology is particularly tailor made to the infrastructure - both hardware and manpower wise - availability in developing countries.

Applicability of DR Process in ESCAP Countries

ESCAP countries like India had always been reckoned to be "potentially one of the happy hunting grounds" of DR and in the last five years this latent potential has at last been taking some concrete shape, perhaps arising out of a growing concern regarding depleting reserves of coking coal, the shortage of scrap and a desire to industrialise. Two coal based plants have already been established in India, one more is under construction and two more, one based on coal and the other on natural gas, are reported to be in fairly advanced stages of planning. India will soon become the country with the highest number of DR processes in operation. Malaysia is also installing two large gas-based DR plants. At this embryonic stage of a new technological area, it is worthwhile looking closely at certain factors like the availability of raw materials, choice of the appropriate process route, etc. which are likely to have a deciding influence.

Availability of Raw Materials for DR

India has large reserves (over 17,000 million tonnes) of iron ore spread over Bihar, Orissa, Madhya Pradesh, Karnataka, Goa, Tamil Nadu and Maharashtra. Except for an adverse alumina/silica ratio of 1.8 to 2.5:1 - (which gives rise to problems in silicon control in blast furnaces but does not affect DR directly), and a relatively high phosphorous content in most cases (which does affect DR), the quality of iron ore on the whole, can be said to be satisfactory. The ultimate choice would be dictated by factors like purity, softening point, phosphorous content, reduction and thermal degradation index as well as the lead distance to a particular plant site. Though matching chemical and physical property requirements are not always straightforward, it can be said with some confidence, that non-availability of a suitable iron ore at competitive price should not be a bottlenech for DR development in most locations like India. Pellets, though better for DR from a technological view point, are often far too expensive compared to lump ore to be competitive. In no case, should a compromise be made on the purity of iron ore for DRI.

On the other hand many of the ESCAP countries have sizeable reserves of non-coking coals spread over comparatively wide area. The total reserves of non-coking coal in India are estimated to be around 10,8300 million tonnes. The high ash content and low ash fusion temperature of the coal ash of Indian non-coking coals could restrict their usage in many DR processes. The low sulphur content is an advantage but the low reactivity could affect rotary kiln processes adversely - these points have to borne in mind when choosing a coal based DR process. ESCAP countries in general, should study the coal properties carefully before choosing the process - high ash low sulphur coals can be used at a cost.

As regards natural gas, the proven reserves in India are around 350 billion cubic metres which are expected to be approximately 15% of India's ultimate gas potential. This can be considered to be abundant particularly for Western India, and could form the basis of many DR units, unless governmental policies and gas prices dictate otherwise. Malaysia, Afghanistan and other ESCAP countries have natural gas whilst Thailand, Philippines, etc. have none.

Limestone/dolomite, used as a flux in all DR processes in small quantities, pose no problems with regard to their availability in ESCAP countries and adequate reserves of these materials are known to exist. The flux consumption being low it does not normally have a predominating influence in any case and fortunately, developing countries have high grade flux materials.

Summing up, it can be safely stated that the availability of the reductant, its geographical location and its price, would have a strong influence on DR development in all countries. Since the type of reductant is dictated by the process, the process choice assumes tremendous importance. Processes which encourage operations at a lower bed temperature than others, will obviously be more logical to counter the low ash fusion temperature and high ash content of non-coking coals in ESCAP countries.

Choice of the Process

As mentioned earlier, the choice of the general type of DR process to be adopted i.e. solid or gas-based, would depend largely on the nature of the locally available energy. If, in a particular region, natural gas is available, then from a technical stand-point, any gas-based DR process would automatically be preferred. Gas-based DR processes are easier to control, the reactor availability is higher and they produce cleaner sponge iron compared to solid reductant-based processes where the process control is difficult, the reactor availability could be poor and the product invariably contains 1-2% char, even with the best type of magnetic separation. In addition, gas-or oil-based processes generally consume less energy compared to coal-based processes because of the presence of hydrogen in the former. The module capacity of the former can also be varied within a wide range to suit the demand-plant capacity can range anywhere between 100,000 tpa to 750,000 tpa whereas a single unit rotary kiln cannot yet be considered fully proven at capacities beyond say 150,000 tpa. Of course, if indigenous market alone has to be catered to, large scale DR units may not be very appropriate for developing countries at least for the present. Hence, the limitation in size of a rotary kiln unit may not be very serious. Market patterns in developing countries could have a deciding influence - merchant DRI plants should not always be encouraged straight away.

Since technology for gas-based DR is not available, in ESCAP countries it will have to be imported and looking at the global status of gas-based DR processes today, it becomes clear that HYL, Midrex and the NSC processes can be considered. Amongst these, the original type of HYL (HYL 1) may be more preferable for developing countries because of its inherent simplicity though the fact that it is a batch-type process would certainly not weight in its favour. The particular socio-economic status of developing countries has to be borne in mind.

With coal constituting the largest reservoir of energy in countries like India, it would appear logical to expect that coal-based DR processes would mainly be adopted here for sponge iron manufacture. As far as coal gasification is concerned, it may not be economical unless the plant capacity is above 1 mtpa under present day's conditions. Further, the gas produced in coal gasification needs a lot of processing before it can be fed to the reduction unit including cooling of gas from 800-850°C to at least 150-200°C, dedusting of the gas followed by composition adjustment, preheating of the gas and finally pressurising. Thus, the use of gasified coal in shaft furnace DR processes appears to be ruled out for the time being. However, coal gasification will continue to generate interest because of the more efficient working of gas based DR units and the availability of non-coking coal in this region. It is necessary, therefore, that claims of coal gasification processes and the use of coal gas in DR units are comprehensively evaluated from a techno-economic point of view before any wholesale acceptance.

If coal cannot be gasified, then it has to be used directly and in this case also, two distinct possibilities exist - i.e. small plants of up to 25,000 tpa capacity for which one of the vertical retort processes may be the most well suited or rotary kiln-based plants of 60,000-150,000 tpa capacity for which the SL/RN, Krupp/DRC, ACCAR and TDR processes can be considered.

Since choice and availability of the reductant market requirements and scale of operation would affect the ultimate choice for any particular DR unit planned in ESCAP region, three different case studies covering these possibilities are presented below :

CASE STUDIES OF TYPICAL DR UNITS IN ESCAP COUNTRIES : Three hypothetical DR plants can be considered for location in various places in this region where iron ore and sponge iron markets are available :

A - a plant of up to 100 tpd capacity where both coal and natural gas may be available.

B - a plant of up to 1500 tpd and more in a location where only natural gas is available in adequate quantities.

C - a plant having capacity between 200 and 500 tpd at a location where natural gas is not available in adequate quantities but non-coking coal of the requisite quality is available.

Case A For such small capacity plants, gas-based shaft furnaces or coal-based rotary kilns would not be economical. The choice would be restricted to small shaft furnace-based DR processes utilising coal as the reductant. These can be erected either individually to cater to the total requirement or in a cluster of small individual units, the latter having the advantage of adding such units as the need arises. The three processes available in this group are NML's VRF, the K-M process and the Midrex coal-based process. They each have their relative merits and demerits and though the ultimate choice would depend upon the economics, the K-M process would appear to be the choice at present. However, the capital cost of a 20,000 tpa K-M plant is expected to be US $ 8-9 million which is rather high in terms of cost per annual tonne of DRI. Before going in for such unit, all other possibilities would have to be carefully explored.

Case B Since 1973, proven reserves of natural gas in India, recoverable through primary recovery techniques, have increased five-fold to around 350 billion cubic metres, most of it being available in the Bombay/Gujarat area.

Thus, Western India like many other areas in ESCAP countries, is ideally suited for locating such plants, since the question of piping this gas to other areas does not arise. Under the Indian conditions, the capital cost of 400,000 tpa HYL/Midrex unit is expected to be around Rs. 100-120 crores - i.e., the capital cost per annual tonne would be in the region of Rs.2500-2700. This cost is not particularly prohibitive but marketing such a large volume of sponge iron in any one region perhaps in all developing countries, definitely India, will be very difficult since 400,000 tpa of DRI can support 700-800,000 tpa of electric furnace steel production and the largest ministeel complex is not expected to be at present over 150-200,000 tpa capacity. Much of the sponge iron would, therefore, have to be transported and transport of untreated gas-based DRI is fraught with dangers, particularly in the rainy months in countries like India, Thailand, etc. Furthermore, the operating costs of a unit of this nature would appear to be prohibitive. For natural gas with a calorific value of 8000-9000 K Cal/Nm^3 priced at Rs. 1800/1000Nm^3 to cater to the energy needs of a process consuming

2.7-3.0 G Cal/tonne of DRI, the cost of natural gas alone per tonne of DRI would be quite high. The nickel-based catalyst required for reforming this gas would have to be continuously imported and which is also not always easy. Finally, the present government policy makes use of natural gas for DR almost impossible since natural gas is earmarked only for the fertiliser and petrochemical industry by many ESCAP countries and rightly so since the efficiency of usage in the latter is at least twice as high as in DR.

Thus, in many ESCAP countries today, the future of large scale gas-based DR does not appear to be too bright though gas-based DR has a more proven track record. Merchant gas-based DRI plants in developing countries should not be automatically set up Looking at the old market for DRI.

Case C For producing sponge iron as a feedstock for steelmaking for partial/complete substitution of scrap there are three coal-based rotary kiln processes, SL/RN, ACCAR and TDR, which can be considered. All these three processes are presently being installed in India - while a 100 tpd SL/RN plant is already in operation at Kothagudem (AP) and is being expanded to 200 tpd by installing a second kiln, a 500 tpd plant based on the ACCAR process has recently gone on stream at Keonjhar (Orissa) and work on the TDR-process based 300 tpd plant at Joda (Orissa) has commenced, (Total cost Rs 35 crores actual plant cost Rs. 28 crores incl. Rs 35 lakhs in foreign exchange and kiln dimensions 4.25^{S} 65 mts).

Energywise, the process heat requirement of the ACCAR is about 3.5 G Cal/t of sponge iron as compared to around 4.5 G Cal/t for both the SL/RN and TDR technologies. However, even after accounting for the same, the running cost of an ACCAR plant will always be higher because in most ESCAP countries, oil is much costlier than coal. From a typical estimate of the cost of total inputs in ACCAR and TDR plants of the same capacity, it is seen that the total input costs per tonne of sponge iron is higher by almost Rs. 90 in the case of the former purely because of the ratio of oil to coal prices in India (Rs. 2700/t of oil and Rs. 250/t of coal). It has to be pointed out at this stage that the capital cost of an ACCAR kiln is likely to be lower than a kiln designed to use 100% coal since not only is the heat requirement in the former case lower but also 20% of the same is met by oil which, unlike coal, contains no ash (in India 20% of the coal charged is ash which is not only an unnecessary ballost but also consumes fuel itself for heating) thereby making the kiln volume per tonne of DRI production lower. This advantage, however, is unlikely to fully compensate for the higher cost of inputs. For 100,000 tpa plant, the higher cost of inputs in the ACCAR process would mean that the capital cost should be at least Rs 6-8 crores lower, which is unlikely.

As such, ACCAR may find it difficult to compete with any all coal process in many ESCAP countries unless it can prove its feasibilty with 95-100% coal - in which case many of the distinctive advantages of the process would be lost, and the carbon content of DRI produced would come down.

STANDARDISATION OF PLANT SIZE : While it may be possible to standardise on a module size for each of the above three categories (Cases A, B andC), it will not be possible in anyone category to fix the reactor dimensions, because each technology is characterised by its own reactor requirements. Furthermore, raw material characteristics would also influence reactor size to some extent even if the same process is chosen.

Any country's fabrication and transportation facilities also have to be considered e.g. when choosing the kiln size for plants above 150,000 tpa capacity, the girth gear of the kiln is likely to be over 6 m in diameter and weigh at least 80-90 t. Under these conditions, if at all larger capacity plants are required, it is better e.g. to go in for a second kiln alongside the first since increasing the size of the first kiln would not only give rise to the problems of logisties but would mean a plant of a size for which rotary kilns cannot be considered as fully proven.

A two kiln unit has other obvious advantages such as flexibility, particularly if a kiln is under reline, gradual increase in capital investment, etc. However, with market in any area being a limiting factor in developing countries, it is unlikely that the need for a unit above 150,000 tpa would arise at present. If for some particular reason, a unit has to be of larger size, it is still preferable to go in for one kiln at a time. Right from the beginning, the material handling and other facilities should be designed to cater to the future requirements as well. A significant advantage of this approach would also be that second unit can be modified/improved depending on the experience gained from the first. This has particular significance in developing countries both from mechanical hardware and personnel points of view.

FUTURE DEVELOPMENTS IN DR AND THEIR RELEVANCE

Unless natural gas reserves are located in large quantities in any country and there is a simultaneous change in government policy on natural gas, gas-based DR processes will not have a major role to play in many ESCAP countries. Coal based processes in shaft furnaces can be adopted for small scale production and these are particularly suitable for the size of steelmaking units available in such countries. However, to make these units more viable and economically attractive. some developments are still necessary particularly in the area of reactor materials and capital cost. Coal-based processes using rotary kilns for larger units still suffer from the disadvantage of high energy consumption compared to other DR processes. Efforts made in the direction of enhancing the thermal efficiency of rotary kiln processes and improvements made in other process parameters which are of interest include:

- reducing the preheating zone in the kiln by submerged air injection (SL/RN has applied this technique successfully in their Piratini and Kothagudem plants and TDR is also developing underbed injection of air in their pilot plant for incorporation on a commercial scale).

- reducing the energy consumption by enriching the secondary air with oxygen - Krupp has successfully utilised this in their plant in South Africa.

- use of alternative reductants such as lignite, charcoal. In this regard, work at the TDR plant has shown that middlings generated in coal washeries in India which are presently available in plenty, can be used very successfully in rotary kilns because they have a substantially higher ash fusion temperature compared to Indian non-coking coal. However, the kiln productivity and thermal efficiency would be low because of the high ash (30-45%) in middlings- this would adversely affect capital and operating costs of units designed to use middlings. Charcoal/Pith/Coconut powder, etc. with low ash content can only be considered if their low bulk density can be taken care of.
- use of a multi-hearth or any other units for preheating the charge ahead of the kiln to improve the thermal efficiency.
- use of kiln waste gases and excess coal fines for charge preheating, power generation and thermal drying of coal.
- addition of small amount of oil/coal-oil slurry for increasing the carbon content of DRI beyond 0.20%which is maximum possible directly in any all coal process (TDR has done this successfully).

Regarding the alternative processes for producing hot metal of blast furnace quality, the future would depend on developments in the next five years. Plants are afoot to set up a 20-50 t/hr pilot plant based on the INRED process in India in the next couple of years; such efforts need further encouragement, particularly since rich iron ores are often available. Developing countries have to look at these processes very carefully in the near future as complimentary to the DR industry.

CONCLUSIONS

With the dwindling reserves of oil and natural gas, increasing use of solid fuels is beginning to emerge as a distinct trend for fulfilling the energy requirements in future this is particularly true of the steel industry. In India, e.g., the reserves of natural gas are meagre compared to the world reserves and are localised in the western region of the country. As no technology is available in the ESCAP countries for gas-based DR plants, utilisation of these gas reserves will require import of technology. With the present natural gas costs and the type of market needs prevailing in many ESCAP countries, installation of large gas based DR units would appear to be premature.

For utilisation of large reserves of non-coking coals available in many countries, small capacity units based on Kinglor metor type processes can be adopted while rotary kiln based DR processes are available for larger units which include SL/RN, ACCAR, TDR, DRC, KRUPP, etc. TDR, being the only indigenous technology available in this area, could have a definite edge over others once its credentials are established on a commercial scale. All these rotary kiln processes will be suitable for units of 200-500 tpd capacity. As sponge iron plants based on SL/RN, ACCAR and TDR technologies are being installed in India, perhaps the relative merits and demerits of these technologies will be proven shortly and can be considered with regard to the establishment of new plants. The process which is best suited to the conditions in developing countries will certainly be known in the next three years and the next decade could witness a phenomenal growth in DR industry, both for producing DRI for electric furnace and BOF steelmaking as well as for export, whenever possible. For export, coal-based DRI is more suitable because the product is not very pyrophoric.

Whatever be the final outcome, with the maturity of DR processes, scrap availability which was beginning to emerge as a rate limiting factor with the recent widespread adoption of continuous casting because of energy considerations, should no longer be a constraining factor in the growth of the iron and steel industry in ESCAP and other developing countries. Adoption of DR processes at present and one hopes new processes for producing hot metal in the near future, could form the ideal compliment to large integrated steel plants. Only in this way, will it be possible to increase the appalingly low per capita consumption of steel in many developing countries. It is heartening to note that the last couple of years has already witnessed the emergence of this trend, and the present indications are that the same will continue.

Tata Steel's TDR process could contribute to the specific needs of developing countries where high grade iron ore and non-coking coal are available. Tata Steel has a 76 year history of association with the iron and steel industry in India - a very noteworthy record with quality and capacity utilisations as the major hall marks. It is hoped that Tata Steel's DR technology, developed in a 12 tpd pilot plant and now in the market, will not be an exception to this record. In the IPITATA sponge iron plant now under erection at Joda, Orissa, India, using the TDR process, Tata Steel is participating in equity and also has linked the "know-how" fees with the plant's production in the first ten years - this approach could be of particular significance in developing countries in the [redacted]ion.

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